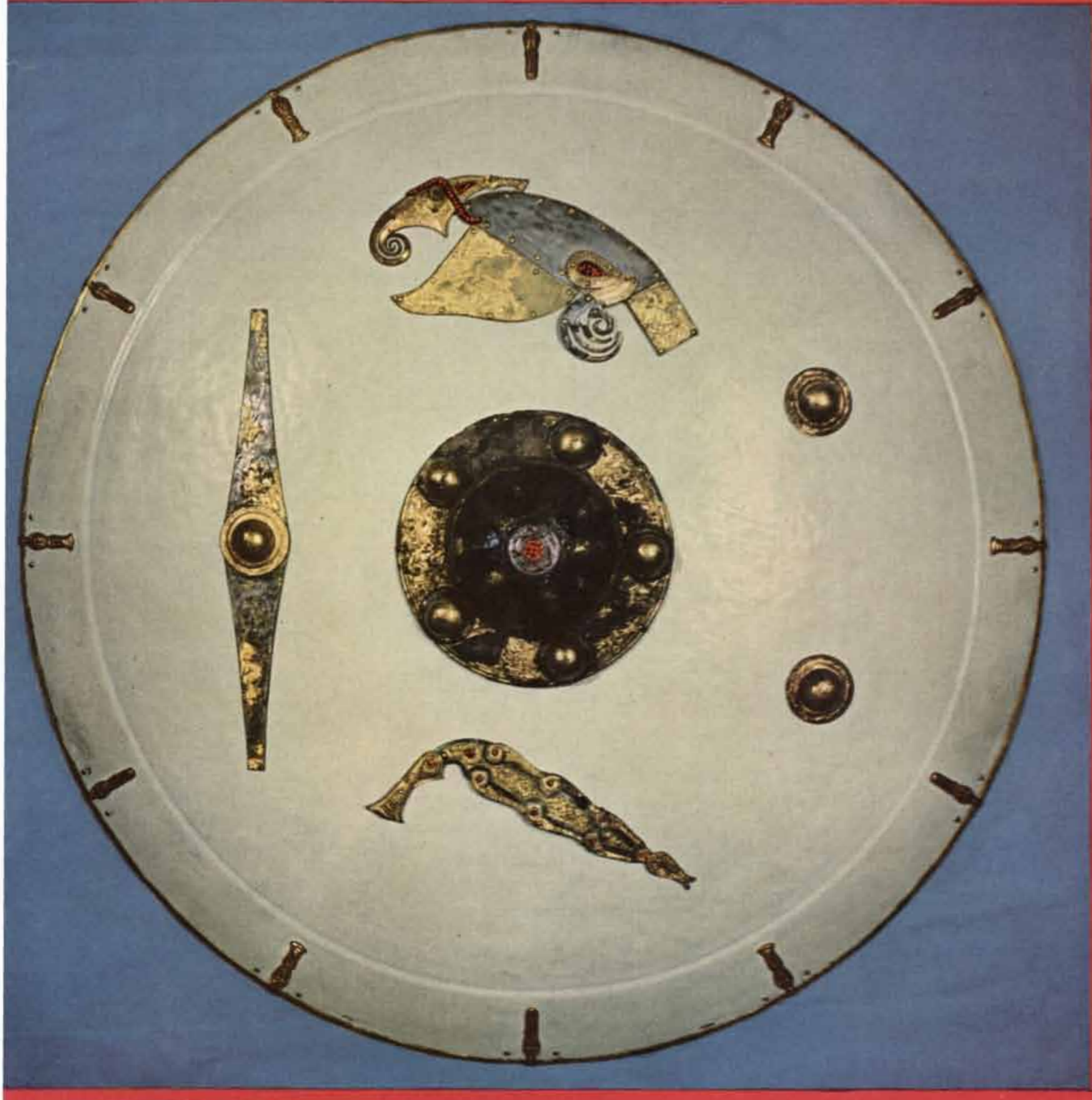
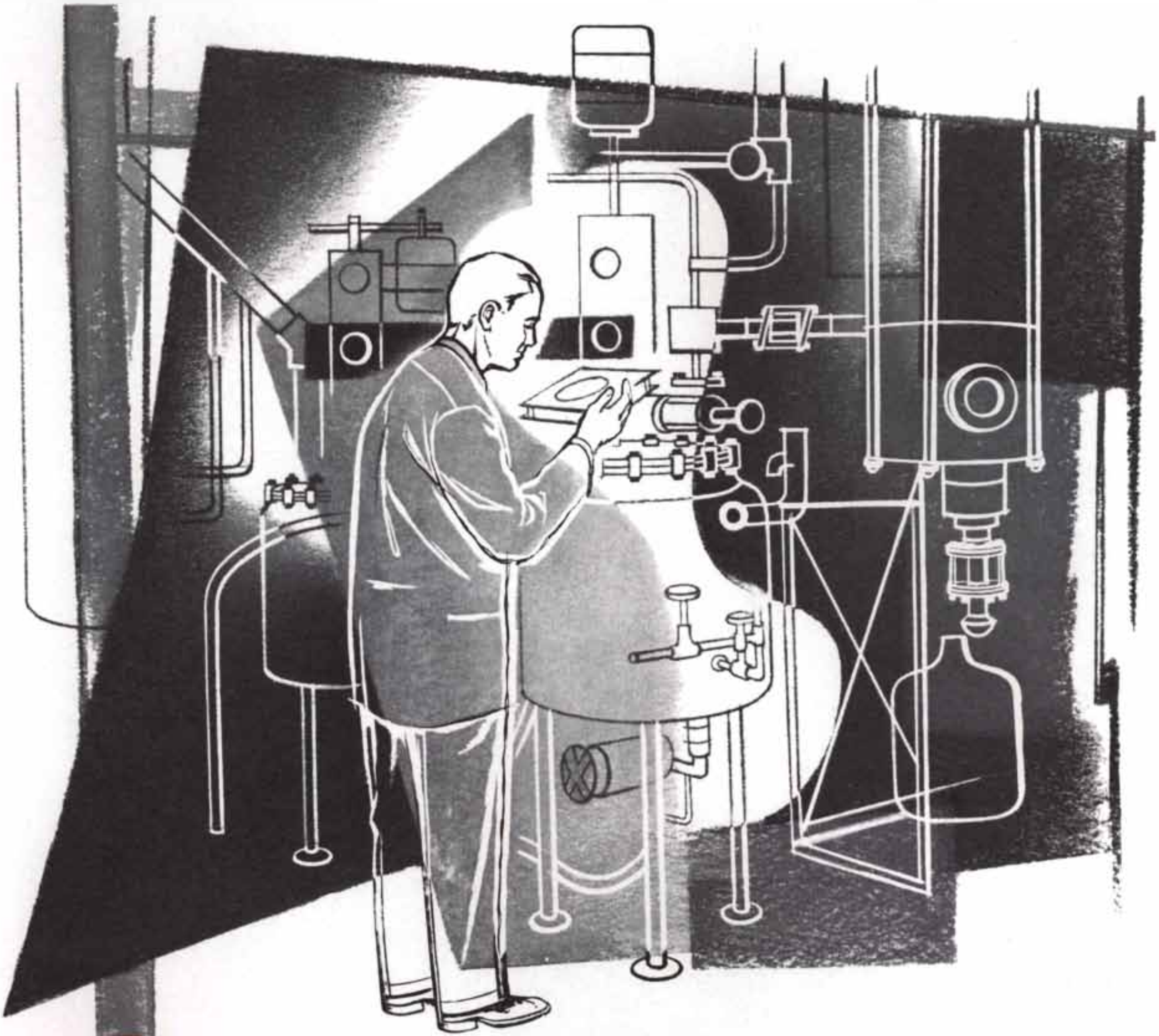
SCIENTIFIC AMERICAN



EARLY ENGLISH SHIELD

FIFTY CENTS

April 1951



CHEMICAL PLANT

Gets a Laboratory Check-up

We have a way to cure production ills before they can become headaches. Above you see a pilot plant, operated to produce chemicals just as a great big, full-scale plant will later yield production runs in much greater volume. The model helps us put the finger on errors, eliminate the cause before it can become a problem in normal production.

Production is regulated step by step from our own mines and forests to finished products, insuring our customers the benefit of unfailing high quality.

Practical research is an extra value in everything you buy from Tennessee . . . make no mistake, it's our aim to bring you extra value every time. It's good business to do business with Tennessee . . . an industry producing for all industry.

TENNESSEE
PRODUCTS & CHEMICAL
Corporation

NASHVILLE, TENNESSEE

PRODUCERS OF FUELS • METALLURGICAL PRODUCTS • BUILDING PRODUCTS • COAL CHEMICALS • WOOD CHEMICALS • FINE CHEMICALS • SPECIALIZED COMPOUNDS

Music's immortals play again, sing again, in RCA Victor's "Treasury of Immortal Performances"

A treasury of **Music's Immortals**

Now artists whose names are musical legend live again for the modern listener. You can hear them, at their finest, in RCA Victor's "Treasury of Immortal Performances."

In recreating these performances on both 33 and 45 rpm, acoustical engineers drew on a vault of master records guarded for posterity by RCA Victor. But new electronic techniques, developed through RCA research, give the new records a quality far surpassing that of the originals.

Because RCA Victor could draw on so vast a storehouse of the past, there is something in the "Treasury of Immortal Performances" for listeners of every age and taste. Caruso sings light and serious music—as do Schumann-Heink, Mary Garden, and others . . . Paderewski is here . . . and, if your taste is for popular music, such greats as Berigan, Armstrong, Waller, in rare early records.

* * *

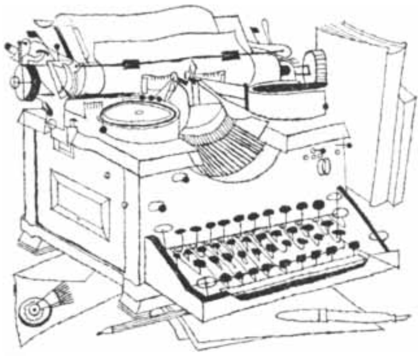
See the latest wonders of radio, television, and electronics at RCA Exhibition Hall, 36 West 49th St., N. Y. Admission is free. Radio Corporation of America, RCA Building, Radio City, N. Y. 20, N. Y.

The magic of RCA Victor's "45" system—as an independent unit, or combined with radio or television receivers—has already led 55 record-makers to adopt it.

RCA

RADIO CORPORATION of AMERICA

World Leader in Radio — First in Television



LETTERS

Sirs:

I thoroughly enjoyed Dr. Barry Wood's article on phagocytosis in the February *Scientific American*; however, I was somewhat disappointed that Barry (a never-to-be-forgotten resident while I was a hen medic at Hopkins) did not include our old professor W. G. MacCallum's description of the "wandering cells," in his *Textbook of Pathology*. I have always considered it one of the most beautiful and artistic examples of scientific writing in the literature. A paragraph from the section on inflammation follows:

"Of course their movements are relatively slow, but when they are photographed in a cinematographic film, at intervals of perhaps a minute, and then thrown on the screen at a rapid rate, as was done in the marvelous films of Dr. Carrell, Dr. Lewis and Dr. Canti, one acquires a completely new impression of cells. There the connective-tissue cells grow out majestically and smoothly from the margin of the field (which really represents a culture of tissues and cells *in vitro*), crossing and interlacing until a firm new structure is formed. Among these cells one may see others of quite different aspect worming their way with no thought of building. Arrived at the margin where they escape from the entanglement of these more serious fibroblasts, they show their true characters. Some are polymorphonuclear leucocytes and they hop about within a limited area in a sort of ecstatic frenzy, evidently throwing out and retracting pseudopods at a great rate. Then there are lymphocytes which move humbly, like slugs crawling only a little way with head to the ground. But also there are macrophages which reach out great arms, perhaps in two or more directions, and at the end of these arms there is a flourish of clear protoplasm with outflung streamers that wave and search about for whatever can be seized or else the whole advancing margin of the cell flows out and comes back like a wave, sucking in any particle that comes in its way. If only we could see all cells in this way, many difficulties would disappear."

HARRIOT HUNTER, M. D.

University of Colorado
Denver, Col.

Sirs:

In the article on Agricola's *De Re Metallica*, in the February *Scientific American*, the subheading is "A Renaissance genius was the earliest modern writer on mining and metallurgy." The text quotes the Hoover translation of Agricola to the same effect.

Since the Hoover translation was first published, another Renaissance genius has received belated acknowledgement of priority in this field. His name was Vannoccio Biringuccio, and his work is entitled *Pirotechnia*, published in Venice in 1540; it is the earliest printed work to cover the whole field of metallurgy.

Biringuccio's *Pirotechnia* was called to public attention by Professor Cyril Stanley Smith in an article, "A Neglected Italian Metallurgical Classic," in *Mining and Metallurgy* for April, 1940, and the English translation by Professor Smith and Martha Teach Gnudi was published in 1942 by the American Institute of Mining and Metallurgical Engineers, as a volume in their Seeley W. Mudd Series.

Some students think that Biringuccio was more competent and scientific than

Scientific American, April, 1951, Vol. 184, No. 4. Published monthly by Scientific American, Inc., 24 West 40th Street, New York 18, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

Editorial correspondence should be addressed to The Editors, SCIENTIFIC AMERICAN, 24 West 40th Street, New York 18, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

Advertising correspondence should be addressed to Charles E. Kane, Advertising Manager, SCIENTIFIC AMERICAN, 24 West 40th Street, New York 18, N. Y.

Subscription correspondence should be addressed to Circulation Manager, SCIENTIFIC AMERICAN, 24 West 40th Street, New York 18, N. Y.

Change of address: Please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.

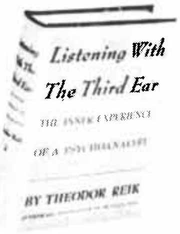
Subscription rates for U.S.A. and possessions: 1 year, $5; 2 years, $9; 3 years, $12.50. Canada and Latin America: 1 year, $6; 2 years, $10; 3 years, $14. All other countries: 1 year, $8; 2 years, $12; 3 years, $16.

THE MOST IMPORTANT BOOKS

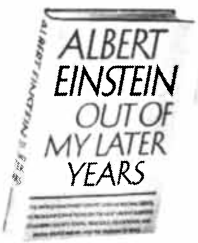
Wherever good books are read and discussed the Book Find Club has become known for the high standard of its selections and their low price—only $1.89 per book, regardless of publishers' higher prices. Such books as MALE AND FEMALE, "a study of sexes in a changing world," by Margaret Mead; GENETICS AND THE RACES OF MAN by William C. Boyd; OUT OF MY LATER YEARS by Albert Einstein; LISTENING WITH THE THIRD EAR, "the inner experience of a psychoanalyst," by Theodor Reik; THE MEANING OF EVOLUTION by George Gaylord Simpson—are only a few of the many notable books available to members.

List Price 4.75
Members' Price 1.89

List Price 5.00
Members' Price 1.89



List Price 6.00
Members' Price 1.89

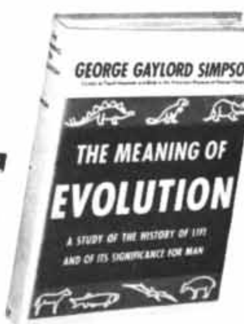


List Price 4.75
Members' Price 1.89

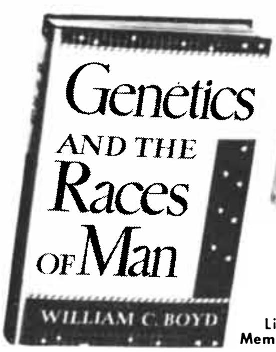
List Price 3.75
Members' Price 1.89

List Price 5.00
Members' Price 1.89

List Price 5.00
Members' Price 1.89



List Price 3.75
Members' Price 1.89



List Price 6.00
Members' Price 1.89

...and at Big Savings to You!

The publishers' list prices of these books range up to $6.00, but as a member of the *Book Find Club* you pay only $1.89 (plus postage and handling). Actually this means an average savings of more than 50% on the books you buy.

Receive FREE Gift Book

You may start your membership in the Book Find Club with any of the distinguished books pictured on this page, and in addition as a new member you may choose a FREE GIFT BOOK from among those listed in the coupon below. You can thus receive **UP TO $12.00 WORTH OF BOOKS FOR ONLY $1.89.**

Join The Book Find Club

It costs you nothing to belong to the Book Find Club. You pay only for the books you want and you may take as few as four in the entire membership year. Each month you receive, FREE, the *Book Find News*, so that you can decide for yourself, after reading the review of the forthcoming selection, if you want the book. If not, you simply return the printed form (always supplied by us) which tells us not to send it. In addition, the Book Find News contains reviews of other notable books available to members. Since it is almost certain that you read at least four Book Find Club selections during the year anyway, why not get them from the Club at the tremendous savings we are able to effect through our large printing orders.

FILL OUT THE COUPON BELOW AND MAIL TO:

THE BOOK FIND CLUB, 401 Broadway, New York 13, N. Y.

Please enroll me as a member and send me the FREE book and first selection I have indicated. I am also to receive FREE each month the Club's literary magazine, the Book Find News. I understand I may accept as few as 4 books a year at the SPECIAL MEMBERSHIP PRICE OF ONLY $1.89 A BOOK (plus 24¢ postage and handling) and may cancel my membership at any time after purchasing 4 selections.

Please send as my first selection ....

Also, send as my FREE book (check title desired):

- ☐ MALE AND FEMALE
- ☐ OUT OF MY LATER YEARS
- ☐ LISTENING WITH THE THIRD EAR
- ☐ GENETICS AND THE RACES OF MAN
- ☐ THE MEANING OF EVOLUTION
- ☐ CRY, THE BELOVED COUNTRY
- ☐ TWO ADOLESCENTS
- ☐ PSYCHOANALYSIS: Evolution and Development
- ☐ MIND AND BODY
- ☐ INISHFALLEN FARE THEE WELL

NAME ______________________ (please print)

ADDRESS ______________________

CITY ______________ ZONE ______ STATE ______

(prices slightly higher in Canada) D-21-2

Agricola. As a matter of fact, Agricola copied portions of Biringuccio's work into his own book. Biringuccio's attitude shows a freshness and spirit that well deserve the adjective "modern." *Pirotechnia* is still delightful reading. Biringuccio's skepticism toward superstition and magic, and his realistic evaluation of alchemy, will impress modern scientists; his brief remarks on safety and on increased production from shorter work periods will interest management experts and industrial psychologists. . . .

WILLIAM G. SCHLECHT

Geological Survey
United States Department
of the Interior
Washington, D. C.

Sirs:

Your readers might be interested to learn that the article appearing in your February issue by Eugene Ayres on solar heating is abstracted from a chapter of a forthcoming book by Eugene Ayres and C. A. Scarlott on *Energy Sources*, to be published this fall by McGraw-Hill Book Company.

CARL E. NAGEL

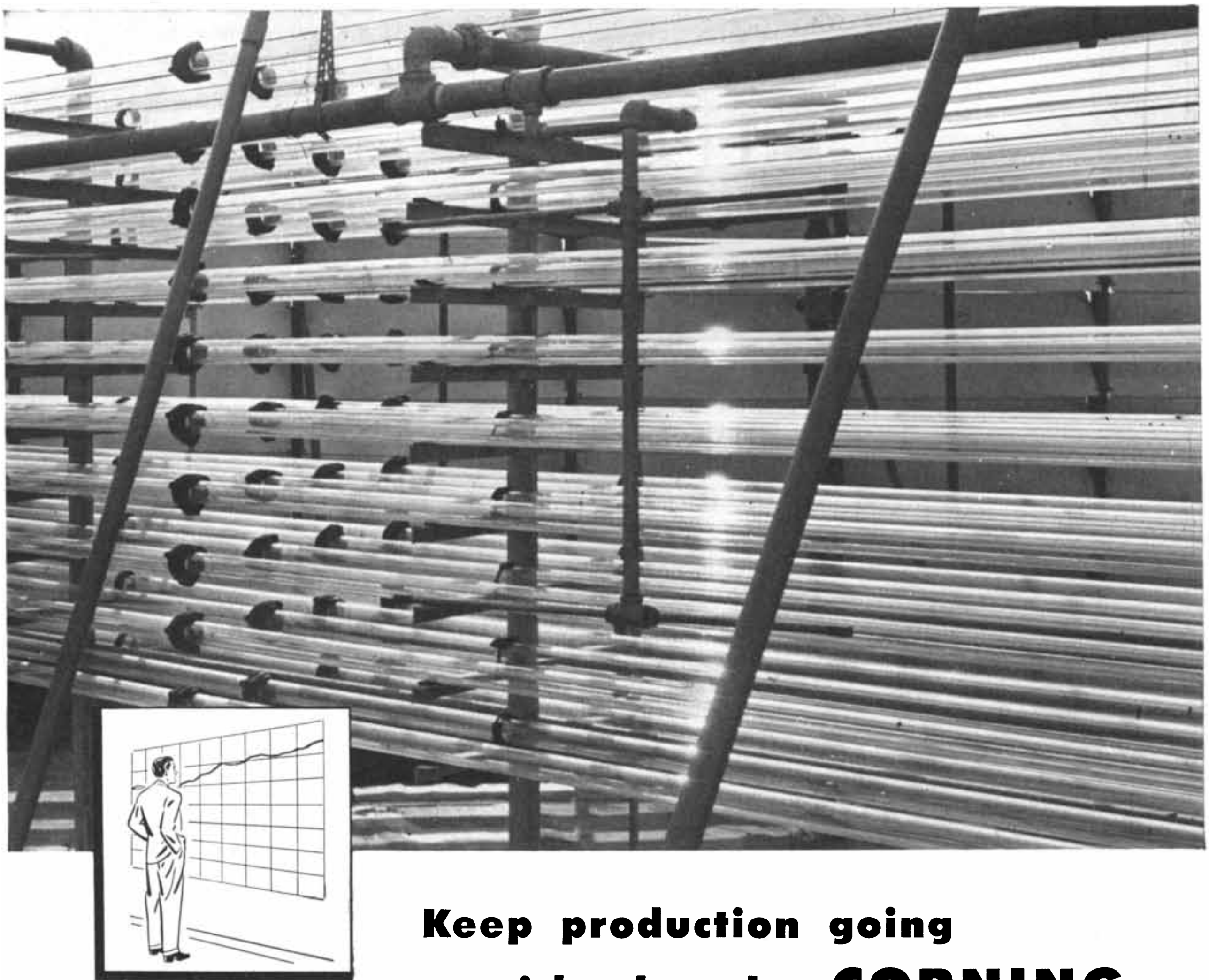
McGraw-Hill Book Company, Inc.
New York, N. Y.

Sirs:

Charles P. Lyman and Paul O. Chatfield, in their article "Hibernation" in your December issue, state, "no man can survive a drastic reduction in his body temperature." As evidence they cite data obtained from the inhuman "experiments" at the Dachau concentration camp, saying, "the hardiest human subject, immersed in cold water, died when his rectal temperature had been lowered to 77 degrees." I question the validity of any "scientific" data obtained by such methods as were used, since the Dachau "experiments" were probably made in order to satisfy a morbid curiosity rather than in the interest of science.

However, human beings *have* been maintained at reduced temperatures of 75-90 degrees Fahrenheit for as long as five to eight days. Experiments in reduced body temperatures have been conducted by Drs. Smith and Fay on patients in advanced stages of hopeless cancer. Their findings are reported in an article entitled "Observations on Human Beings with Cancer, Maintained at Reduced Temperatures of 75-90 F." in *Temperature, Its Measurement and Control in Science and Industry*.

Smith and Fay state that 33 patients have been subjected to 75 individual general reductions of body temperature to 74-90 F. during the period from December 1938 to October 1939. All were



Keep production going with glass by CORNING

If your production curve is subject to dips for lack of scarce materials, investigate glass by Corning. Hundreds have—and found glass not only a practical, low cost material but one which often does a better job.

The installation above is a case in point . . . a process for which formerly, corrosion resistant pipe of another material had been used. Because Pyrex brand glass pipe is so resistant to corrosion, heat and physical shock, it "proved an excellent solution." It's easy to clean and provides visible check besides. Like other glass by Corning it is *available* today.

Whether your product or process involves chemicals, electronics, appliances, industrial tools, lighting, or household goods, Corning technicians can dip into the reservoir of over 400 glasses in current melt to meet your needs. These glasses provide an amazing range of characteristics. Once the glass you need is selected, it can be pressed, blown, rolled or molded to the design required.

Don't penalize production for lack of an inquiry to Corning. You tell us what the problem is and we will do our best to solve it. As a starter, send for the booklet illustrated below. It will show you how glass by Corning is being applied in many ways today.

1851
100 YEARS OF MAKING GLASS
BETTER AND MORE USEFUL
1951

Corning means research in Glass

Corning Glass Works
15 Crystal St., Corning, N. Y.
Please send me your "Designers Bulletin IZ-1."

NAME________________ TITLE____________
COMPANY____________________________
ADDRESS____________________________
CITY______________ ZONE____ STATE________

TM REG PYREX US PAT OFF

hopeless, terminal cases of cancer, most of whom were in extremely poor physical condition—"emaciated, cachectic, often anemic."

Their observations indicate that basal metabolism is apparently reduced by as much as 20-25 per cent. They state that any activity or even feeding tends to raise the body temperature. This may indicate the reason why the Dachau subjects died at 77 degrees. It would probably be an understatement to say that the Dachau subjects unwillingly submitted to such treatment and probably struggled to keep warm against the opposing cold.

In contrast to the Dachau "experiments," the patients of Smith and Fay willingly submitted to treatment by reduction of body temperature. In quite a few cases, patients obtained temporary relief from pain and a temporary slowdown in the growth of cancer.

ALLEN D. CLARK

Friendswood, Tex.

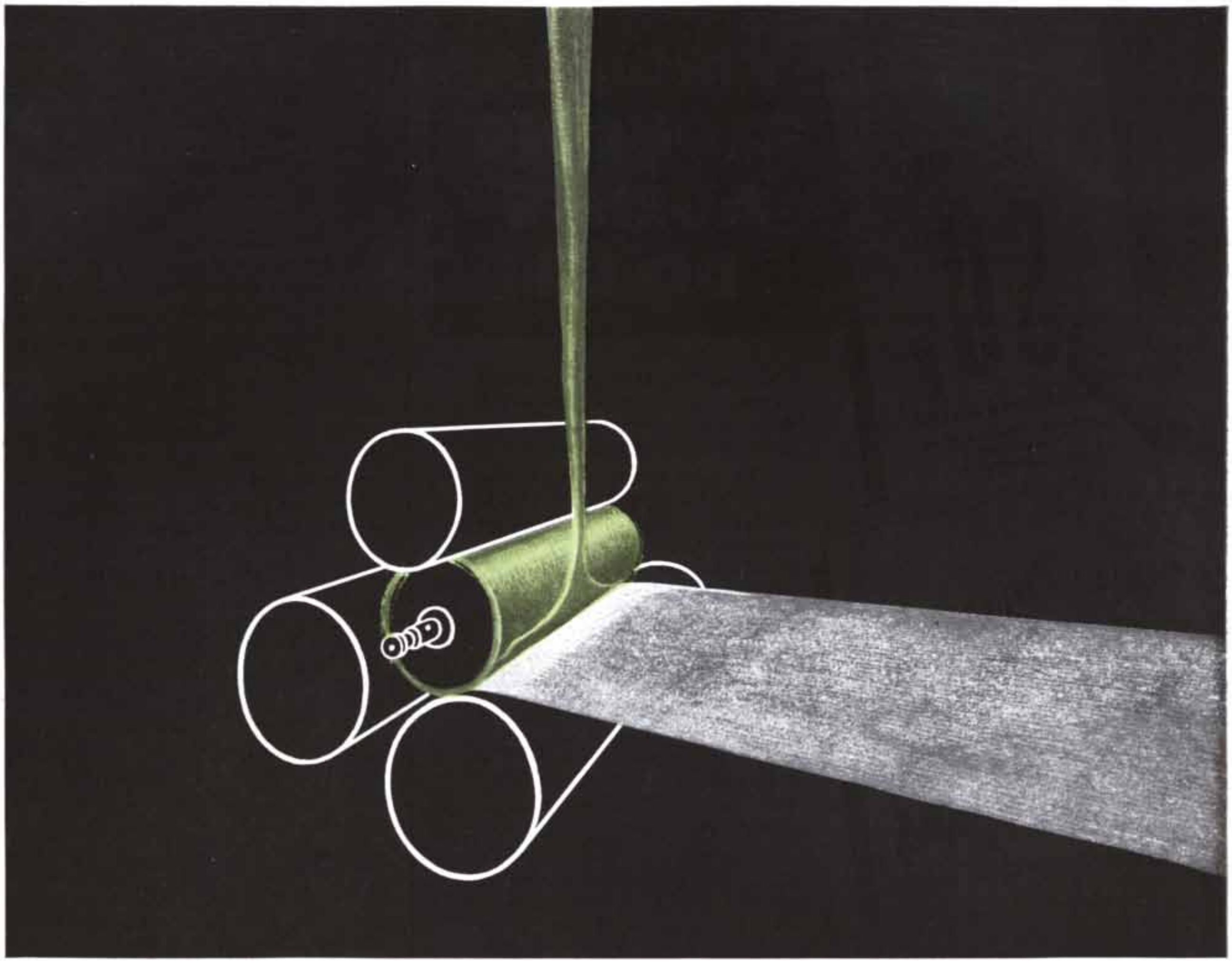
Sirs:

We were somewhat hesitant in including in our article any evidence produced by the Nazis, and I quite agree with Clark's criticism that such results are open to some question. Apparently these particular experiments have been reviewed quite carefully, as they are quoted in at least one authentic work on temperature control in human beings. We were familiar with Smith and Fay's work on patients who were chilled when suffering from hopeless cancer. The fact that their temperature was lowered to 75 degrees Fahrenheit, in contrast to the 77 degrees which we stated as fatal, does not seem to me of any great significance because the human body can vary a few degrees, depending on where the temperature is taken. Very little is known about the tolerance of humans to hypothermia, and the fact that Smith and Fay's patients were drugged would certainly make some difference in their reaction to cold. The point we were trying to make was that human beings could not suffer the profound lowering of temperature to, say, 40 degrees which is seen in animals which are in deep hibernation, and I think that Clark will agree that all the evidence agrees with this thesis.

Incidentally, the brief note at the end of our article states that I am research associate in the Department of Physiology at the Harvard Medical School. I should like to correct this statement; I am research associate in the Department of Anatomy.

CHARLES P. LYMAN

Harvard Medical School
Cambridge, Mass.



STRUCTURAL PLASTICS YOU CAN BUILD ON

You are going to hear more and more about the newly developed reinforced structural plastics that on a strength-weight basis are comparable to the metals in mechanical strengths. The new BAKELITE "C-8" Resins provide several distinctive and unusual qualities for such structural plastics.

The illustration portrays a typical application — high strength tubing. Woven glass fiber is shown being wound on a mandrel while a liquid BAKELITE "C-8" Resin is poured on. The union of glass cloth and resin is brought about at room temperature and at contact pressure, curing to a final hard, tough, durable state in a few hours. The application of higher temperatures would reduce the curing time still further.

BAKELITE "C-8" Resins are highly chemical resistant, will even withstand 40 per cent caustic. The electrical properties of the "C-8" Resins are outstanding too. For AC service, a typical resin in this group has a very low power factor—.0079 at 60 cycles. For DC application this resin provides exceptional insulation resistance as evidenced by tests such as ASTM D-257-49T (1). Dielectric strength is 435 volts per mil.

BAKELITE "C-8" Resins are still in the developmental stage which limits their production at the present time. They are available only in small quantities, principally to assist manufacturers and scientists in furthering their research and development programs. Those interested in evaluating the "C-8" Resins for structural, electrical, or chemical service—as molding, laminating, bonding, casting and adhesive materials—are requested to provide full details. Inquiries directed to Department BU-42 will be treated in strictest confidence.

BAKELITE
TRADE-MARK
C-8 Resins for REINFORCED PLASTICS

TRADE MARK

BAKELITE COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N. Y.

50 AND 100 YEARS AGO

APRIL 1901. "Profs. Liveing and Dewar have lately studied the inert gases of our atmosphere by liquefying air by contact with the cooled walls of a vessel at −200 degrees C. The more volatile portion was distilled over into spectrum tubes after it had been freed from every trace of nitrogen, argon and the compounds of carbon. The tubes showed the spectra of hydrogen, helium and neon with great brilliancy, and also a large number of other lines which could not be referred to any known origin. This result showed that a sensible proportion of hydrogen exists in the earth's atmosphere, a point that has been much disputed."

"In his annual report the director of the Harvard College Observatory, Prof. Pickering, again refers to the need of a large telescope in the Southern Hemisphere to carry on work that cannot be done by the instruments set up in America, Europe and England. These great instruments are fully employed on especially difficult problems relating to stars of the Northern Hemisphere. The great reflector of Melbourne is now little used, and the same is true of the refractor of the Royal Observatory at the Cape of Good Hope. The field for work is boundless and at the same time there are certain definite problems demanding attention—such, for example, as a spectroscopic determination of the motion of the southern stars in the line of sight. Work of this sort is fully attended to in the Northern Hemisphere, but the final results, which will give the motion of our solar system in space, cannot be attained until corresponding observations are made upon all the brighter stars of the Southern Hemisphere."

"It is announced that on April 1 M. Curie, the chemist, separated a new gas from radium. It is intensely phosphorescent and will glow for months in the dark. It was also announced that M. Naudon found means for producing X-rays without the aid of electricity by exposing a metal plate to the rays of the violet end of the spectrum."

"Five years have elapsed since Prof. Roentgen startled the world by the announcement of his discovery of the rays which are now quite commonly called by his name. We must admit that no more is known today as to the essence of the rays than was contained in Prof. Roentgen's original paper. Thus their identity in character with light rays has not been established by the usual tests. They do not behave like any other radiation known to science; yet scientific men are generally of the opinion that they belong in the ultra-violet region of the spectrum, perhaps having the shortest wave length of any known radiation—so short that it is not possible to deviate them from their course by any known form of reflecting or refracting substance. In disclosing and locating foreign bodies buried in the tissues, great progress has been made. Five years ago it was thought impossible to make a picture which would show the condition of the soft tissues of the body. This is now easily done."

"Prof. Henry A. Rowland died at Baltimore April 16, and by his death America has lost one of her most illustrious physicists. He was well known as an inventor, and his numerous devices include the multiplex telegraph instrument and a machine for making diffraction gratings. His investigations resulted in a large number of electric and optical discoveries and improvements, and some of the photographs which he succeeded in making of the solar spectrum were the finest ever secured."

APRIL 1851. "The British Government has issued orders stating that no contract will be entered into with iron ships."

"The locomotive is the most perfect of machines. It approaches nearer to the spiritual and physical combination of the human machine than any other. In it we behold what the steam-engine is when 'unchained to the rock, and unfettered to the soil.' One of the grandest sights in the world is a locomotive with its huge train dashing along in full flight. To stand by night at the side of a railroad, when a large train is rushing along at the rate of 30 miles per hour, affords a sight both sublime and terrific. No wonder the simple backwoodsman declared that the first locomotive he ever saw was 'pandemonium in harness.'"

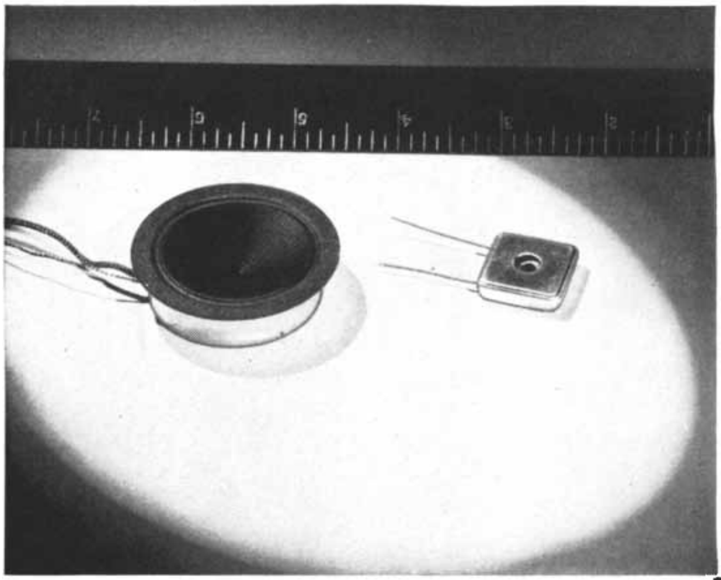
"The next meeting of the American Association for the Advancement of Science will be held at Cincinnati early in May next. This will be the first session of the Association in the West, and it is hoped that there may be a general attendance, particularly from the Western and Southwestern states. The results of American scientific research cannot be diffused to any extent by any other organization in this country, and the 'American Association,' founded upon the model of the British Society from which it derives its name, has already earned an honorable place among scientific institutions."

"Many of the London journals notice the death of Mr. Audubon. One of them characterizes him as the greatest ornithologist that ever lived."

"Some very ingenious daguerreotypes of the moon, as it appears through the Cambridge telescope, have been made by Mr. Whipple of Boston. In those views the volcanic mountains may be distinctly traced, with deep valleys between, and the distant plains."

"We noticed some time since the account of an alleged discovery in the island of Madagascar of certain enormous fossil eggs. Full confirmation of the statement has been received by the recent arrival in France of three of the eggs, with some bones of a gigantic bird, which is not doubted to have hatched them, or been hatched from one of them. These extraordinary remains have been made the subject of a formal report to the *Academie des Sciences* by M. Isidor Geoffroy St. Hilaire, a distinguished naturalist, who pronounces them to be those of a bird which he has named Epiornis. It is classed along with the gigantic fossil birds of New Zealand, which were wingless, or non-flying. It begins to be evident that all the wonders of the antediluvian era have not yet been rescued from the earth, in which they have been so long hidden away from human eyes."

"The American Republican Mail Steamship *Pacific* arrived at this port on Saturday at 10 A.M., after a passage of 9 days and 20 hours from Liverpool, the shortest on record. When news of the *Pacific's* arrival was announced at the Exchange, three cheers were given for its Line. It is expected by many now living that they will yet cross the Atlantic in seven days."



THE COVER

The photograph on the cover shows a shield reconstructed from fragments found in the tomb of a seventh-century Anglo-Saxon king (*see page 24*). The fragments were iron and bronze decorated with gold and garnets. They were first assembled into the six ornaments grouped about the center of the shield; then they were mounted on a disk covered with white leather that approximates their original setting. The shield was more richly ornamented than any other known to have been made by the Teutons of northern Europe. It probably came from Sweden; thus it is another clue to the origin of the peoples who came to Britain after the Romans had left.

THE ILLUSTRATIONS

Cover by E. Howard Symmonds from Black Star

Page	Source
15-17	Irving Geis
18	Soil Conservation Service, U. S. Department of Agriculture
20	U. S. Army Air Corps
21-23	Irving Geis
24-25	Courtesy the Trustees of the British Museum
26	Eric Mose
27-30	Courtesy the Trustees of the British Museum
44	Argonne National Laboratory
45	Matthew Greene
46	Argonne National Laboratory
47	Matthew Greene
48	Los Alamos Scientific Laboratory
49	Matthew Greene
52-53	Bernarda Bryson
54	Courtesy G. Ledyard Stebbins, Jr.
56	"*Primula Kewensis* and Its Derivatives," by W. C. F. Newton and Caroline Pellew. *Journal of Genetics*, Vol. XX, No. 3; January, 1929
57	Adolph Brotman
58-59	Courtesy G. Ledyard Stebbins, Jr.
60-62	Sarah Love
64-65	David Stone Martin
66-69	K. Chester
71	Wide World Photo
77-78	Roger Hayward

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR APRIL 1951 **VOL. 184, NO. 4**

ARTICLES

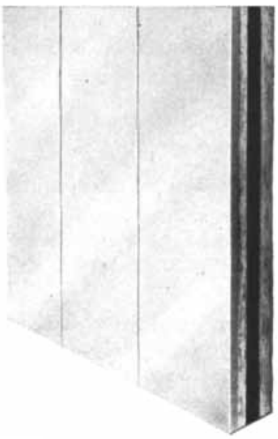
DEPARTMENTS

What's New at CRUCIBLE

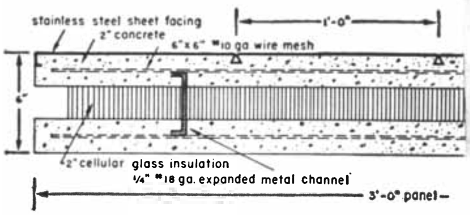
about stainless curtain walls

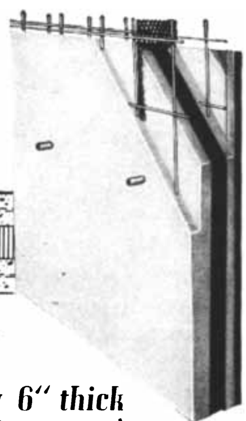
Modern construction methods have changed walls from the self-supporting type to a mere covering which does not support its own weight for more than one or two stories. Hence the definition of "curtain wall":—the facing or enclosure of the structural steel frame. This frame supports the entire weight of modern buildings.

The need has existed for a covering that would not only clothe the building, but be lightweight, economical and space saving. Because these requirements are more than adequately met with stainless steel curtain wall construction, this method is becoming increasingly popular with cost and space conscious owners, builders and architects.



the CRUCIBLE "sandwich"





the CRUCIBLE "sandwich"— only 6" thick (can be less)

Crucible stainless steel curtain wall panels are in the form of 6-inch thick "sandwiches". The facing consists of flanged, light-gauge stainless steel sheets with a factory, or site-fabricated, sandwich consisting of cellular glass insulation between two layers of concrete with connecting reinforcing. Crucible 18-8 stainless as the outside face offers excellent resistance to weather and fire while providing eternal beauty with a minimum of maintenance; the inside face can be finished or painted to suit the requirements of modern building interiors.

Here are technical problems—solved by co-ordinated research:

moisture penetration

The unique characteristics of the cellular glass insulation stop moisture vapor migration from one face of the panel to the other. The cellular insulation properly designed and installed assures that condensation will not take place *anywhere* within the sandwich.

insulation

Although less than half as thick as the usual wall construction, this Crucible stainless steel panel construction has more than twice the insulating value. The "U" value (overall thermal conductivity) is approximately 0.15 BTU Hr./Sq.Ft./°F.

fire resistance

The Crucible sandwich met the requirements of a standard 4-hour fire test conducted in the testing laboratories of the National Bureau of Standards. This meets all old building codes and is double, or better, the requirements of modern enlightened building codes.

erection and fabrication

Since a building frame is not precision built, the attachment of the panel walls to the frame is done with fastening devices that provide necessary 3-dimensional adjustment. Panels can be made at the building site, and a 24-hour casting-to-fastening cycle is possible.

technical service available

Though the use of stainless steel is now restricted, Crucible metallurgists and development personnel are continuing to investigate improved methods of curtain wall and other construction so that better buildings can be built when stainless is more freely available. For more information write: CRUCIBLE STEEL COMPANY OF AMERICA, 405 Lexington Ave., New York 17, New York.

CRUCIBLE first name in special purpose steels

51 *years of Fine steelmaking*

Spaulding Works, Harrison, N. J. • Midland Works, Midland, Pa. • Park Works, Pittsburgh, Pa. • Spring Works, Pittsburgh, Pa. National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

SCIENTIFIC AMERICAN

APRIL 1951 VOL. 184, NO. 4

THE CENSUS

The 17th decennial count of the human resources of the U. S. reveals that the population increase of the past decade was much larger than expected

by Philip M. Hauser

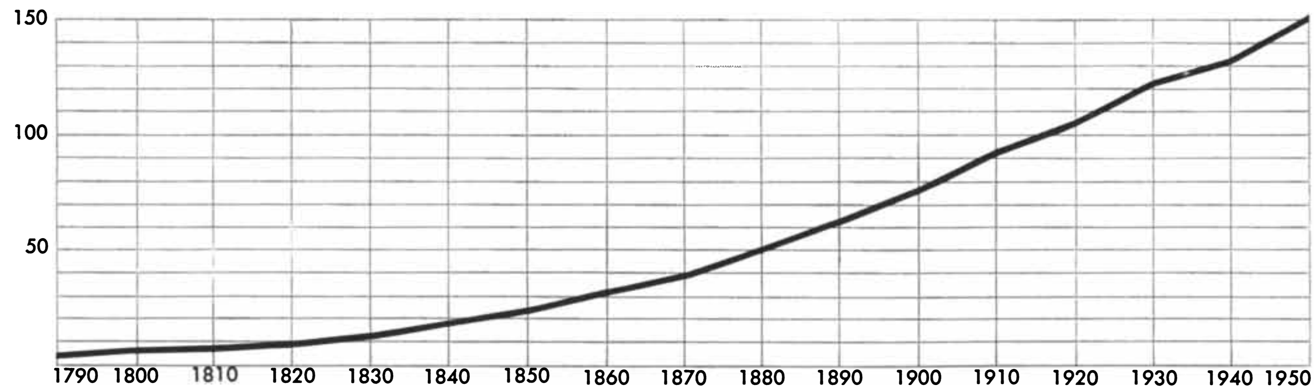
BETWEEN 1940 and 1950 the U. S. experienced the largest numerical population increase in its history. According to the official 1950 Census count, our population rose by over 19 million during the decade. This large increase was not anticipated: the 1950 total of 150,697,361 was about seven million above the highest prediction made by population experts a decade ago. What is the meaning of this great population upsurge? Does it herald a reversal of the long-run downward trend in our rate of increase? These and other questions can be answered, at least in part, by analysis of the first detailed returns from the 1950 Census.

By far the largest factor in our population growth during the past decade was natural increase; that is, the excess of births over deaths. Of the total increment of 19 million, about 18 million represented an excess of births over deaths. The past decade has been especially favorable to natural increase. War-induced prosperity lifted the birth rate to 27 per 1,000 persons in 1947 (a 26-year high), and in the decade as a whole the U. S. produced its largest crop of babies—more than 32.2 million. Concurrently our death rate fell to a new low—less than 10 per 1,000 persons during the decade. Immigration, although a relatively negligible factor, also added to our population: partly as a result of modification of our quota restrictions to admit refugees and displaced persons, the excess of immigration over emigration during the decade was about one million.

The great population increase of the 1940s was accompanied by important shifts and changes in the make-up of our population, but let us first consider the significance of the increase itself. On its face this upsurge seems to belie the experts, who for decades have been calling attention to the declining U. S. birth rate and forecasting that the nation's population would become stationary or begin to decline by the end of this century. To evaluate the increase of the past decade, however, we must analyze it in the historical context. Just as one swallow does not make a summer, the experience of a single decade cannot lightly be interpreted to represent the reversal of the long-term trend.

IN THE century and a half of its existence the U. S. has experienced a population increase unprecedented in human history for so large an area over so long a time. Since 1790, when the nation had only 3.9 million people, its population has increased 39-fold. It has doubled five times. The first three doublings each took 25 years. The fourth doubling took 35 years, from 1865 to 1900. The last doubling took 50 years, from 1900 to 1950.

Thus as a long-term trend the rate of increase has been declining since the Civil War. In the depression decade of 1930-1940 the percentage increase dropped to its lowest point: 7.2 per cent. During the decade just ended the percentage increase was twice as high (14.5



THE 17 CENSUSES have measured the growth of the U. S. from 3.9 million in 1790 to 150.7 million in 1950. The population at each census is given in millions. The rate of increase has declined during recent decades.

per cent), but it was still the second lowest recorded for any decade in our history.

Why was the rise in the past decade so much higher than authorities had predicted? For one thing, they did not anticipate the war and the consequent upsurge in our marriage and birth rates. Moreover, the rise in part reflected a large "deficit" in marriages and births accumulated during the depression decade. In the 1940s many people began to have children that were postponed during the 1930s. This is indicated by the fact that most of the increase in births during the 1940s was in first and second children, not in further additions to the family. P. K. Whelpton of the Scripps Foundation for Population Research, who has intensively analyzed the changing birth rate, remarks that the 1940-1950 increase in the birth rate was largely "a matter of timing rather than a reversal of the trend toward fewer children per completed family."

Nevertheless, the great upsurge in population growth produced by World War II does require serious attention, at least for its short-range effects. Among other things, it poses unexpected and serious problems for our educational system. The bumper baby crop of the 1940s by 1958 will raise enrollment in elementary and secondary schools to more than 34 million, a 40 per cent increase over the enrollment of 1947. Thus the problem of expanding our school plant and teacher staffs, already acute, will become much more severe in the coming decade.

WHAT of the changes within the structure of our population? In the first place, as everyone knows there have been large shifts in its geographic distribution. Despite the general population increase, four states—Oklahoma, Mississippi, Arkansas and North Dakota—actually had net losses of population; Oklahoma's loss was 4.5 per cent. In addition, 22 other states lost by migration, though the higher birth rate saved them from a net loss. Of the states that gained (mostly in the far West) California led with an increase of 53 per cent.

Besides the shifts from region to region, there have been sharp changes within regions. Almost half of our 3,103 counties lost population during the decade. One shift has been from rural to metropolitan areas: the 168 "standard metropolitan areas" in the nation gained more than 20 per cent in population, while the rest of the country gained only six per cent. Another shift has occurred within the metropolitan sections themselves—from the cities to the suburbs and surrounding countryside. The increasing importance of suburbs in our national life is strikingly demonstrated by the fact that nearly half of the nation's total population increase took place in such areas.

A second important change is in the sex composition of the population. For the first time in a Decennial Census report women outnumber men, in the ratio of 100 to 98. Throughout most of its history this country has had more males than females, reflecting its frontier character and the influence of immigration, which was predominantly male. At the peak of their predominance in 1910, males outnumbered females 106 to 100. Two major factors have contributed to the shift in the balance of the sexes. The first is our immigration restriction laws. The second is the lower death rate of females, whose average lifetime is increasing more rapidly than that of men. Although more males than females are born, the women's better survival rates have placed them in the majority.

A third major change is in the age structure of the population. In spite of the high birth rate of the 1940s, the preliminary 1950 Census returns show that the median age of the entire population rose from 29 to 31.2 years—the highest ever recorded for the American people. The aging of the population, which is taking place in other Western countries as well as the U. S., is due mainly to declining fertility and declining mortality. Of special significance, perhaps, is the rapid increase in the number and proportion of our "senior citizens"—persons 65 years old and older. While the population of the country as a whole has doubled since 1900, the number of persons 65 years and over has quadrupled. They now constitute more than eight per cent of the nation's population.

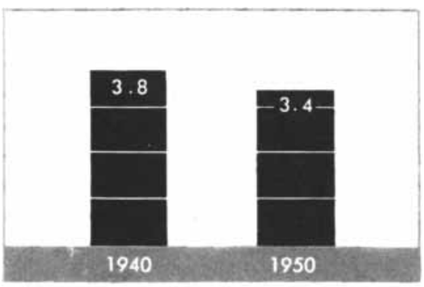
The marriage rate rose sharply during the decade and reached an all-time recorded peak of 16.4 per 1,000 persons after the demobilization of the armed forces in 1946. In consequence, the 1950 Census reported the largest proportion of married persons in the history of the nation—about 67 per cent of all persons 14 years old and over, in contrast with 60 per cent in 1940 and 53 per cent in 1890, when the Census Bureau first published statistics on marital status.

The proportion of nonwhite persons in 1950 was 10 per cent, about the same as a decade earlier but far less than in 1790, when Negroes made up about 20 per cent of the population. In 1950 less than seven per cent of the white population was foreign-born—the lowest percentage ever recorded since the Census of 1850 first reported such data.

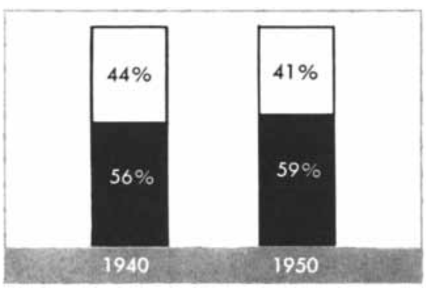
As in previous decades, the number of households continued to increase more rapidly than the total population—a reflection of the fact that the American people are living in relatively smaller household units. In 1950 the average number per household was only 3.4, as compared with 3.8 in 1940 and 5.8 in 1790. The total number of households was 42.5 million.

THE available Census returns show a substantial advance in the social-economic level of our people during the decade. Despite the disruptions of the war, by 1947 the average person 14 years and over had completed approximately two years of a high-school education, as contrasted with less than one year in 1940. The proportion of persons with less than five years of schooling decreased to less than nine per cent, while those with a high-school education increased from 16 per cent to about 22 per cent and those with a college education from 3.8 per cent to 4.4 per cent.

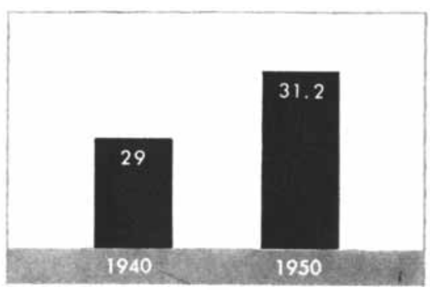
The wartime mobilization of our manpower expanded the total labor force from about 55 million in April, 1940, to a peak of 66.2 million in April, 1945. In April, 1950, on a comparable basis, the labor force was still 63.5 million, well above the prewar "normal trend." During the decade unemployment shrank from about 8.4 million to 3.5 million, or less than six per cent of the working



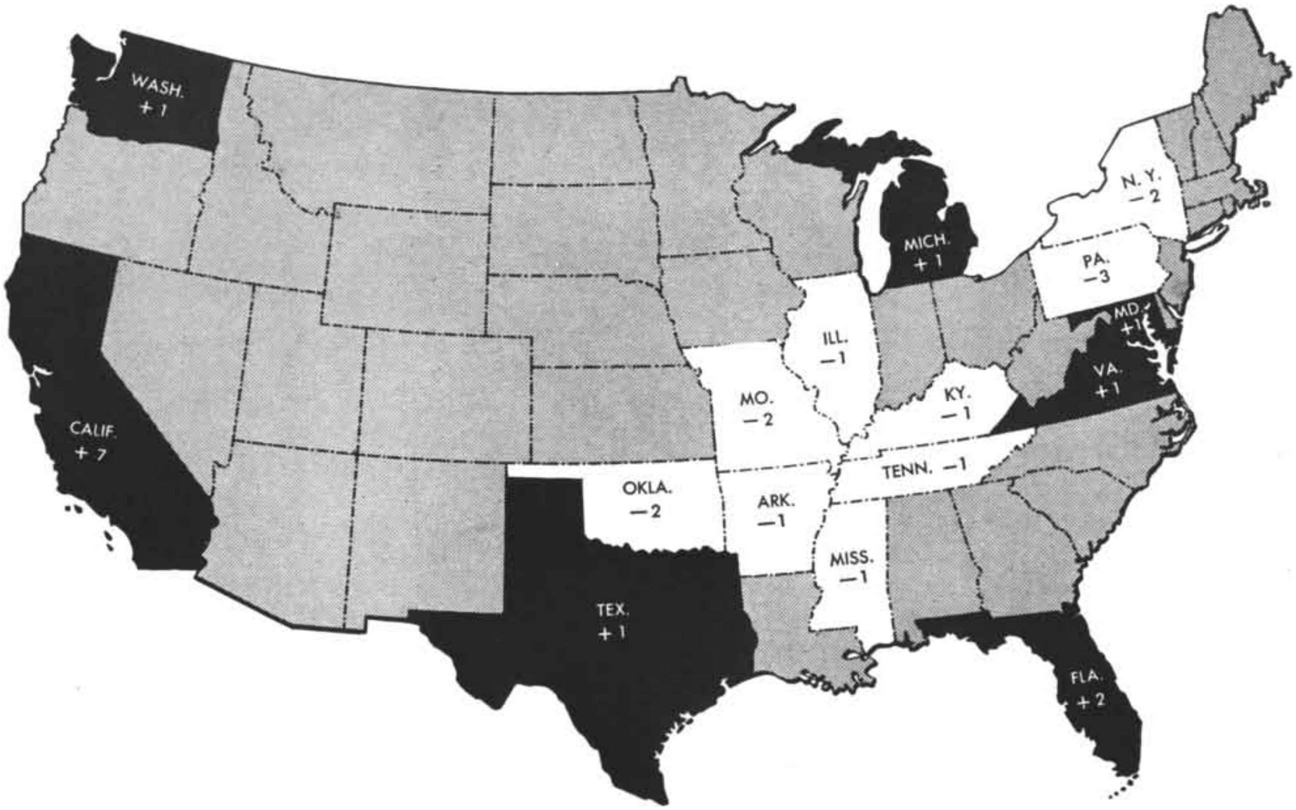
SIZE OF FAMILY decreased. In 1940 the population per household was 3.8; in 1950 had fallen to 3.4.



URBAN POPULATION gained. In 1940 56 per cent of the people lived in urban areas; in 1950, 59 per cent.



MEDIAN AGE of the population increased. In 1940 it was 29 years; in 1950 it had gone up to 31.2 years.



SHIFT IN POPULATION is reflected in the forthcoming change in the apportionment of Representatives to Congress. The seven states that will gain Representatives are shown in black; the nine states that will lose them are shown in white. The number of Representatives gained or lost is shown on each of the states involved.

population. Particularly striking was the increase in the proportion of working youngsters aged 14 to 19 (from 29 to 37 per cent), of women (from 22 to 32 per cent) and of oldsters aged 65 years old or over (from 24 to 26 per cent) in the labor force. The increases in the proportions of younger and older persons in the labor force were counter to previous trends and directly reflected the pressures of the war economy, the full effects of which were by no means dissipated at the time of the 1950 Census.

The Census shows an appreciable increase in the real income of individuals and of families during the decade. The median wage and salary income earned by persons 14 years of age or over rose from $789 in 1939 to over $2,000 in 1949, an increase of 156 per cent. Allowing for the decrease in the purchasing power of the dollar (from about $1 to about 59 cents), the average rise in real income was about 50 per cent. Thus despite inflation the average individual earner gained a substantial increase in purchasing power, though the increase was considerably less for women than for men.

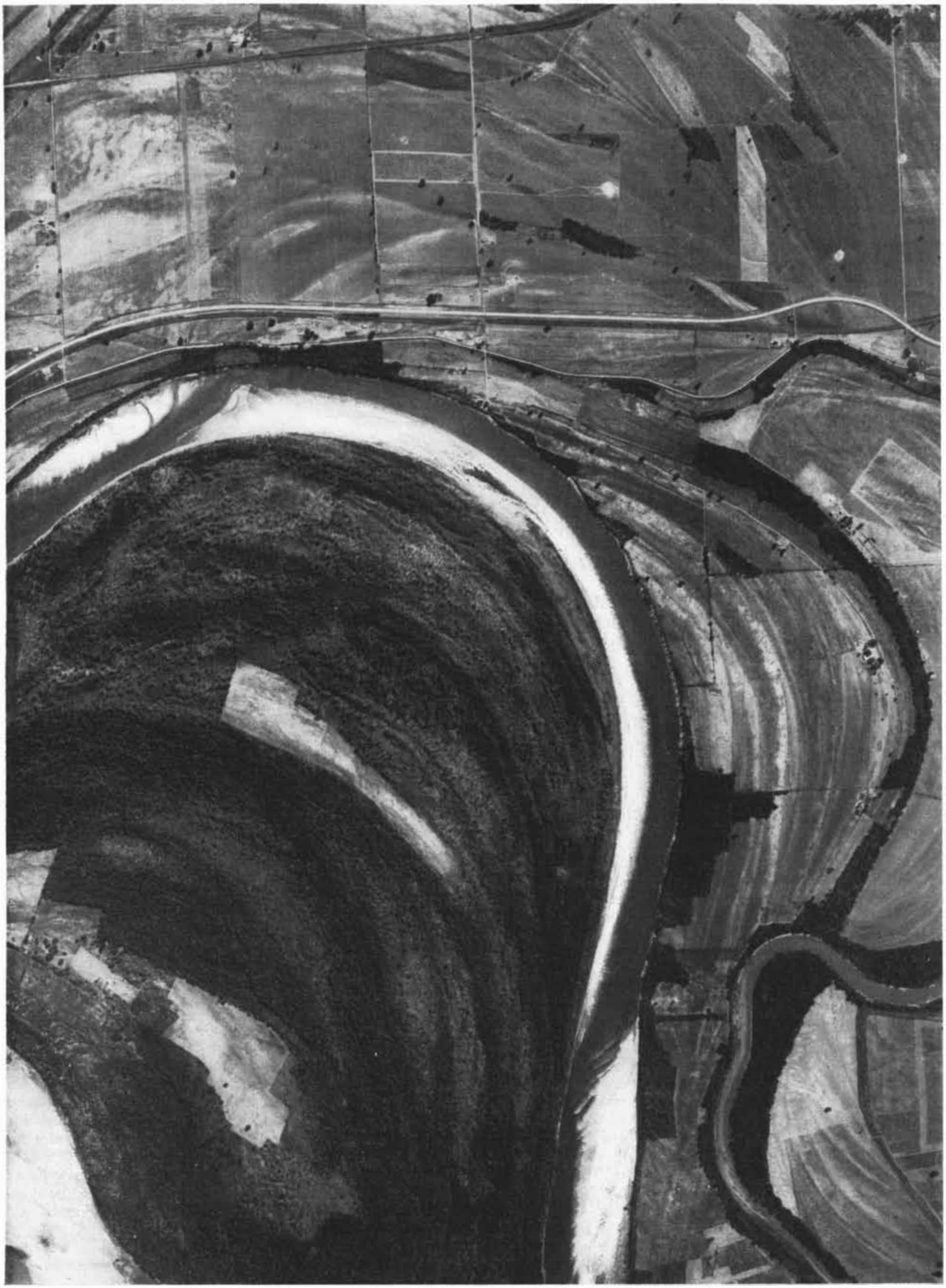
Another set of data indicates that the gain in income occurred during the war, and that since the end of the war there has been no real increase in income. These figures give the total money income of households in 1944 and in 1949. The median income of families or individuals living alone in 1944 was about $2,200, in 1949 about $3,000. This gain of about 36 per cent was almost completely offset by the decrease in the purchasing power of the dollar during that period.

WHAT will the population and economic changes of 1940-1950 mean in our national life? The acceleration in the growth of our metropolitan areas and the increased decentralization of population within them are having important effects on urban land values, city planning, slum clearance and on housing. State and local governments, which adjusted their planning to relatively small population increments during the 1930s, are faced with the necessity of re-examining their plans and their budgets. Public and private agencies concerned with housing must look forward to continuing and perhaps augmented difficulties in the coming decade. The large increase in marriage rates during the past decade, and the continued decrease in size of family together with increased family purchasing power, have created a demand for housing which imposes unprecedented pressures on the housing supply.

Private and public agencies concerned with welfare and social security problems will have occasion to shift their sights. In the 1930s they focused their attention on problems of unemployment, poverty and old age. The problems of an aging population are still with us, to be sure, but they have been joined with renewed intensity by problems of youth. Concern with poverty and unemployment must give way in part to concern with the problems of utilizing increasing proportions of our labor reserves.

Finally, the population changes of the past decade have important implications for national defense. In the immediate future we shall have a relative decline in young manpower; because of the drop in the birth rate during the depression 1930s, there will be decreasing numbers of young men and women reaching the age of 20 in the next few years. But after 1960, when the record baby crop of the 1940s begins to reach maturity, the supply of youths for productive work on the home front and for manning the armed services will climb rapidly. The advances in education and in levels of living during the past decade also are encouraging for our national future. In sum, the 1950 Census shows that we achieved substantial gains during the decade in both our human and our material resources.

Philip M. Hauser is professor of sociology at the University of Chicago. He was formerly Acting Director of the U. S. Bureau of the Census.



AERIAL PHOTOGRAPH of the Mississippi between Grand Tower and Aldridge, Ill., shows the markings of its former courses. From such photographs maps of past and present courses of the river have been prepared.

PARADOXES OF THE MISSISSIPPI

The water of the great river is generally assumed to be muddy, its bed rising above the surrounding country, its delta building out into the Gulf of Mexico. None of these assumptions is true

by Gerard H. Matthes

OL' MAN RIVER, that thousand-mile stretch of the Lower Mississippi from Cairo, Ill., down to the Gulf of Mexico, is renowned in story, in song and in school books as our biggest and best-known river. Actually it has been our most misunderstood river. No stream in the U. S. has been the subject of so many persistent misconceptions. School books, college texts, technical writings and encyclopedias to this day contain a strange mixture of conflicting information concerning the Mississippi. It is given the reputation of being a very muddy river. The great load of sediments it carries is supposed to be building up the bed and banks of the river so that its flood stages will steadily continue to rise and require the raising of levees to ever greater heights. The river is asserted to flow down to the Gulf of Mexico on a broad ridge it has built up above the level of the surrounding country. There is a firmly rooted belief that the Mississippi's sediment discharge is steadily building its delta mouths farther and farther out into the Gulf of Mexico. Not one of these assertions and beliefs is correct.

The colossal proportions of the Mississippi—its 1,244,000-square-mile watershed, equal to 41 per cent of the whole U. S. area; its enormous floods, which discharge as much as two million cubic feet of water per second and make the river a mile wide and from 50 to 200 feet deep—have ever intrigued the imagination and furnished food for theorizing and controversy. The prime mystery has always been that the Mississippi, an alluvial (soil-washing) river, does not behave at all like other well-known alluvial streams, such as the Yellow River, the Po, the Nile, the Euphrates and the Tigris. The sediments carried by those rivers have built their beds and valley lands to ever higher elevations. Yet measurements covering more than half a century prove that no such build-up has occurred in the Mississippi. Why? In the past 14 years men have finally begun to collect the facts that make it possible to resolve the paradoxes of Ol' Man River.

IN THE winter of 1936-1937 a great flood began to gather on the headwaters of the Mississippi. Unusually heavy and protracted rains pointed to a record flood. It so happened that the stage was admirably set just then for undertaking a highly detailed study of this flood from start to finish. A large number of engineers and surveyors were working on the shortening of the Mississippi by means of artificial cutoffs for the Mississippi River Commission. It was an organization trained in river work, fully equipped with instruments and boats. Ample funds were available. The result was that this flood, the greatest to flow all the way to the Gulf within its levees (without a single break) was given the most intensive study ever bestowed on a flood of its size. This investigation marked the commencement of an era of research on the Mississippi which continued for more than 10 years and to which many organizations and individuals contributed. Thousands of borings were made in all parts of the alluvial valley; the valley was thoroughly photographed from the air; elaborate hydraulic laboratory experiments were conducted on models of the river; river depths were traced by supersonic instruments; the early geological history of the valley was painstakingly investigated.

The geological work established that in its early history the Mississippi did build up its bed by alluvial deposits. During the waning of the last ice age some 30,000 years ago the ocean level was from 300 to 400 feet lower than at present. The beds of the Mississippi and the Ohio, then unconnected streams, sloped steeply down toward the sea, and the rivers therefore cut deeply into the rock bottom of the valley and were able to transport very coarse gravel. With the melting of the icecap and the rise of the sea level, the gradients of the rivers flattened. The coarse, heavy gravel then began to build up in the river beds and the sediment transported by the rivers became progressively finer. Eventually these alluvial deposits raised the river valleys an average of 150 feet (*see diagram on page 21*).

Geologically the Mississippi still functions as an alluvial river. It continues to deposit sediment on its valley surface wherever it is not held in check by levees. But even before civilized man began to build levees to confine the river to its channel some 200 years ago, the rate of build-up of the valley had become insignificantly small. The evidence brought to light by geologists and engineers shows that during the past 1,500 to 2,000 years the river has not measurably built up its bed, its banks or its alluvial plain. Paradoxical as this may seem, the evidence is incontestable. It is confirmed by detailed investigations of the river's 1,500-year-old meandering courses, which have not been obliterated, of its channel and natural levees, of its sedimentary deposits and of its behavior during the last 70 years. Incidentally, these observations prove, contrary to what has generally been thought, that neither man's abuses of the land and water in the watershed nor the vagaries of droughts, floods and climatic fluctuations over the long course of time have left any measurable imprint on the behavior of the Mississippi River.

JACKSON CUTOFF eliminates a bend in the river. When this photograph was made in 1939, the trees had been cleared from the zone of the cutoff.

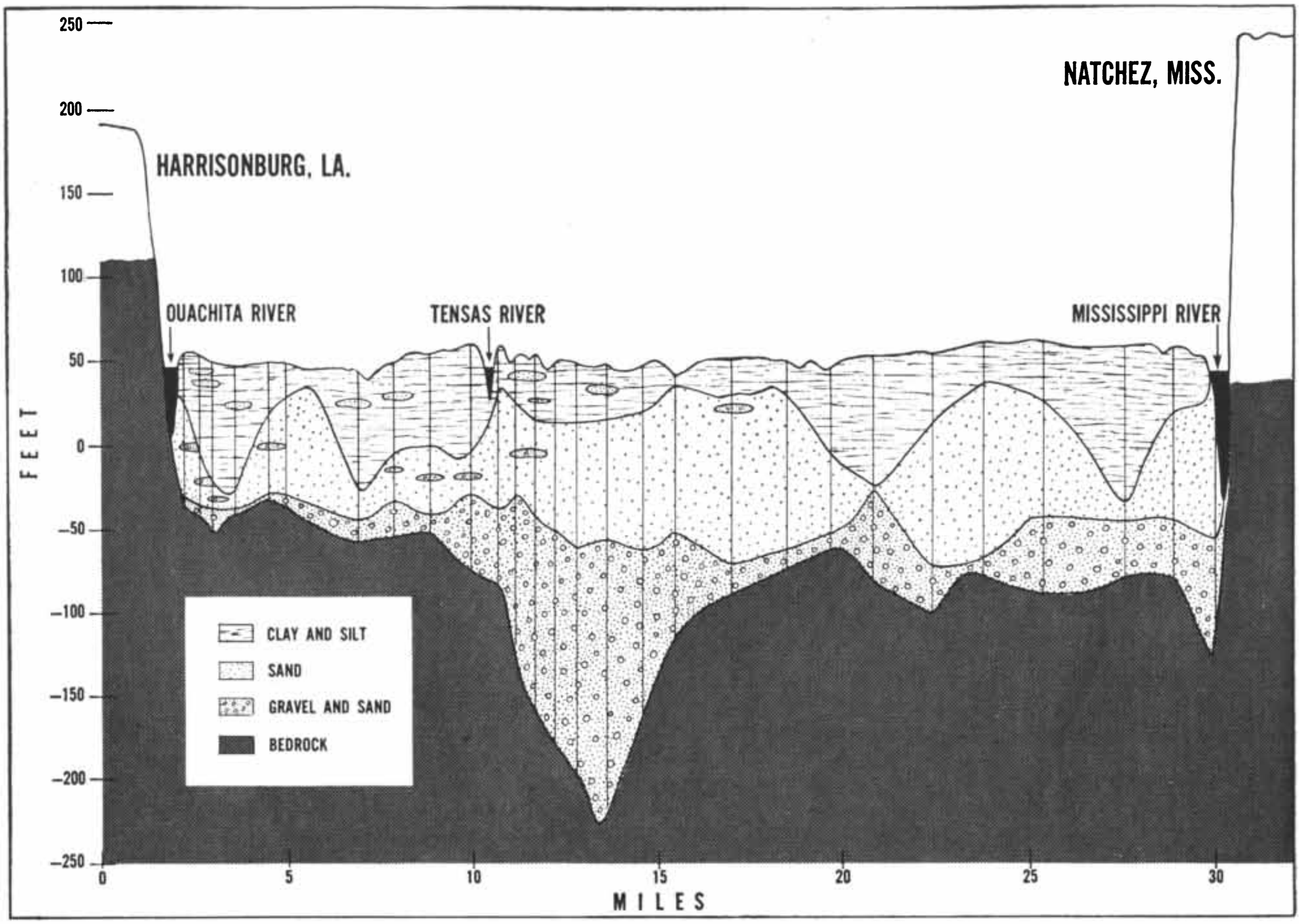
NOW the Mississippi is known to carry a huge load of sediments. Each year it transports some 400 million tons of silt and gravel downstream, approximately 90 per cent of it in the form of fine particles suspended in the water and the rest heavier material that is dragged or rolled along the bottom. Yet despite that immense wash of soil the Mississippi has shown no appreciable build-up of its bed or valley lands for thousands of years. What is the explanation of this astonishing paradox?

Part of the answer is that the Mississippi's volume of water is so huge that its sediment load of 400 million tons is actually relatively light. Year by year its freight of suspended sediment averages 550 to 600 parts per million by weight in ratio to the weight of the water. This is about one tenth of the average annual concentration of suspended solids in other rivers such as the Missouri and the lower Colorado (before the building of the Hoover Dam). In flood the Mississippi's concentration of sediment steps up to 2,600 parts per million; in contrast, the concentration in the Missouri during flood may go as high as 20,000 parts per million, in the Colorado 40,000 parts per million and in the lower Rio Grande 40,000 parts per million. And the Yellow River in China carries a vastly heavier load: the weight of the solids suspended in it often exceeds the weight of the water itself.

Actually the Mississippi is a comparatively clear stream. During extremely low stages its concentration of sediment has been known to drop as low as 50 parts per million. In late September, 1936, during such a low stage, the Mississippi flowed water as blue as that of the Danube (which, incidentally, also is blue only during low-water periods). The normal turbidity of the Mississippi is due not to mud but to minute fragments of mineral matter, mostly sparkling silica grains, suspended in the water. A glass of water dipped up from the river clears itself quickly. The water is soft and pleasant to drink, despite the fact that it represents the runoff from more than a million square miles of soils and rocks. During dry periods, when much of the Mississippi's flow is derived from ground water (*i.e.*, from the valley soil and rocks), the hardness of its water increases noticeably.

Paradoxically the Mississippi's load, which according to theory should consist of nothing coarser than sand and silt, also contains gravel, some of it as large as potatoes two and a half inches in diameter. Most of this gravel is picked up by the river during floods, when it scours down 100 feet or more into the bottoms of bends and brings up coarse pebbles from the bottom layers of the deposit. Coarse gravel is contributed also by the Ohio River and by some of the small streams that descend from the eastern escarpment bordering the valley.

Another misconception about the Mississippi has been that most of the sediment load carried by the lower part of the river comes from the caving of its banks. Back in the 1890s measurements showed that the soil dropping into the river from its banks amounted to nearly a billion tons annually. Paradoxically, this was more than twice the annual load of suspended sediment. In recent years protection of the banks has reduced bank caving, yet the suspended load shows no evidence of a decrease. Hence bank caving obviously has little effect on the total amount of sediment that the Mississippi River pours into the Gulf of Mexico. Actually the bulk of the river's suspended material, some 280 million tons of it, comes from the Missouri River. The Ohio River, which flows on a rock and coarse gravel bed, brings in only 40 million tons of suspended matter; the Arkansas River about six million and other tributaries about four million. The bank cavings contribute only about 50 million of the 400 million tons of the river's suspended load. Most of the material from the cavings travels only a short distance along the bed and builds up the convex shore downstream. For this reason the river, despite its phenomenal caving, does not widen. As one bank caves, the bank opposite is



ALLUVIAL VALLEY of the Mississippi is shown in cross section at a point between Harrisonburg, La., and Natchez, Miss. The vertical scale is greatly exaggerated. Data were provided by borings (*indicated by vertical lines*).

built out by soil carried down from the caving next upstream on its side.

PERHAPS the biggest paradox is the situation at the great river's mouth. It is popularly supposed that the mouths of the Mississippi are continuously building out into the Gulf of Mexico. Other great alluvial rivers certainly do so; the Euphrates and Tigris, for example, are advancing their joint delta into the Persian Gulf at the rate of about 160 feet a year. But the fact is that the Mississippi is not building out its delta at all; one obvious sign of this is that jetties constructed at its mouths as long ago as 1875 have not had to be extended. Furthermore, the Gulf of Mexico as a whole has not become more shallow. What, then, has become of the billions of tons of sand and silt dumped into the Gulf by the Mississippi River?

In 1939 the Louisiana State University geologists Richard J. Russell and Harold N. Fisk suggested the answer, and later studies confirmed them. The explanation, revealed by borings in the Gulf, is simply that the earth's crust there has sunk under the weight of the accumulated sediment load. The subsidence of the crust along the south shore of Louisiana began as early as 30,000 to 40,000 years ago, about the time when the icecap of the last glaciation started its final retreat. The rivers then flowing into the Gulf, probably larger than the Mississippi is today, unloaded enormous quantities of coarse gravel. Since the surface of the Gulf was more than 300 feet lower than at present, these rivers flowed on slopes steep enough to generate a tractive force capable of rolling gravel up to five inches in diameter. These ancient river courses, through shifting, brought into existence seven deltaic gravel deposits, strung out over a semicircular Gulf Coast front of some 150 miles. These deposits radiate, fan fashion, for 80 miles from a center near New Orleans. Each is bowl-shaped, with a maximum thickness at its deepest point of about 3,000 feet. Under the weight of this gravel the earth crust has been pressed down about the same distance. This large-scale subsidence of the crust in the Gulf has been accompanied by an uplifting of adjacent land areas, notably a marked rise of coastal lands in the state of Mississippi.

The modern Mississippi is in the act of superimposing on the early deposits in the Gulf a deltaic fan with a 17-mile radius, composed of fine silts, sands, logs and other remnants of vegetable origin. Its shape, in many respects similar to that of the earlier gravel deposits, has been likened to that of a ladle with a handle extending up the Mississippi River.

ANYONE navigating the Mississippi soon after a flood has subsided cannot fail to notice the new layer of sand that the overflowing river has deposited on the tops of its banks. These deposits, varying in thickness from a few inches to as much as two feet, afford visual evidence that the Mississippi still is an alluvial river. What an observer cannot see from the river is that the deposit is heaviest on the rim of the bank and thins out rapidly on the landward side. The reason for this is that when the river overflows its banks, it drops the heaviest part of its load immediately, for the velocity of the water decreases suddenly after it charges over the bank. As the overflow advances slowly inland, willows and other vegetation conspire to rob the water of most of its sediment in a relatively short distance. The net effect of the deposits on the tops of the banks is to create a ridge 12 to 15 feet high along the river on each side. These structures, known as the river's natural levees, account for the fact that the Mississippi's valley lands have experienced no appreciable build-up through the long course of time.

Along the Mississippi it is an observed fact that the heaviest part of a sedimentary deposit on a high bank is the first to drop back into the river when the bank caves. In consequence, the natural levee does not continue to rise indefinitely but periodically caves and rebuilds anew.

The presence of the natural levees has misled many people into believing that the river flows on a ridge built up from its own deposits. This is not the case; actually the Mississippi is a very deep river. In many places its bottom is below sea level, even as far upstream as 470 miles, where the land is 100 feet above sea level. Throughout the entire 850 miles of the Mississippi between Cairo and Baton Rouge its mean low-water level is all of 30 feet below the adjacent land surface. Consequently the river must rise at least 30 feet before its water level equals the elevation of the land, not taking into account the additional height of the natural levee. The mean annual height of the river in flood ranges from 40 to 45 feet above the low-water mark in its upper section to 32 feet at Baton Rouge. Most of the year the water level is not as high as the land. Below Baton Rouge the river assumes the form of a tidal estuary some 200 miles in length. Here the land surface on either side is low, in some places only a foot and a half above sea level. High artificial levees are necessary to keep the river confined during flood.

The fact that flood stages in the Mississippi have risen materially with time is due solely to the confinement of its flood waters between the high levees. In the course of a century the high-water mark mounted 6 feet at New Orleans, 13 feet at Baton Rouge, 8 feet at Natchez, 12 feet at Vicksburg, 15 feet at Arkansas City, 13 feet at Memphis and 8 to 9 feet at Columbus, Ky. Since 1932 the flood stages have been lowered by artificial cutoffs that have eliminated some of the worst bends and shortened the river about 170 miles. This operation has reduced flood stages 3 feet at Natchez, 10 feet at Vicksburg, 15 feet at Arkansas City, 5 feet at Memphis and 1.5 feet at Columbus.

It is common knowledge that the length of the Mississippi has not changed materially by natural means in the long course of years. Its length between Cairo and Baton Rouge was roughly 850 miles in 1765, 894 miles in 1825, 833 miles in 1882, 842 miles in 1910 and 846 miles in 1930. During this time the river made many changes in its meandering course, but evidently the wanderings that lengthened the river were offset by shortenings.

The general impression has been that the river shortens itself simply by cutting off some of its bends from time to time. Whenever a bend becomes too distended, flood waters erode a new channel across the narrow neck of the loop. Now there is no doubt that this process produces important shortenings of the river. Since 1765 a total of 19 natural cutoffs has occurred in the river stretch between Cairo and Baton Rouge. (Paradoxically, Yucatan Cutoff, the last natural one before the inauguration of artificial cutoffs in 1932, was not caused by a flood but unobtrusively made its debut during low water in the fall of 1929.) These cutoffs have effected individual shortenings ranging from 6 to 22 miles, and in aggregate the shortenings total 249 miles. But during the same period the lengthenings of the river have amounted to something approaching 500 miles, or nearly twice as much as the shortenings. Since the Cairo-to-Baton Rouge stretch of the river has not increased in total length, cutoffs cannot account for all the shortening that has taken place. Clearly other shortening processes must be at work.

Two such processes have been recognized by engineers. One has to do with the large sand bars that are commonly formed by cavings. These bars frequently build out a mile, sometimes as much as several miles, in the path of the stream, gradually forcing the river to detour by making a bend. Across such bars floods usually erode shallow swale-like depressions called "chutes." Because they are dry most of the time, the chutes are inconspicuous at first, but they slowly enlarge and deepen, and in the course of time they tend to become secondary river channels that act as short-cuts for the river. The time comes when a chute ceases to be a mere overflow route for flood waters and flows water the year round. It then robs the main channel of a part of its flow, thereby causing it to deteriorate by shoaling. Eventually the chute channel takes over and becomes the main channel. The entire process is so gradual, also so commonplace, as to lack the spectacular attributes of a cutoff across a narrow neck, hence it rarely finds mention in the press. At least one important chute, named Brandywine, is in process of development at the present time some 15 miles above Memphis. It will shorten the river about five miles.

The other generally unnoticed shortening process is a method by which the river gradually wears away and straightens out slight bends. This process is much less important than the other two, but it produces enough shortening to be recognized in the yearly revisions of river mileage on the Mississippi River Commission's navigation maps.

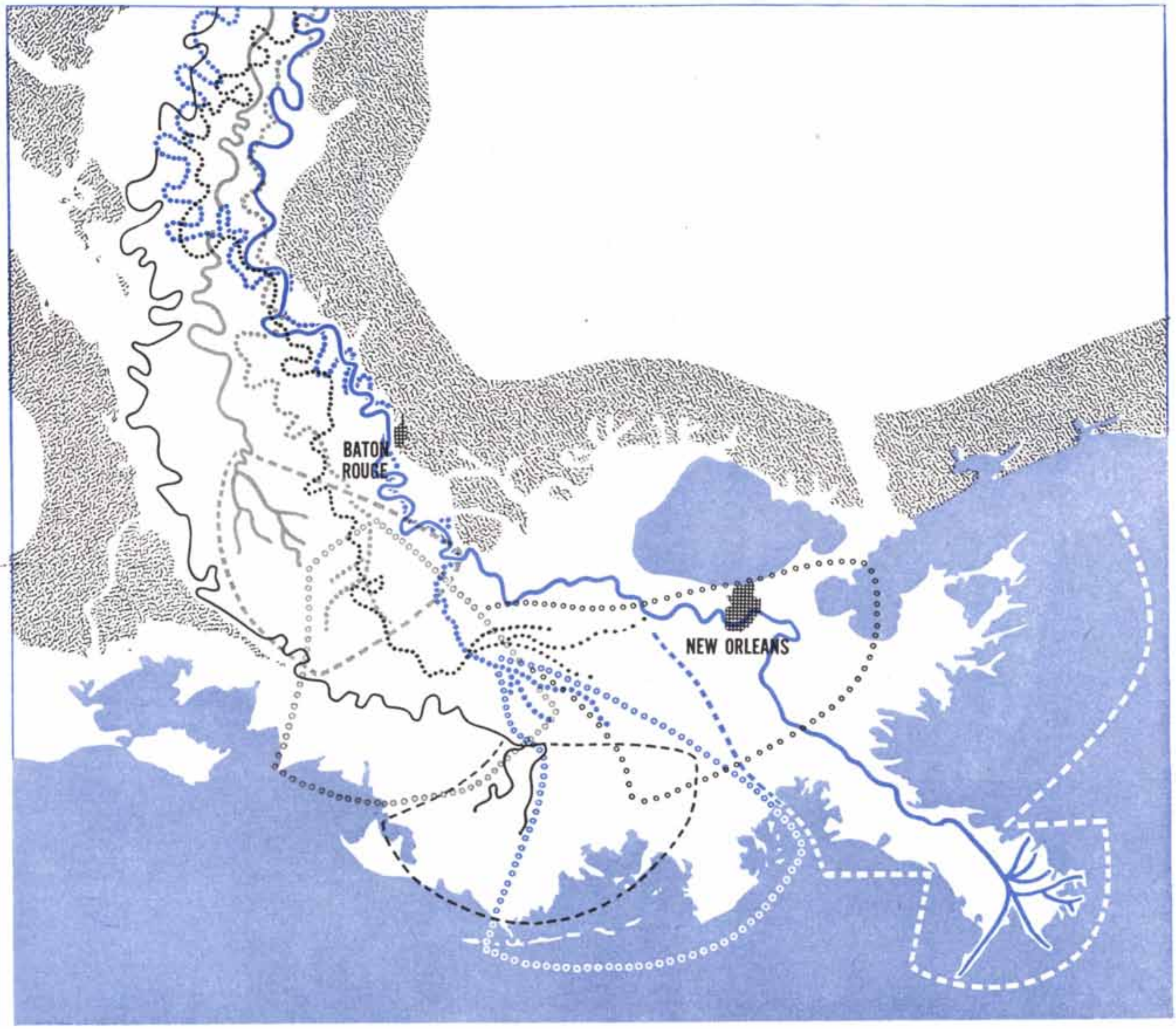
One of the most interesting paradoxes of the Mississippi relates to the advance of a major flood. The common conception pictures the crest of the flood as rushing with raging speed down the river. It is true that during a great flood the water on the top of the stream attains a velocity of 9 to 13 feet per second—from three to five times the speed of normal currents of the river at low water. But the crest of the flood as a whole actually moves down the river only half as fast as a small rise in water level during the low-water season.

The explanation of this paradox is as follows: During the rising stages of a major flood a large volume of water is continually being subtracted from the advancing flood-wave to fill that part of the channel ahead of it where the water surface still is low. In the case of the Mississippi the volume of water so required, technically known as "channel storage," is exceptionally large, owing to its channel width of 4,000 to 5,500 feet and its high banks rising 30 feet above low-water level. A great deal of water is also absorbed by sand bars and by the banks. Furthermore, when the flood wave overtops the banks an even heavier drain on it develops. In short, as the advancing flood-wave front moves downstream it is literally robbed of vast quantities of water, and this naturally slows its advance. Although the velocity of its top currents may be six to nine miles per hour, the flood itself moves at only about 1.5 miles per hour. If it does not overtop the river banks, the flood may speed up to three to four miles per hour. Before the river was artificially shortened by cutoffs of some of the bends, it commonly took a high flood crest about 25 days to travel from Cairo to Baton Rouge.

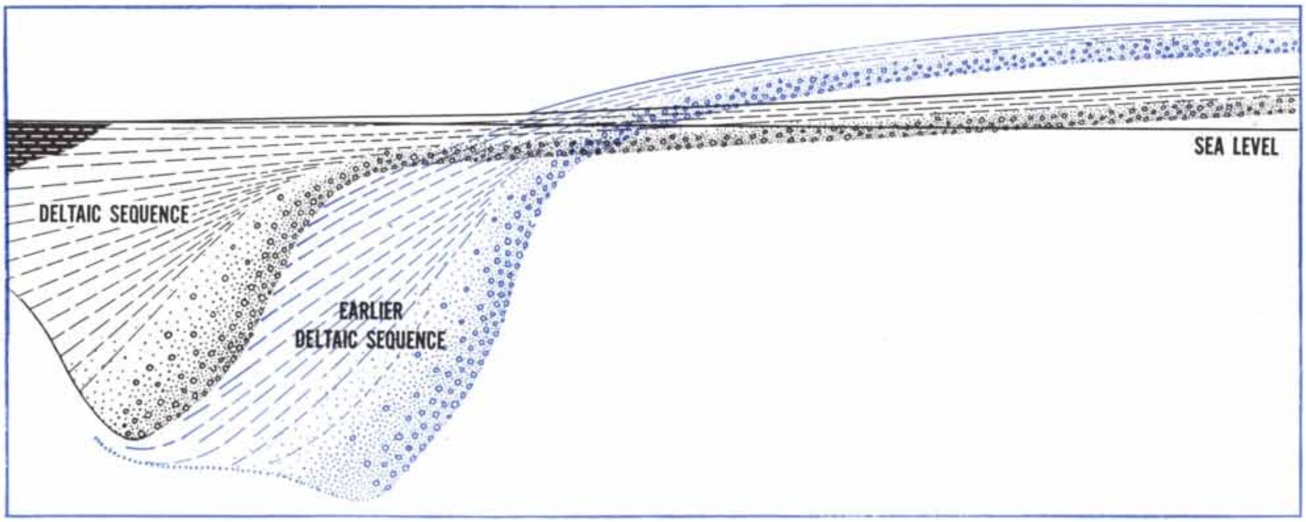
On the other hand, an entirely different situation controls the rate of transmission of a small rise in stage in the river at low water. The river then consists of a succession of deep pools, each several miles long, separated by shallow sand bars. A small rise in water travels from the upper to the lower end of such a pool with the speed of a wave, sometimes at the rate of 15 miles per hour. Because of this the "pop-rise," as it is called, moves downstream in about half the time taken by a flood crest; it makes the journey from Cairo to Baton Rouge in about 11 days.

The shortening of the river by artificial cutoffs has reduced the time of travel of flood crests noticeably, but just how great the effect will eventually be cannot yet be determined. The abandoned bends still take flood water, so retardation by channel storage continues undiminished. When the river has become stabilized, floods should pass down it in considerably less time than before man intervened.

Gerard H. Matthes is a consulting engineer who was formerly Head Engineer in the Office of the President of the Mississippi River Commission.



DELTAS of the Mississippi were laid down at various periods in its history. The present delta is shown by the blue and white broken line. The other deltas, in reverse order of their historical sequence, are shown in blue and white dotted line, black broken line, black dotted line, gray dotted line and gray broken line.



DELTAS SANK into the plastic bedrock as their weight increased. Later deltas were then built on top of and adjacent to them. As the deltas sank, the land adjacent to them rose. In the map at the top of this page the black stippled area running east and west to the north of New Orleans shows definite signs of having risen.

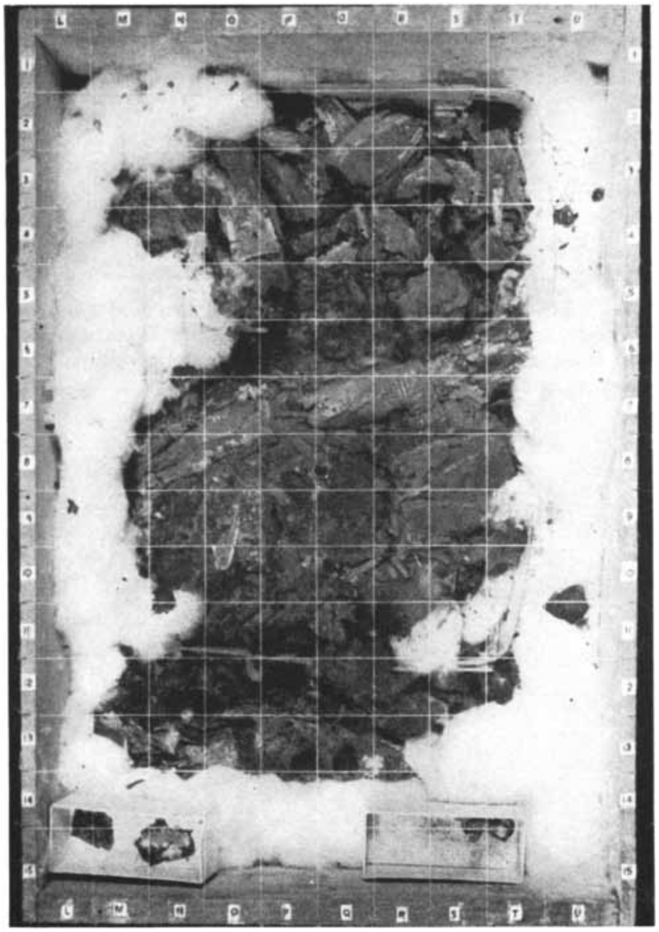
THE SUTTON HOO SHIP-BURIAL

The rich tomb of a seventh-century Anglo-Saxon king has yielded an archaeological treasure that illuminates an obscure period in the history of the English people

by R. L. S. Bruce-Mitford

THE story of the birth and beginnings of the English people is remarkably hazy. We know far more about the Romans who occupied Britain in Caesar's time than about the Anglo-Saxon peoples who invaded the island about 450 A.D. (after the Romans' departure) and made it their permanent homeland. The early Anglo-Saxons left no temples, no pyramids, no cities, roads, aqueducts or colossal figures, no written documents. Indeed, we should have no trace or knowledge of them at all were it not for the fortunate fact that they followed the pagan custom of depositing offerings in the graves of their dead. The archaeology of the early English (of about 450 to 650 A.D.) is an archaeology of little things—"nothing larger than a bucket or longer than a sword." It consists mainly of brooches, bead necklaces, knives, work-boxes, combs, glass vessels, weapons, pottery and the like. From these humble "grave-goods"

BURIAL DEPOSIT was excavated by an archaeological team. At left is C. W. Phillips, director of the excavation.



DEPOSIT FRAGMENTS were boxed and photographed through thread grids to record their original position.

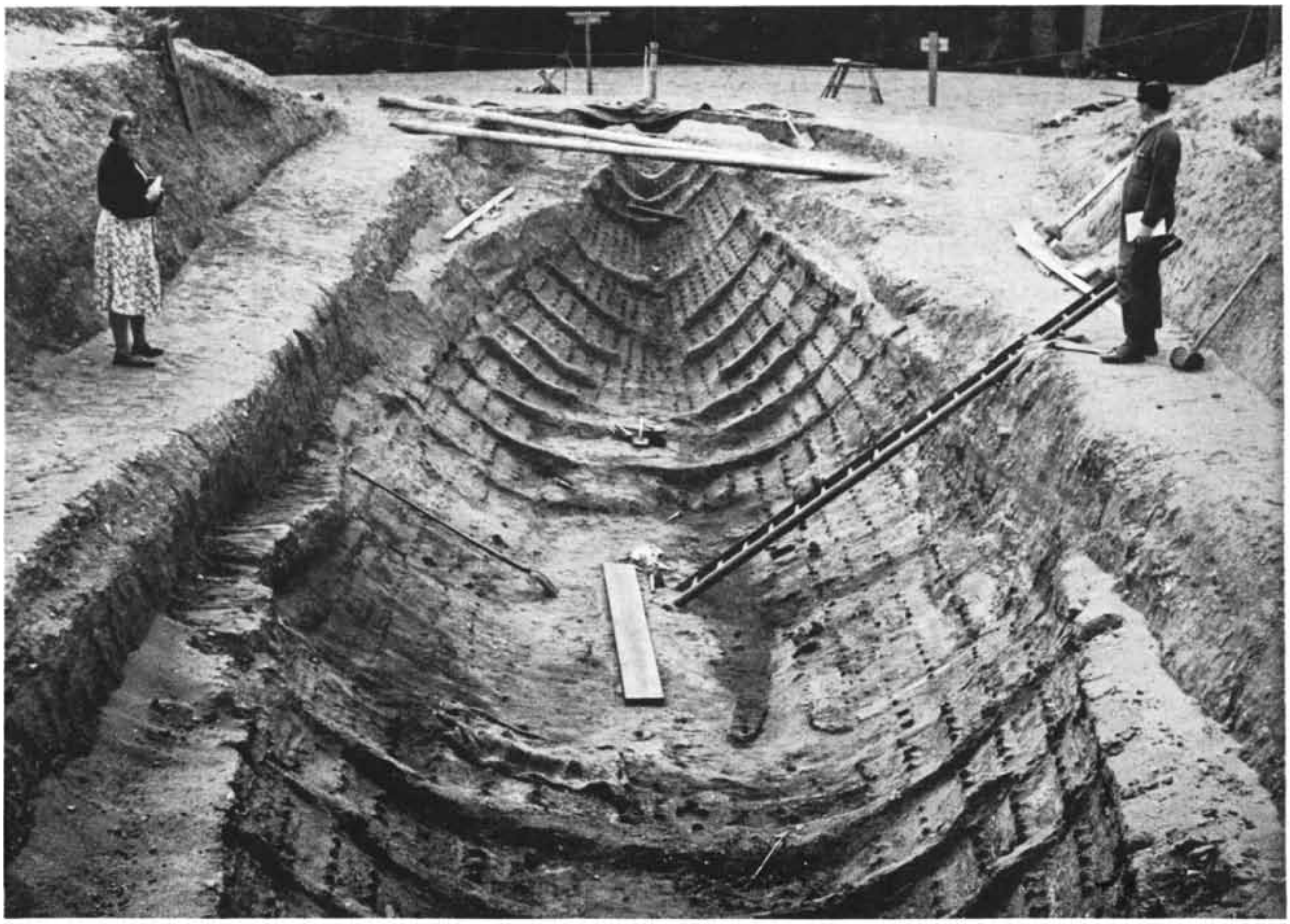
the historian has attempted to reconstruct the early history of the English people as a detective attempts to reconstruct a crime from such slight evidences as fingerprints or a shred of cloth. Like the detective's clues, the objects found in the graves seldom have much artistic distinction or intrinsic value.

Into this modest archaeological field there burst in 1939 a discovery such as occurs once in two or three hundred years. It was a discovery unprecedented not only in historical importance but also in intrinsic value. This find was the Sutton Hoo ship-burial—literally a buried ancient ship containing a priceless treasure of gold, silver and other objects. It is the richest find of its kind and its period to come to light in the era of modern scientific archaeology. No strictly comparable discovery had taken place in this part of the world since the opulent grave of the Frankish king Childeric I (died 481 A.D.) was unearthed in 1653, and most of the finds from that grave were eventually lost or stolen. Hence the Sutton Hoo ship-burial constitutes by far the finest collection of evidence archaeologists have today on life in the early Dark Ages of northern Europe.

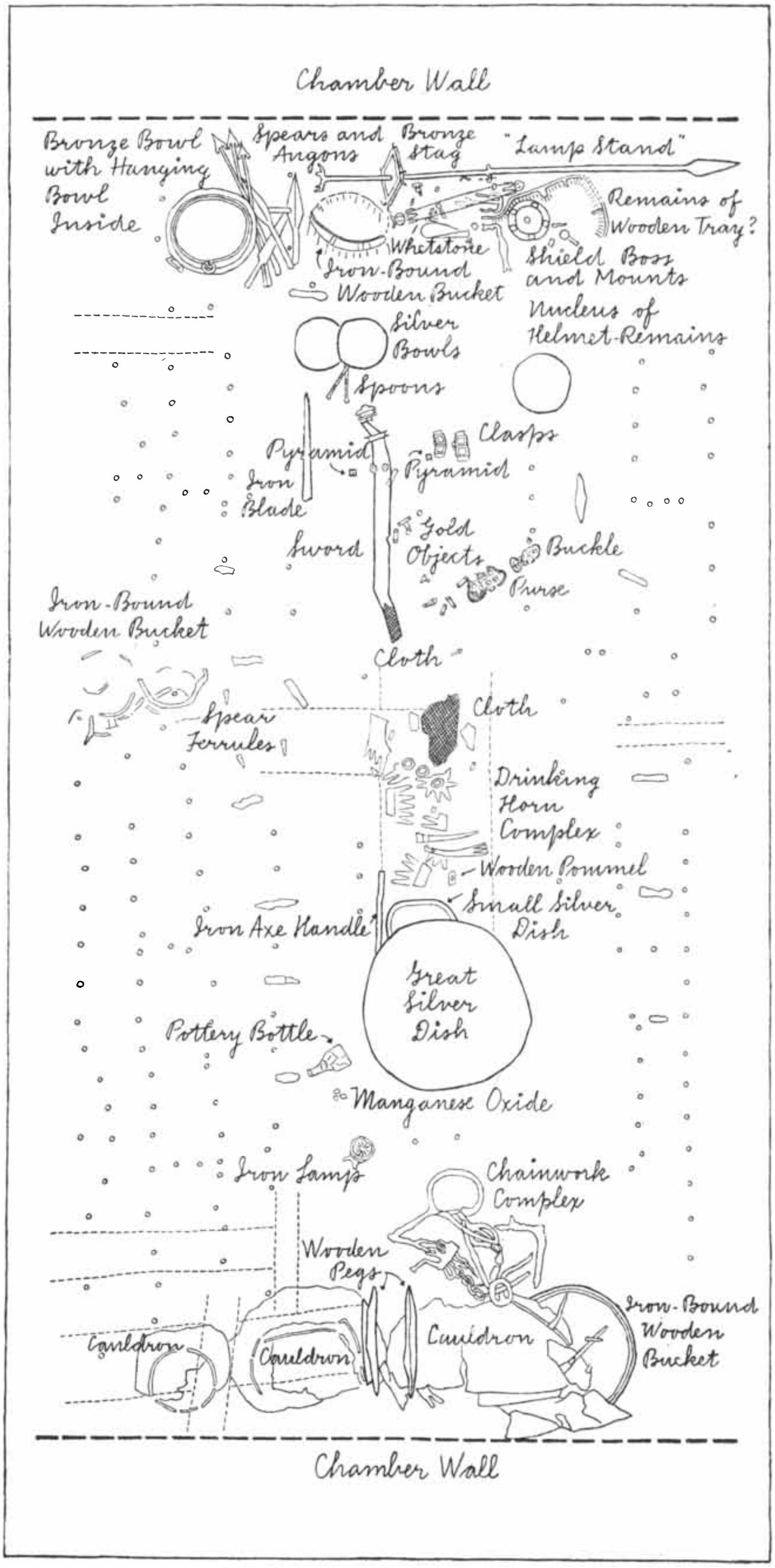
The circumstances of the discovery were themselves dramatic. Sutton Hoo is the name of a private estate near the little country town of Woodbridge in Suffolk on the East Coast of England. The estate is beside the tidal estuary of the River Deben. In 1939 its owner, the late Mrs. E. M. Pretty, decided to investigate a cluster of ancient burial mounds that lay on an escarpment 100 feet above sea level, overlooking the estuary. The excavation was started under the direction of the Ipswich Museum. The diggers soon began to unearth grave-goods of such extraordinary richness and complexity that it was clear they had come upon a discovery of great scientific importance, demanding greater archaeological resources and skill than were available locally. The investigation was therefore turned over to C. W. Phillips, a Fellow of the Society of Antiquaries and of Cambridge University, who enlisted the assistance of some of the ablest British archaeologists to complete the excavation. As it had become plain that what they were digging up was the remains of an old ship, Phillips also called in an expert in the history of ship-construction, the late Commander J. K. D. Hutchison of the Science Museum. The Sutton Hoo find owes no small part of its value to the fact that it was well excavated and recorded by professional archaeologists of distinction.

LATE in August, 1939, only seven days before war broke out, the painstaking excavation was finally completed and the whole find laid bare. Most of it, of course, was in fragments, and the reconstruction of some of the original items required prodigious skill and labor. The great ship, of which only the iron bolts and nails survived, was 86 feet in length. The burial deposit of precious objects lay amidships in what had apparently been a wooden chamber or cabin. It included 37 gold coins. This was a great stroke of luck, for though none of the coins is precisely datable, analysis of the whole group makes it possible to say with certainty that the ship was buried between 650 and 670 A.D.

Aside from the coins, the excavators found 41 objects of gold. They were ornaments belonging to a royal harness and sword-belt. The most important and ambitious items in the harness were a unique pair of hinged gold epaulets and a purse; 13 of the 41 gold pieces came from the richly decorated bone or ivory lid of this purse. The epaulets and purse were heavily encrusted with garnets and



OUTLINE OF THE HULL was described by its iron bolts and nails after the excavation had been completed. The burial deposit was found amidships in the area occupied in this photograph by the plank and the ladder.



PLAN OF THE BURIAL DEPOSIT shows the location of its various objects. The dots are nails; the unlabeled oblong objects, iron cleats.

ornamented in addition with small blue-and-white or pink-and-white patterns in mosaic glass picturing men, birds and beasts—the whole, with the red garnets, giving a gay polychrome effect. The sword that went with the harness had a blade made in the Rhineland, a splendid gold and garnet pommel, two gold filigree mounts on the grip, gold quillons and two jeweled gold scabbard-bosses. With the sword were found two small jeweled gold pyramids of miraculous workmanship. Other items from the harness included a great gold belt-buckle weighing 14.5 ounces and numerous smaller buckles, strap-mounts and fittings, most of them jeweled with gold-mounted garnets arranged in patterns.

The silver pieces were a pair of spoons inscribed with the names Saul and Paul in Greek, a cup and ladle, a set of 10 pretty bowls and two larger dishes. All these apparently had been made in Byzantium or Asia Minor. The largest silver dish, 27.5 inches in diameter, bears the control stamps of the assayers of the Byzantine Emperor Anastasius I; this shows that it was made between 491 and 518 A.D. (the period of his reign), and that it had not only traveled from one end of Europe to the other but was some 150 years old when it came to be buried in the soil of Suffolk.

Many other objects, besides those of gold and silver, were found in the deposit. There was an astonishing ceremonial whetstone, two feet long, with bronze fittings and human faces carved in the stone. There was an iron stand, six feet four inches high and surmounted by a finely modeled bronze stag, which is believed to be a royal standard. There was an iron helmet with face mask, ornamented with a silver crest, panels of tinned bronze and figures of warriors and dancing men stamped in the metal. There were also a large, richly decorated shield; three buckets; three bronze cauldrons; three bronze hanging-bowls with enameled ornaments; a bronze bowl; seven drinking horns with silver-gilt mounts; various objects of leather, bone and wood; some bits of fabric and last, but not least, a small six-string harp.

EVERYTHING in the grave was of exceptional quality or rarity. The helmet and shield were more richly ornamented and of finer quality than anything found elsewhere among remains of the early Teutons of northern Europe. No other grave has produced symbols of authority so impressive as the giant whetstone or the standard. The ship itself was longer than any yet discovered from the Viking Age, which came later. The goldsmith who made the jewelry was without a doubt the finest goldsmith yet known from an age

HELMET was made of iron overlaid with tinned bronze. The crest and wires inlaid into the eyebrows are of silver.

WHETSTONE has decorated ends. The cup at the top is made of bronze; the knob beneath it is painted red.

of fine goldsmiths—a creative artist as well as a supreme craftsman.

From the great richness and distinction of the find, from its location (near a seat of the East Anglian kings) and from the presence of the symbols of royal power and office, we can safely conclude that the Sutton Hoo ship-burial is a royal burial—the first ever unearthed in Anglo-Saxon archaeology. It is thought to be the monument of the East Anglian King Anna, who died in 654, or of his brother and successor Aethelhere, who died in 655.

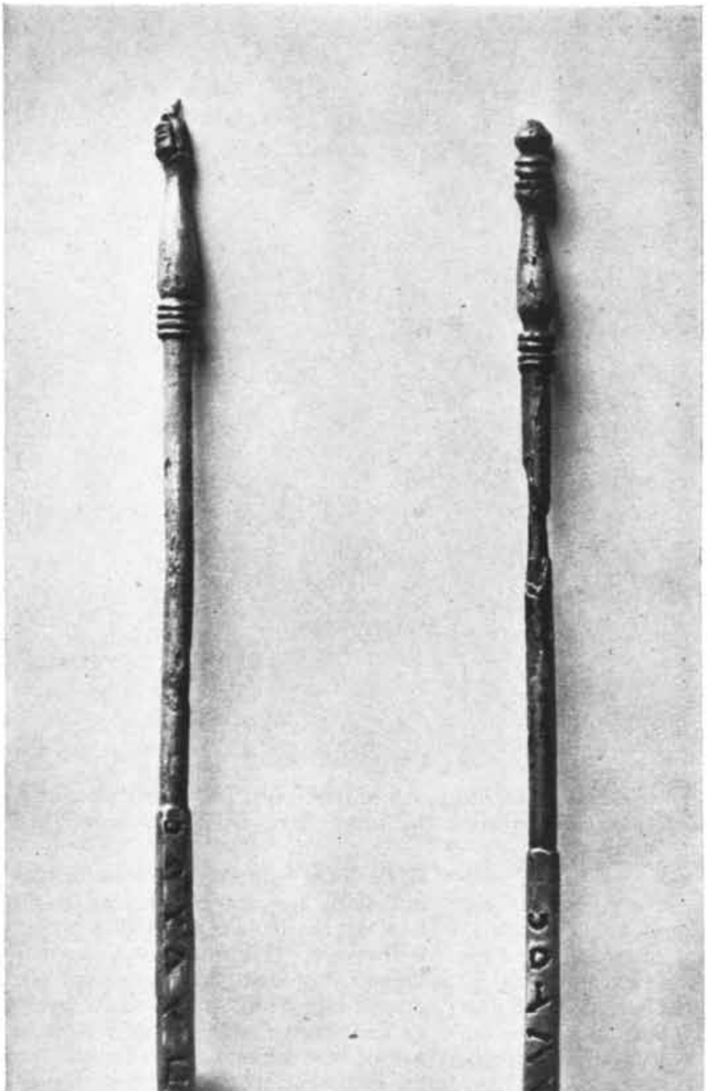
Considered simply as *objets d'art* and collectors' items, the finds were immensely valuable. The gold and silver items alone were valued in Britain before the war at about £250,000; American collectors would have given many times that amount. When the excavation had been completed, a coroner's inquest was held, in accordance with ancient English law, to decide who was the owner of the treasure. The jury found that it was the property of the landowner, Mrs. Pretty. With memorable generosity she promptly presented the entire find as a free gift to the British nation.

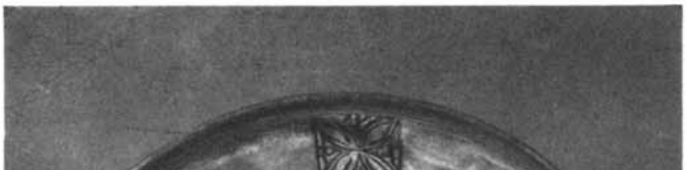
Its value to historians of course is incalculable. It provides our first tangible contact with the heroic life of the warrior class in the early centuries of medieval England, and it illustrates that life with a completeness and color equaled only in the epic of *Beowulf*. The ship-burial itself offers a remarkable parallel to the famous description in *Beowulf* of the passing of the Danish king Scyld, who was given a richly furnished funeral in a ship, though in that case the ship was sent out to sea instead of being buried in the earth.

"Then, at the fated hour, Scyld, a man most valorous, departed to go into the keeping of the Lord. His beloved friends carried him to the sea's flood. . . . There, at the landing-place, the ring-prowed vessel lay, the prince's ship, covered with ice and eager to start. They laid then the beloved chieftain, the giver of rings, on the ship's bosom, glorious by the mast. There were brought many treasures, ornaments from far-off lands. Never have I heard that a vessel was more fairly fitted out with war-weapons and battle-raiment, swords and coats of mail. On his bosom lay a host of treasures, which were to travel far with him into the power of the flood. . . . They set besides a golden standard high above his head and let the sea bear him—gave him to the ocean. . . ."

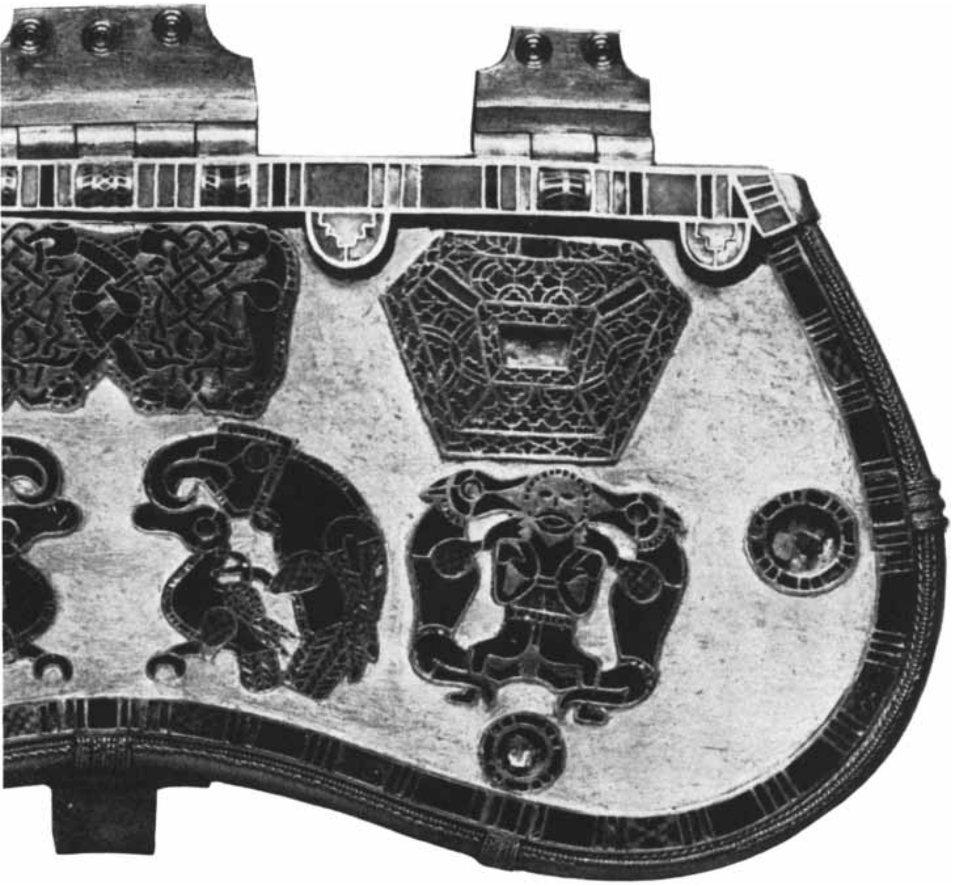
The grave-goods of Sutton Hoo give us a colorful picture of the social life of the Saxon aristocratic hall. The sword with gold and jeweled mounts, the golden jeweled accouterments, the 16 silver vessels suggest the pride and ceremony of hall-life on occasions of importance. The six-quart drinking-horns, used for beer or mead, and nine tiny vessels made from gourds, which must have held something a great deal stronger, speak for the copious supplies of drink that inspired Saxon fighting men to eloquence and deeds of valor. Most interesting of all the finds, both from the point of view of hall-life and of the history of the nature and rhythm of Old English poetry, is the harp. This small, quadrangular-shaped instrument of maplewood was preserved, although in fragments, by the fortunate fact that it was enclosed in a pair of bronze bowls when buried. It is the earliest stringed instrument of post-Roman Europe that has been found sufficiently preserved to be reconstructed.

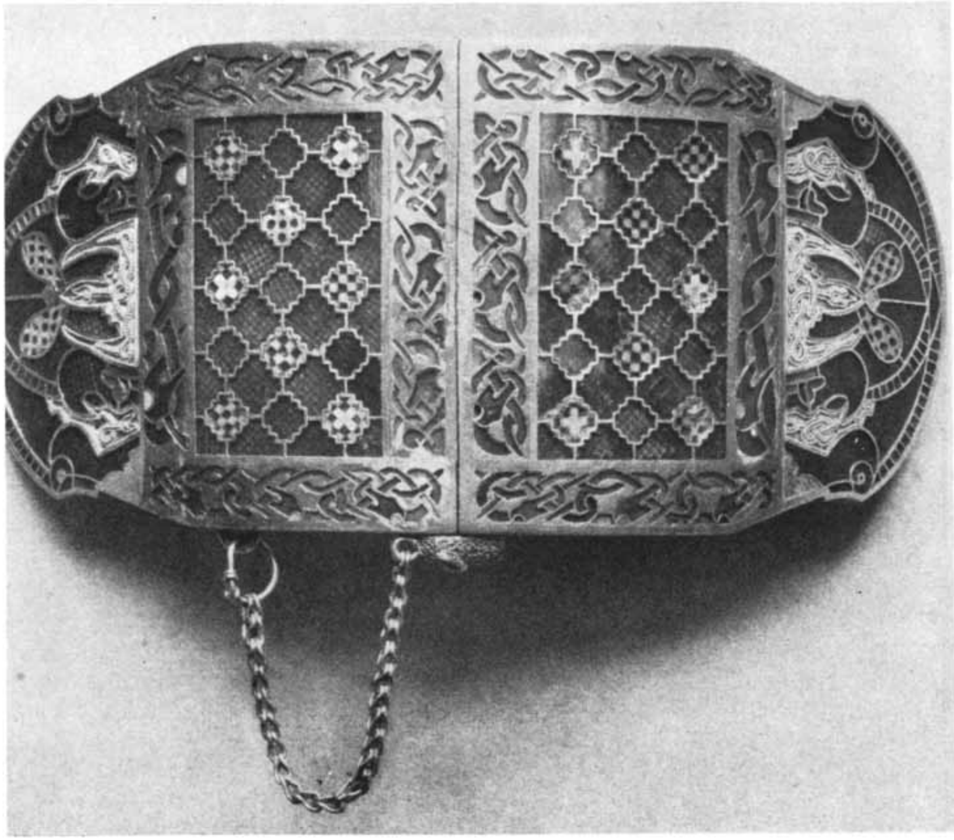
THE story of this reconstruction illustrates the patient detective work, involving the collaboration of many specialists, that remains to be done after a find has been excavated. From the Sutton Hoo deposit the excavators recovered hundreds of bits of crushed and distorted wood belonging to the harp. The fragments, like grotesquely mutilated pieces of a jigsaw puzzle, were put together slowly and painfully. The assembly began with the reconstruction of two tenon-and-mortise joints in the main framework; to these were fitted two gilt-bronze plaques from which projected rivets that had held the joints fast. Most of the framework for the strings was now assembled (*see photograph on page 30*). The upper arm of the frame, which had been straight originally, was bent in a curve, due to compression of the damp wood within the bowls in which it had lain. It was possible to see that the harp had been some 18 inches high and had had six strings. There were six holes in the upper arm, and the stumps of six pegs were found among the





RICHLY DECORATED OBJECTS were found in the burial deposit. At left are two silver spoons inscribed "Paul" and "Saul" in Greek. At upper right is the lid of a purse. Its frame and fittings are of solid gold inlaid with garnets and mosaic glass; the white surface beneath them is a reconstruction of the original bone or





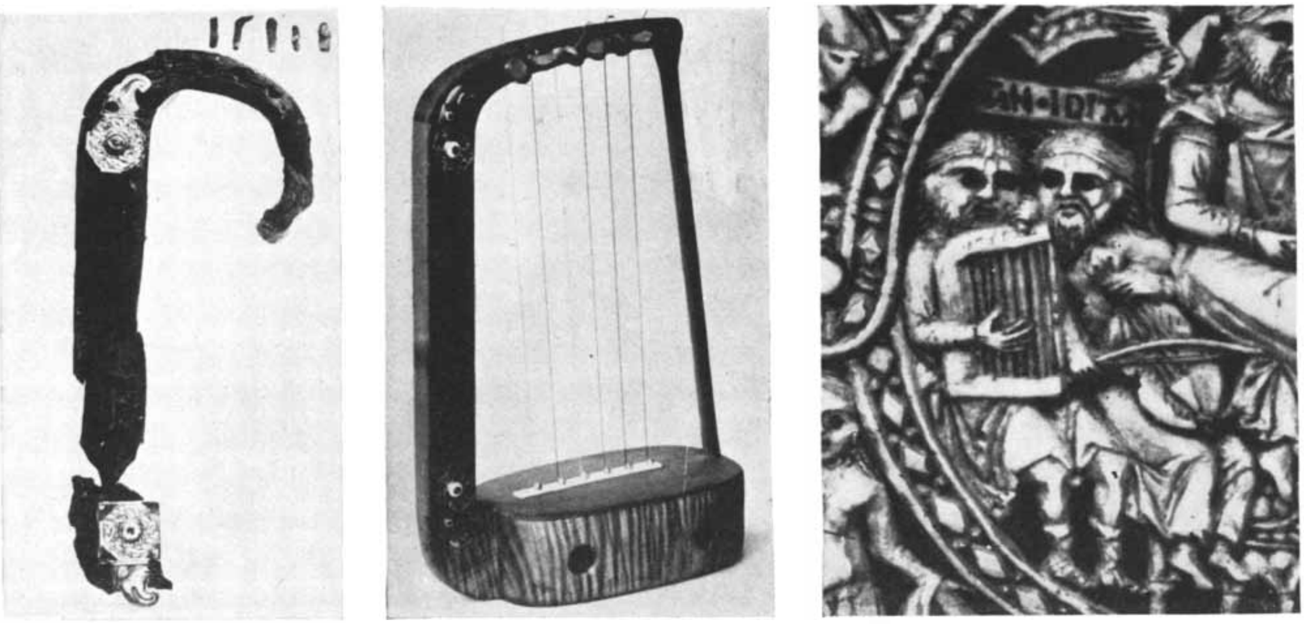
ivory. At bottom center is a silver bowl decorated with a ceremonial cross; it is one of a set of 10 from the Eastern Mediterranean. At lower right is one of a pair of solid gold epaulets decorated with garnets and mosaic glass.

fragments. Botanists called into consultation identified the wood of the pegs as either poplar or willow and the frame itself as maple. Some dark patches on the frame were found, on microscopic examination, to be made up of animal hairs, which were eventually identified as those of the beaver. From the distribution of hairs it was deduced that the instrument had been kept in a beaver-skin bag.

It now became necessary to seek further clues in the literature on stringed instruments of the ancient world. This inquiry showed that the instruments fell into two classes: lyres and harps. Lyres were invariably designed symmetrically about the upper arm, or peg-arm. Harps, on the other hand, were designed asymmetrically. The Sutton Hoo instrument was asymmetrical, and therefore definitely a harp. Still, it was not quite right: in a harp the longest limb consists of a broad hollow box which functions as the resonator of the instrument. In the Sutton Hoo instrument the reconstructed limb was thin and solid. The instrument must have had a resonator to function at all, and the only solution its surviving remains allowed was that the harp must have been of quadrangular form, with two limbs of approximately equal length and with the resonator at the bottom. The material taken from bronze bowls in which the instrument had been enclosed was examined anew, and to the investigators' great delight many fragments of thin maple sheeting found there were identified as the remains of a capacious sound-box.

Musicologists were now consulted, and the problem was taken to the workshop, where experts began to work out the practical details of constructing a playable instrument on the Sutton Hoo model. They made several experimental models. The result (or one result) is the reconstruction shown in the photograph on page 30. This model has a soft, charming tone and wide melodic range. That it is a reasonably close approximation to the original instrument is borne out by some existing illustrations of early English harps. A 12th-century Anglo-Saxon manuscript in the possession of Cambridge University, for example, shows a player performing on an instrument of this kind. Another harp very similar to the Sutton Hoo instrument was found pictured on the ivory cover of a 12th-century psalter.

This brief account of the reconstruction of the harp gives some slight indication of the intensive scientific study and wide comparative research that are being brought to bear upon the Sutton Hoo remains. It is fortunate indeed that the discovery was saved for the era of modern scientific archaeology. Had it been made in an earlier day, much of its historical value would doubtless have been lost. We can extract from it now far more information than has ever been



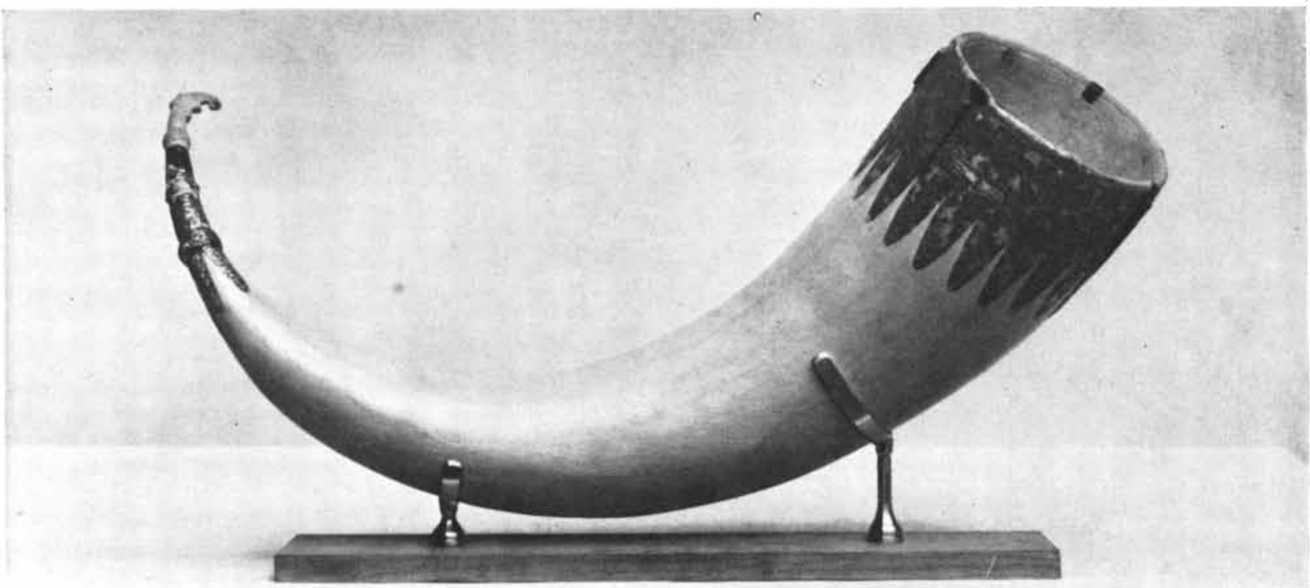
FRAGMENT OF A HARP (*left*) was found enclosed in a pair of bowls. A reconstruction (*center*) was made in the workshops of Arnold Dolmetsch, Ltd., partly on the basis of a 12th-century representation (*right*).

possible from any comparable find in the past.

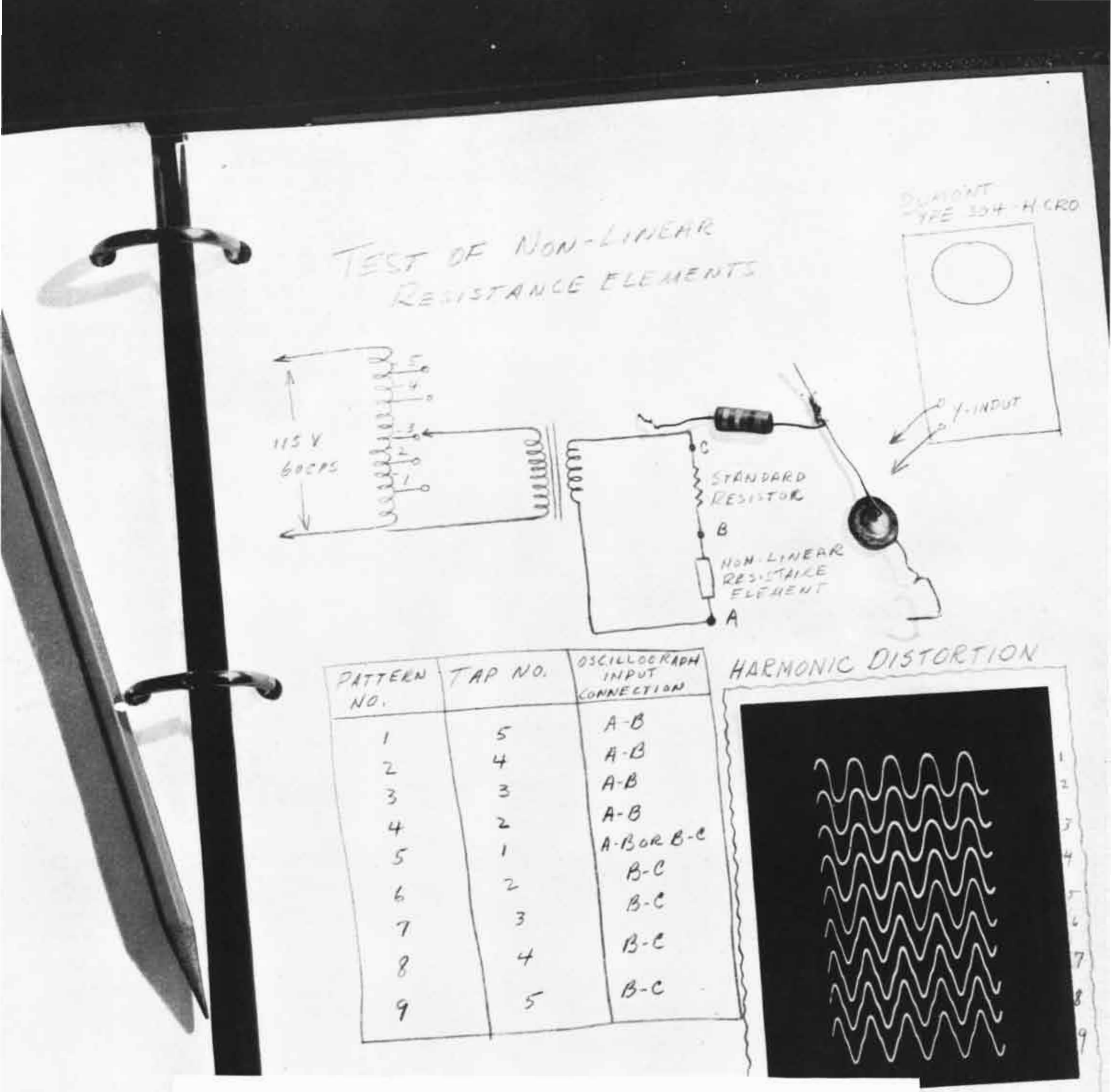
THE Sutton Hoo ship-burial tells us much that is new and surprising about the life of an early Anglo-Saxon royal court. We see with astonishment how far-reaching were its contacts, how cosmopolitan its life, how rich, even brilliant, its material culture. The coins found at Sutton Hoo came from mints on the Continent in the area that is now France; many of the bronze and silver objects came from Alexandria, Constantinople and elsewhere in the Near East; the helmet, shield and sword very probably were from the Baltic coast of Sweden. It is significant that boat-burial seems to have been a peculiarly Swedish custom in that period; at least no evidence of it has been found anywhere except in Sweden and at Sutton Hoo. The connection with Sweden revealed by the Sutton Hoo burial is a complex matter, but it may well be that analysis of all the factors will ultimately establish that the royal house of East Anglia (the Wuffinges, as they were called) were of Swedish origin. Such a connection between the Anglo-Saxons and Scandinavia, at a period many generations before the first Viking raids on the British Isles, would be an entirely new fact in English history.

Seven mounds on the Sutton Hoo estate still remain to be excavated. It is not impossible that some of them, like the buried boat, may be intact (*i.e.*, undisturbed). They will probably shed further light on the great ship-burial. Meanwhile American readers of this account may safely be urged, if they should find themselves in London, to visit the Sutton Hoo finds in the British Museum. They will not be disappointed.

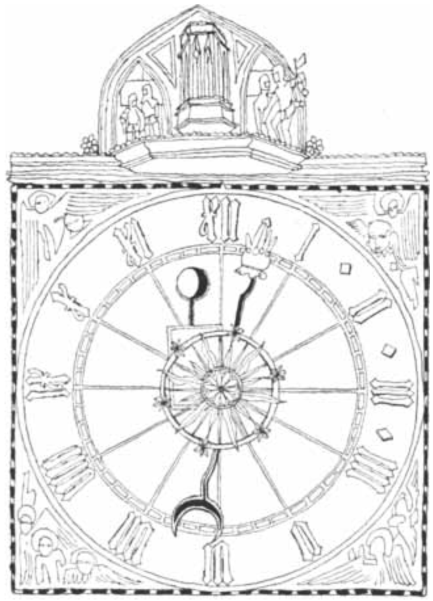
R. L. S. Bruce-Mitford is Assistant Keeper of the Department of British and Medieval Antiquities in the British Museum.



GREAT DRINKING-HORN was reconstructed on the basis of gilt bronze ornaments found in the burial deposit. The size and shape of the horn indicate that it came from the virtually extinct aurochs, or European bison.


DUMONT TYPE 304-H CRO
TEST OF NON-LINEAR RESISTANCE ELEMENTS
115 V. 60 CPS
STANDARD RESISTOR
NON-LINEAR RESISTANCE ELEMENT
Y-INPUT
HARMONIC DISTORTION
PATTERN NO.
TAP NO.
OSCILLOGRAPH INPUT CONNECTION
A-B
B-C
A-B OR B-C
H. H. S.
1-4-51

SCIENCE AND



Waterman Heads NSF

ALAN T. WATERMAN, physicist, who has been the Chief Scientist of the Office of Naval Research during the past three years, will be the first director of the National Science Foundation. After long delay President Truman nominated Waterman for the post last month and cleared the way for the new Foundation to begin its work. There was little doubt that the Senate would confirm the nomination.

The President chose Waterman from a list of seven names submitted to him by the Foundation's governing board of 24 members, headed by James B. Conant of Harvard University. The director serves for a six-year term at an annual salary of $15,000.

A Princeton graduate and Ph.D., Waterman was for many years a professor of physics at Yale University. During World War II he held several important positions in the Office of Scientific Research and Development, and in 1947 he became the top civilian officer in ONR, with major responsibility for its grants of funds to scientists for basic research.

DDT Shortage

THE supply of the insecticide DDT, which in the space of six years has become one of the great world necessities, almost comparable to steel and fuel, has begun to give concern to health workers. The World Health Organization last month reported a developing shortage of the chemical so serious that it threatens the breakdown of the campaign against insect-borne disease, which since the end of the war has wiped out malaria in many parts of the world.

The U. S. produces 75 per cent of the world's supply of DDT; its production is about 65 million pounds a year. The shortage is due to a combination of factors: increasing use of the insecticide by farmers and others; allocation of 25 per cent of the production to the armed forces for the defense program; and shortages of the ingredients needed for production of the chemical, due to a lack of sufficient tank cars for transporting chlorine, to the diversion of benzene to synthetic-rubber manufacture, and so on. The result is that DDT has doubled in price as well as become difficult to obtain. The Pan American regional office of WHO reported that it had not been able to get DDT since the middle of January, and Asiatic and European users are in the same plight.

John R. Murdock, assistant director of WHO's Pan American Sanitary Bureau, warned that unless production is increased "all the ground gained in the last four years in the control of malaria, typhus and plague, easily affecting 300 million people in tropical countries of the world, will be lost." Roberto Caceres Bustamente, Under Secretary of Public Health in El Salvador, declared: "DDT is for us a problem of living or dying. In a population of 2,500,000 there are more than 200,000 cases of malaria." The insecticide has reduced the incidence of malaria 40 per cent in El Salvador, he said, but "we need 500,000 pounds of DDT and the Bureau has managed after great difficulty to get only one fifth of this."

NEPA

THE four-year-old NEPA project, which has been studying the possibility of nuclear-powered flight, is being terminated this month. Its sponsors, the Atomic Energy Commission and the Air Force, announced that the Fairchild Engine and Airplane Corporation, prime contractor, has "completed its contract."

Newspaper stories, apparently inspired by Air Force spokesmen, added that the end of NEPA (Nuclear Energy for the Propulsion of Aircraft) meant that the theoretical phase of the study had been completed and the design of a nuclear airplane engine was ready to proceed to the blueprint stage. But the official announcement said only that "other projects in the field of nuclear-powered flight will be continued."

If it is true that the basic problems of design of a nuclear aircraft engine have been overcome, much more rapid progress must have been made than the AEC expected last summer. In a speech last July to the Institute of Aeronautical Sciences in Los Angeles, Lawrence R. Hafstad, the AEC's Director of Reactor Development, said: "The aircraft propulsion project should be continued in an extensive study phase, both theoretical and experimental, for the next two or three years. By that time data might become available to permit re-evaluation and a more decisive conclusion."

The Architecture of Water

WHAT is the structure of water? Classical theory says it is a loose collection of H_2O molecules which slide around each other with as little interaction as a heap of marbles. Physicists have not been entirely satisfied with this theory because it is contradicted by the behavior of sound in water: whereas the theory predicts that water should transmit sound waves easily, actually it strongly absorbs them.

The Harvard University physicist Gerald J. Holton, on the basis of some recent experiments, now suggests a new theory. He subjected water to pressures as high as 12,000 atmospheres. Under this high compression water behaved as it should in the classical theory: sound waves passed through it with little absorption. Holton's conclusion is that at normal pressures water molecules are not amorphous but have a loose crystal structure. Sound waves passing through the water twist and deform the crystals, and this is what dissipates the waves' energy. When high pressure is applied to water, it breaks up the molecules' crystal structure and makes them truly structureless.

Surgery for Heart Disease

A NEW operation for coronary disease has been developed by Claude S. Beck of the Western Reserve School of Medicine in Cleveland. The operation is designed to circumvent the shortage of blood in the heart muscles caused by diseased coronary arteries. Beck achieves this by transforming a large vein of the heart into an artery. Using a section of vein taken from the patient's arm, he connects the heart vein to the aorta, the giant artery that carries fresh blood out of the heart chambers. Arterial blood then flows back into the heart muscles through the former vein, by-passing the diseased arteries.

The operation is performed in two stages three weeks apart. Beck found that advanced cases of heart disease could not tolerate the operation, but 12 selected patients without enlargement of the heart or high blood pressure showed good results. There was only one death, and this in a patient with advanced disease. Dr. Beck thinks that with proper selection of patients the mortality of the operation could be kept at "about 5 to 10 per cent." The operation was thoroughly tested beforehand on dogs. Though "the short-term results on patients were favorable," Beck said it will take another year to determine whether the operation is of permanent value.

Fiber V

TO nylon and Orlon the du Pont Company will soon add a third synthetic textile fiber for which it has high hopes. Its name is Fiber V. Chemically unrelated to nylon or Orlon, it is claimed to combine very light weight, high tensile strength and high resistance to stretching, both wet and dry—which means that a Fiber V suit will hold its shape in the rain and will not wrinkle easily.

The fiber is a British invention known in England as terylene. Du Pont owns the American rights and has been testing the fiber since 1946. It has put a limited number of curtains, blouses and men's suits on the market to find out how it performs in actual use. The results have been encouraging enough for du Pont to decide to build a Fiber V manufacturing plant on a 635-acre tract in North Carolina originally intended as a site for a nylon plant. Construction of the plant will start this year.

Fiber V is expected to find uses not only in consumer goods but also in industrial products such as fire hose and transmission belts.

Wooden Tires

AN important use has recently been found for lignin, the lumber component that has long been the paper industry's most troublesome waste product. This complicated chemical substance, which binds cellulose fibers together and constitutes 25 per cent of some woods, has had a great deal of attention from industrial chemists, but has defied most efforts to find large-scale uses. Pulp mills dump huge quantities of lignin into rivers and pollute many North American streams.

Now three chemists of the West Virginia Pulp & Paper Company have found that the substance can be used to strengthen natural rubber. Addition of up to 50 per cent of lignin increases the tensile strength of the rubber more than an equal volume of any other material. The mixture is not only stronger but also harder, tougher and lighter than ordinary rubber, which is strengthened with carbon black.

How to Attract Mosquitoes

WHY do mosquitoes like some people better than others? A careful investigation of the tastes and preferences of mosquitoes has been made by A. W.

A. Brown, a zoologist of the University of Western Ontario. He used as subjects two dummies set up in a Canadian forest glade. They were water-filled steel tanks kept at a temperature of 98 degrees Fahrenheit and clothed in various experimental garments. Brown measured the "comparative attractancy" of the types of clothing by counting the number of mosquitoes landing on each dummy per minute. His main findings:

Dark clothing is from two to 10 times as attractive to mosquitoes as light-colored material.

Sweaty clothing is twice as attractive as clean.

Cotton is more attractive than nylon.

When the temperature is above 60 degrees, mosquitoes prefer moist clothing; in cooler weather they are more attracted by dry clothes.

Carbon dioxide, ether and gasoline attract mosquitoes; chloroform fumes repel them. If you hold your breath, mosquitoes will bite you only two thirds as often.

Seasonal Stillbirths

OLD wives' tales are not always wrong. Recently two British physicians made the surprising discovery that the incidence of a congenital deformity which causes many stillbirths is especially marked at certain seasons of the year.

The disorder is anencephalus, a malformation of the central nervous system that deprives the fetus of a brain. Thomas McKeown and R. G. Record of the University of Birmingham report in *The Lancet* that "the stillbirth-rate for anencephalus is lowest in May (1.91 per 1,000 births) and highest in December (3.09 per 1,000 births); between these two months the rate increases and decreases fairly regularly."

The Lancet, commenting on the article, suggested that the phenomenon may be related "to the prevalence of some maternal infection in April or May, to diet, to allergy, or perhaps to abnormal activity of pregnant women during spring-cleaning."

Male or Female?

A CORRECTIVE operation on a hermaphrodite always poses a puzzling problem to a physician, to say nothing of the patient: Should the ambivalent patient be made a male or a female? Doctors are usually guided in their decision by the person's physiology. In a report on this problem in the *American Journal of Obstetrics and Gynecology* four physicians of the Duke University School of Medicine take a different view. They urge that the patient's existing sexual orientation should be the deciding factor.

The physicians—E. C. Hamblen, F. Bayard Carter, James T. Wortham and Juan Zanartu—give 11 case histories of male pseudohermaphrodites (people with male gonads but undeveloped or abnormal sex organs). The patients ranged in age from 5 to 27. Eight of them, though physiologically male, were registered as female on their birth certificates and had been brought up as females. In seven of the eight cases the surgeons removed the testes. This operation, sometimes coupled with injections of female sex hormones, resulted in a satisfactory development of female characteristics and recession of the male. For physical reasons it was decided that one 13-year-old patient who had been reared as a girl should be a male. This patient at the age of 26 is "a socially maladjusted, sexually frustrated individual with a record of a number of petty encounters with the police."

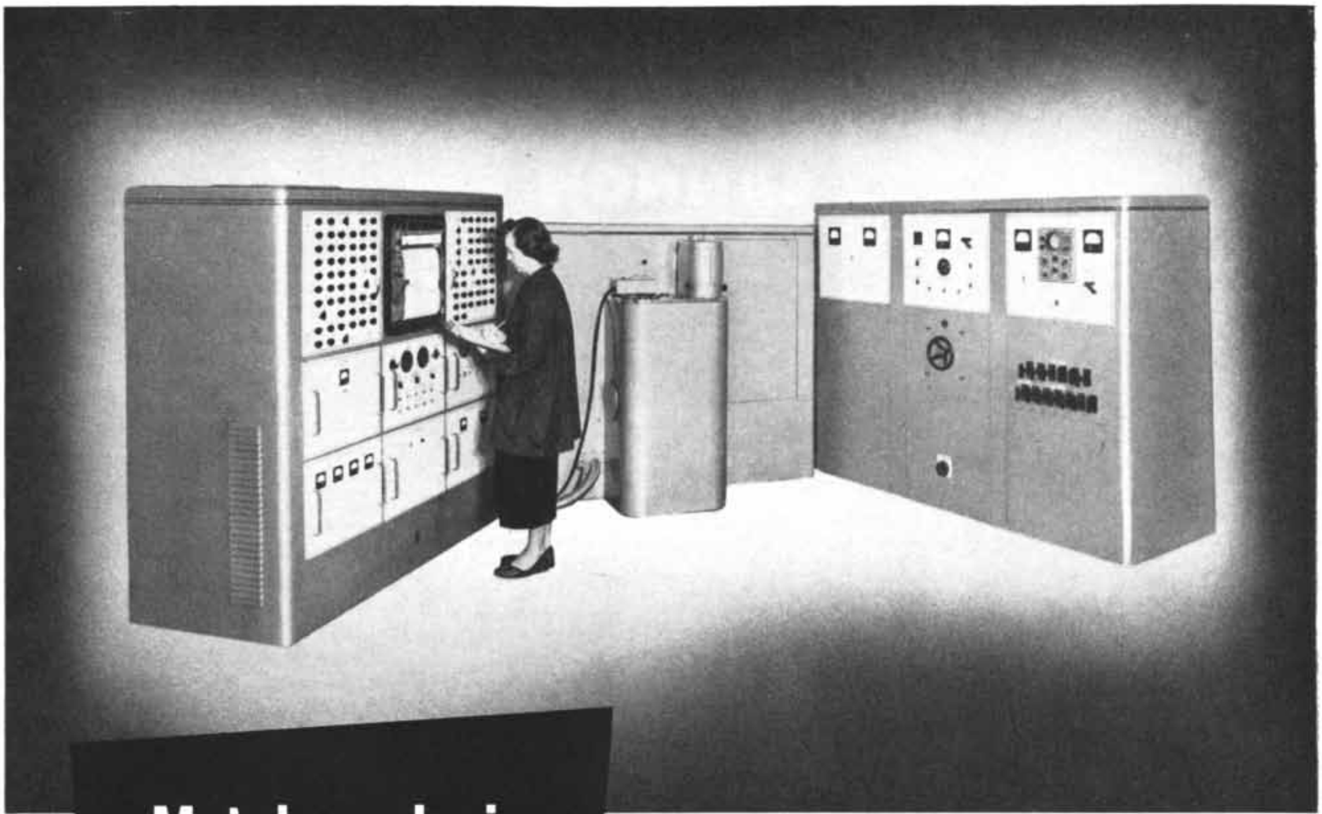
The physicians conclude that the "surgical approach" used to determine the sex of this patient is far more harmful than "the simple expedient of accepting the sex certified on the birth certificate and requiring that the individual conform to it." But they acknowledge that their approach raises new psychological and legal problems. "One of our patients, following castration and without estrogen therapy, married as a female and reported normal coital activity and connubial adjustment. What would be the legal status of this marriage, if evidence was submitted that the patient was a castrated male, despite certification at birth as a female? Another of our patients, following castration and estrogenization, has developed an active sexual drive with gynecoid orientation and has been practicing satisfactory coitus with an apparently normal male. Should this patient marry, provided the proposed husband knows that menstruation and childbearing are impossible?"

The four physicians are not prepared to say.

The Hollandaise Trouble

THE New York City Health Department has recently taken firm steps against the dangers of hollandaise sauce. This delicacy is a particularly happy breeding ground for bacteria. It is made, to begin with, of butter and egg yolks, which every laboratory technician knows is just what the bacteriologist orders. Then it must be kept at a temperature around 100 degrees, precisely right for bacteria. (If the sauce is allowed to cool, it spoils; if it is overheated, you have scrambled eggs.) The problem is aggravated by the fact that it is the custom of restaurant chefs to prepare their sauces first thing in the morning—so germs have all day long to multiply.

Aroused by reports of some 40 cases of hollandaise-sauce poisoning per year in New York City, the Health Department began by sending out inspectors to watch chefs preparing hollandaise.



Metal analysis in 2 minutes...

with ARL Production Control Quantometer

Leader in Performance

No other instrument in this field offers you so many outstanding features for obtaining complete, accurate, high-speed chemical analyses.

Leader in Popularity

ARL Production Control Quantometers are in daily use in all fields of metal analysis.

Representing the most advanced type of direct-reading spectrometer yet developed, this multiple-purpose instrument provides pen-and-ink recorded analyses of samples, element by element, almost instantaneously. These graphic records may be made in multiple for high-speed analytical control.

The instrument can be designed for many purposes, including testing of metal alloys and other inorganic materials. As many as 25 elements can be measured with one instrument—up to 20 simultaneously. Individual units are not limited to one type of analysis but can be designed for diverse and versatile service to meet the requirements of several major plant problems. Results are comparable to chemical analyses in accuracy.

The latest and most elaborate unit in the complete ARL line of spectrochemical equipment, the ARL Production Control Quantometer offers the modern scientist the equivalent of a complete laboratory in one compact unit. Manufactured by the world's oldest and largest producers of direct-reading instruments, the Quantometer is available to help you in your analytical and production problems. Write for complete details.

APPLIED RESEARCH LABORATORIES

4336 San Fernando Road, Glendale 4, California

New York, Pittsburgh, Detroit, Chicago, Los Angeles

The result of these observations was the promulgation of a set of rules for New York chefs: don't re-use leftover sauce; don't use leftover butter to make the sauce; don't keep the sauce more than two hours; don't taste the sauce with your fingers; wash the eggs before you break them to make the sauce. Inspectors are making frequent rounds to see that the rules are obeyed.

Clinic for Criminals

AN attempt to cure habitual lawbreakers by psychotherapy has recently been started by a group of New York psychiatrists, who have formed the Association for Psychiatric Treatment of Offenders. About 20 criminals including rapists, forgers and dope-peddlers, sent to the Association by the Probation Department of the Court of General Sessions and other agencies, are being treated free in the private offices of the psychiatrists.

The Association also sponsors forums and discussion groups to explore the problems in its field. Its goal is the establishment of a special psychiatric clinic for criminal offenders.

What Makes Gobies Jump?

GOBIES are tropical shore fish about an inch and a half long. As they swim about near the shore they sometimes get trapped by a low tide in shallow land-locked pools. When a goby finds itself in such a fix, it may leap out of the pool and over rocks toward deep water, sometimes clearing nine inches in a jump. And the most remarkable thing about it is that the fish always knows which way to jump. If it leaped onto shore instead of into the ocean, it would be a dead goby; but the canny animal never guesses wrong.

How does the goby know which way to jump?

This problem in fish psychology was tackled by Lester R. Aronson of the American Museum of Natural History. After watching a great many gobies jump about in the waters near Bimini, British West Indies, he began to have a suspicion of the answer. To test his theory he put some gobies in a tank containing four separate pools. Most of the fish stayed in their own pools; the few that ventured to jump jumped wrong—into a part of the tank without water. Then Dr. Aronson flooded the tank. The gobies had a chance to swim over the bottom and learn its topography. When he lowered the water level to separate the pools once more, the gobies now happily jumped from one pool to another, never making a mistake.

Dr. Aronson's conclusion: the gobies remember the terrain they swim over, and when trapped, jump from memory. He thinks they can remember for as long as two weeks.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Never has industry turned out more goods than during the past few years of unprecedented customer demands. In endeavoring to meet these, Revere has developed new techniques, established new plants, installed the newest equipment and modernized the old, and stepped up its training program, including the development of some new ideas in relation to safety. Throughout the country, similar steps have been taken by manufacturers generally. This is the response of free enterprise to the stimulus of a free and growing market. It is fortunate that American industry was not only willing but able to do this, because now it is evident that these facilities and these skills must be devoted more and more to the defense of our freedom.

Defense Orders or "DO's" are being issued, and their volume is bound to increase. Already prime contractors are seeking sub-contractors, and sub-sub-contractors are receiving orders too, down to small local firms operating only a few machines. Perhaps few people realize the importance of the "small shop"; the fact is that these establishments have a tremendous total capacity supplementing that of the great corporations, which practically never make everything that is needed for a finished product such as a tank, a plane, a ship, radar equipment. The "smalls" are just as vital as the "bigs."

Revere knows that when the time of trial comes, it is more important than ever to increase production efficiency. This makes complete information essential to those who have taken on DO contracts. Revere pledges its full cooperation, and will gladly provide all it knows about its metals.

This knowledge is made available in two principal ways. First, there are many booklets containing technical data, including physical properties, and also in many cases suggestions as to recommended fabrication practices. In addition to the booklets, which are distributed on request, Revere either reproduces or summarizes them in the various Sweet's Files, Chemical Engineering Catalogue, Marine Catalogue, Refinery Catalogue. This printed material is therefore available freely to all who will ask for it, or look it up. The second way in which Revere's knowledge and skill is made available is through the Technical Advisory Service, a group of capable men whose collective experience covers practically all applications of copper and copper alloys, and aluminum alloys. In war and peace, these men have rendered invaluable service, collaborating closely on such matters as selection of the proper metal, temper, width, gauge, and in helping to solve production problems. As a result, scrap has been reduced, rejects lessened, production increased, money and materials saved. The services of the Technical Advisors are obtainable through the Revere Sales Staff which also has wide experience in the selection and application of Revere Metals. If you have orders whose specifications include non-ferrous metals, Revere will gladly place its information at your disposal.

If you purchase and work with other materials, Revere suggests that it should be realized that not only is American productive capacity tremendously greater, but that there has been a likewise large growth in knowledge about materials of all kinds. So it is recommended that no matter what you make now, or are called on to make in the future, you ask your suppliers to share their knowledge with you. It will make you and our country stronger.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

Executive Offices:

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

150th YEAR OF SERVICE TO AMERICA

SEE "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY

Management was listening when this cop asked "WHY?"

They came to us with a questioning mind. Their oak trailer floors were heavy, easily damaged, replaced several times in a trailer's life. Moreover, state laws were tough on overloaded trailers.

These facts led the trailer maker to echo "why not increase payloads by making trailer floors lighter?" He came to us saying, "can there be a floor as strong as 1¼″ oak—saving about 500 pounds—keeping costs low?"

The trailer maker and our engineers first explored aluminum plate and sheet formed into channels. Then an Alcoa man said, "let's try extrusions." Extrusions put the metal where it does the most structural good.

Together, we drew up designs, picked the most likely extrusion alloys from results of tests at Aluminum Research Laboratories. Samples were extruded. Experimental floor sections were built in Alcoa's Process Development Shops.

Now for testing. But no facilities existed for testing sections as wide as a trailer and ⅓ as long. We built them. Then, working with strain gauges, we loaded the sections to failure. The best design was selected. The less expensive alloy proved strong enough.

Would aluminum floors last in service? Could they be installed easily? World-wide test stations and Alcoa laboratories provided data on aluminum's resistance to weather, salt spray and chemicals. Assembly experience demonstrated the ease of installation.

Extruded floors are now common. Seldom need replacement. Add extra cargo capacity. . . . Proof that it pays to be dissatisfied with your product. Proof that a long-range program of research and testing can change your company's competitive position.

for such 1 *Knowledge and Specialists* IN MANY FIELDS

Aircraft
Architectural Specialties
Automotive
- Passenger Cars
- Trucks and Trailers
- Buses
- Parts and Accessories

Bearings
Building Industry
Business Machines
Chemical Equipment
Communications
Corrosion Studies
Diesel Engines
Electrical Conductors
Electrical Equipment
Farm Machinery
Food Equipment
Handling, Packaging and Shipping
Hardware
Heat Exchangers
Home Appliances
Instrumentation
Insulation
Marine Industry
Mining Equipment
Paper Machinery
Petroleum
Pressure Vessels
Printing Machinery
Railroad Equipment
Structural Engineering
Textile Machinery

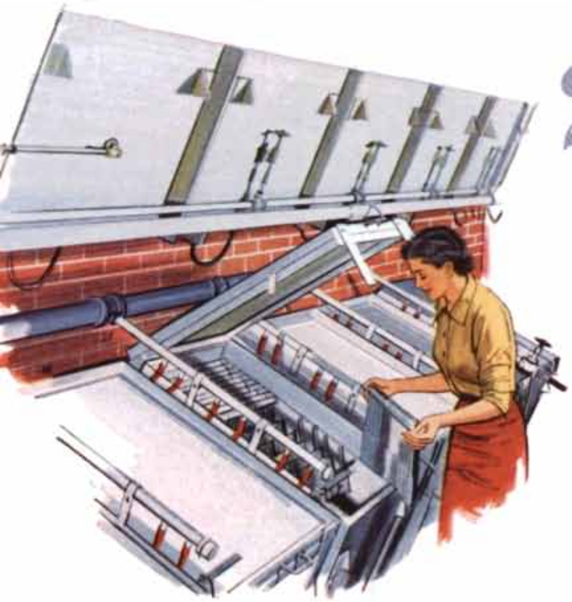
Among these specialists at the Development Division are men already familiar with the problems of your industry. They are your liaison with the Alcoa research, test and fabricating facilities that can be put to work on your problem. Through them the sum total of Alcoa's knowledge will be brought to bear. Knowledge of practical problems of fabrication and costs, gained in thousands of other projects, will flow toward yours.

ALCOA ALUMINUM ®

there are no limitations on *Imagineering*

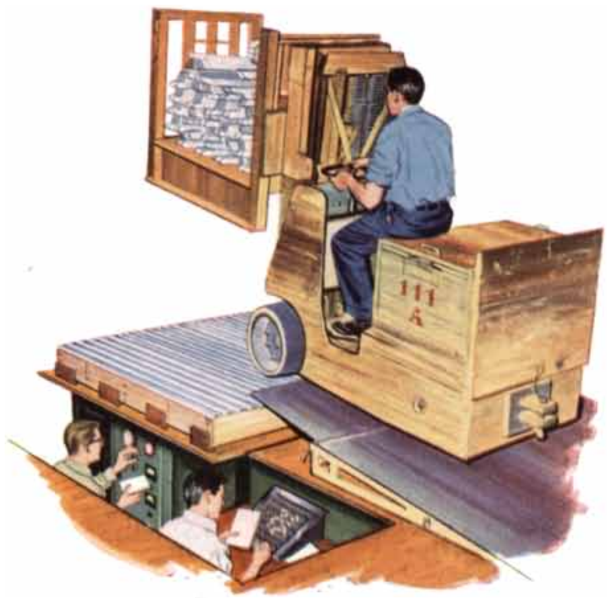
DEVELOPMENT DIVISION

long-range projects we have these to offer:



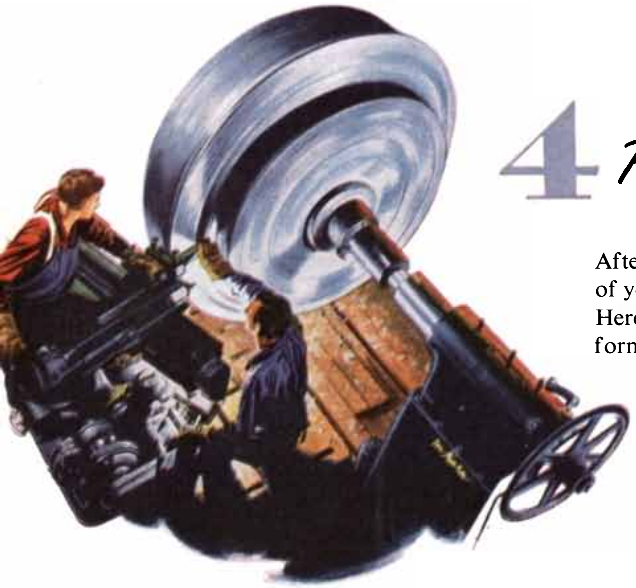
2 FACILITIES FOR BROAD *Research*

Like extruded floors, your project will require facts about the physical and chemical properties of aluminum. Perhaps a new alloy must be developed. Aluminum Research Laboratories have extensive facilities for this fact-finding job. Facilities such as this corrosion test equipment.



3 ADVANCED *Test* EQUIPMENT

Proving the theories of basis research requires testing equipment to duplicate every conceivable service condition. Even equipment like Alcoa's giant tensile tester or our 70,000 rpm whirlpit may not simulate the punishment your product must take. Then we design and build special equipment—like this set up for testing extruded flooring.



4 *Process Development Shops* FOR PILOT AND MODEL WORK

After thorough research and testing, the actual fabrication of your project in aluminum may pose further problems. Here Alcoa makes available all the techniques of welding, forming, machining, casting, heat treating and finishing to create a practical pilot model, then suggests low-cost, efficient methods for its fabrication.

ALCOA

For more details on the personnel, research and testing, and shop facilities available at Alcoa, write for your copy of the folder, "Road Map to a Better Product." It is your first step toward putting 63 years of aluminum knowledge to work on a long-term project that may effect a major change in your company's competitive position. Address ALUMINUM COMPANY OF AMERICA, 2182D Gulf Bldg., Pittsburgh 19, Pa.

PUSH-BUTTON SELF-STARTER FOR THE FIRST U. S. TURBOPROP TRANSPORT

ANOTHER AIRESEARCH FIRST!

A flick of the switch . . . a 2750 hp Allison 501 engine roars into action. Seconds later a twin 501 is fired . . . and America's first turboprop airliner is ready for takeoff.

It's the Convair Turboliner purchased by Allison Division of General Motors to demonstrate turboprop engines in air transports. This is the first turbine powered airliner in the world able to start its own engines an unlimited number of times.

This self-starting system was pioneered by AiResearch, working with the Navy Bureau of Aeronautics. A low pressure pneumatic system, it consists basically of a small gas turbine the size of a hand valise and two small air turbine starters. It is the only self-contained, continuous self-starting system for turboprop and turbojet engines light enough to be airborne!

Development of the AiResearch low pressure pneumatic power system was begun six years ago. It is also being used on the Navy Convair XP5Y turboprop flying boat and the Navy Douglas A2D turboprop dive bomber now in production.

Another AiResearch *first* — this system reflects our technical skills and ability to solve problems of unusual difficulty in the field of aeronautics.

AiResearch lightweight gas turbine

AiResearch
DIVISION OF
THE GARRETT CORPORATION

• AiResearch — Specialists in the design and manufacture of equipment involving the use of high-speed wheels — is a leader in the following major categories:

Air Turbine Refrigeration • Cabin Superchargers • Gas Turbines • Pneumatic Power Units • Electronic Temperature Controls
Heat Transfer Equipment • Electric Actuators • Cabin Pressure Controls

AiResearch Manufacturing Company, Dept. K-4, Los Angeles 45, California

REACTORS

The machines designed for the controlled use of nuclear energy take many forms and present many problems. A report on some typical reactors and the AEC program of reactor development

by Lawrence R. Hafstad

NUCLEAR reactors are the machines for converting the energy of nuclear fission into forms that can be turned to useful purposes. They are large, complicated, expensive and controversial. They provide man with the most concentrated energy source thus far devised, and in the imagination, at least, they have unlimited possibilities. The uses proposed for them have ranged from performance of the world's drudgery to the powering of rockets for space travel. Some of the proposed uses are strictly figments of the imagination. But reactors themselves, as a new type of machine with new potentialities, are a functioning reality, and it is now possible to discuss some of them publicly in considerable detail. Much of the information on the construction and performance of five early reactors, three of which are in the U. S., has recently been declassified by agreement between the U. S., Britain and Canada.

This report will briefly describe the three declassified U. S. reactors and will survey the Atomic Energy Commission's general program of reactor development, with particular reference to new reactors of pioneering design now under development and construction.

Not the least striking feature of reactors is the great variety of possible designs. This is one of the things that makes them so vastly different from the power plants that we have been used to. Conventional coal burning furnaces, for example, are all generally recognizable as belonging to a common genus; they may differ in size and details, but essentially they are built and operated on the same fundamental plan. Imagine, however, a furnace variation which for fuel used carbon dioxide, say, instead of coal, which burned its fuel in a medium of water instead of air and which operated in a kettle instead of the usual firebox. That would certainly be a radical variation, but it is no more radical than the variations among the nuclear furnaces called reactors. The three reactors to be described here, all low-power machines used mainly for research, represent three very different types which indicate the wide range of possibilities.

The Graphite Pile

Let us take first the world's oldest nuclear reactor—the uranium-graphite pile at the University of Chicago in which a chain reaction was first achieved in 1942. This pile, later taken apart and rebuilt at the Argonne National Laboratory near Chicago, is a cube-shaped mass of blocks of graphite containing lumps of natural uranium or uranium oxide in a lattice arrangement; the oxide was used because only a small amount of pure uranium metal was available when the pile was built. The graphite blocks, which act as the moderator and the structural bricks of the pile, are 4⅛ inches square in cross section and of various lengths, usually 16½ inches. Some of the blocks have holes bored in them at intervals 8¼ inches apart. In these are inserted the uranium lumps, each a cylinder 2¼ inches in diameter and about six pounds in weight. The uranium-loaded blocks are called "live." The solid graphite blocks without uranium are known as "dead" graphite; they are used for spacing and neutron-reflecting purposes. The pile was built up, layer by layer, with alternating layers of live and dead blocks (*see photograph on page 44*). It became "critical"; *i.e.*, started a self-sustaining chain reaction, when the 50th layer was laid on. Four layers of dead blocks were then laid on top as a reflector, and over this went a cover of six inches of lead and about four feet of wood. The sides of the pile were surrounded with a similar reflecting barrier of at least 12 inches of dead graphite and with protective walls of concrete five feet thick.

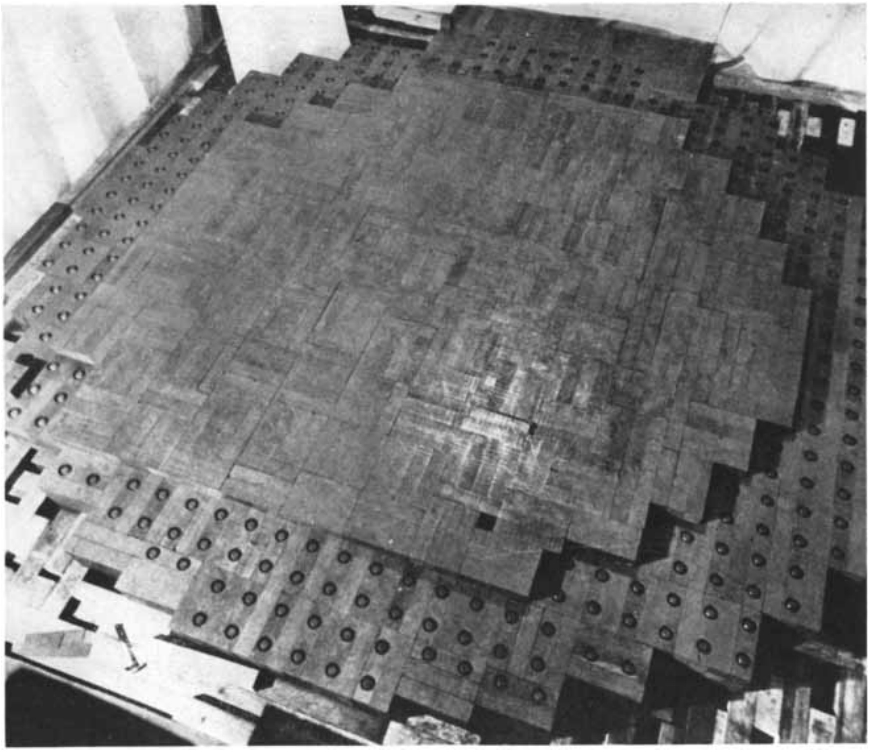
When completed, the pile measured 30 feet wide, 32 feet long and 21 feet high and had a total weight of more than 1,400 tons. It contained approximately 52 tons of uranium, in 3,200 lumps of the pure metal and 14,500 lumps of uranium oxide.

Openings were provided in the pile for five control rods 17 feet long. They are bronze strips covered with cadmium, an excellent absorber of neutrons. Three of the rods are automatic safety controls; they are equipped with 100-pound weights that quickly pull them into the pile in the event of electrical power failure or other emergency. The operating level, or power, of the pile is controlled by a single rod which is moved in or out to regulate the neutron flux. Because it lacks a cooling system, the maximum safe operating power of this pile is only 200 watts.

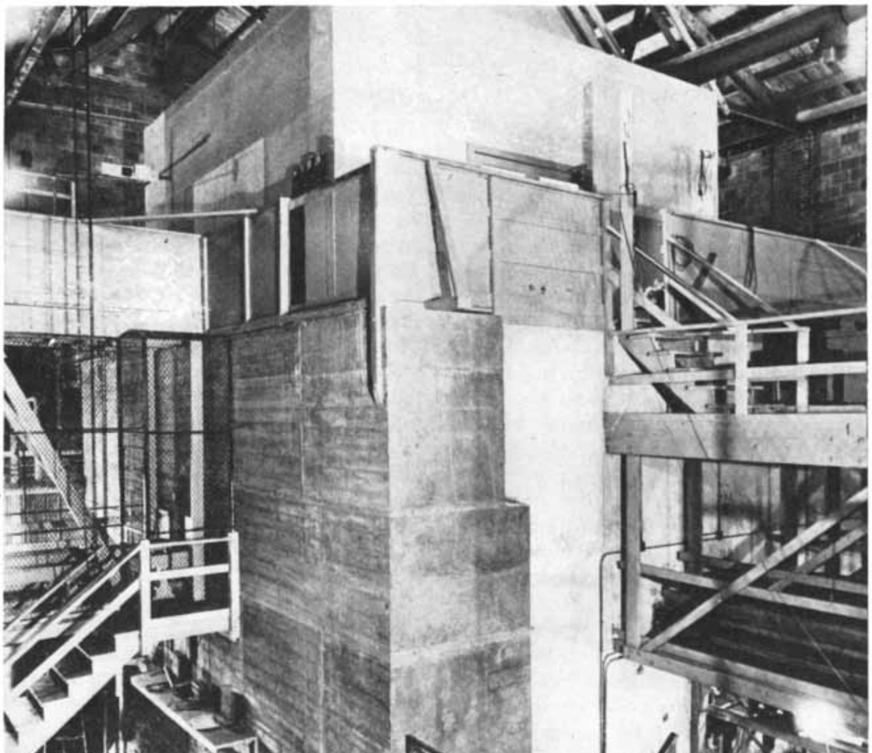
The research reactors at Oak Ridge and Brookhaven, and the great production piles at Hanford, are roughly similar to this first reactor. Their mass is largely graphite, and they are fueled by natural uranium. But they have systems for cooling, either by air or water, and therefore can run at higher power levels. They also have devices for loading and unloading fuel without tearing down the reactor. In addition they incorporate a number of other improvements and refinements required to provide dependable control for their much greater power and to serve their different purposes.

The Heavy-Water Tank

The second type of reactor is the heavy-water unit at Argonne. This machine, whose dimensions have now been declassified, also was the first of its type in the world. It was built by the Manhattan District during the war because of the remote chance that graphite piles might not be able to produce fissionable material in the amounts needed for bombs. In this reactor heavy water, instead of graphite, is the moderator that slows fast neutrons emerging from the fission of U-235 atoms to the thermal speeds necessary for their capture by U-235 and the continuation of a chain reaction. In an aluminum tank six feet



UNIVERSITY OF CHICAGO PILE was built up in layers. Here a layer of "dead" graphite blocks is laid on a layer of "live" blocks containing uranium.



ARGONNE NATIONAL LABORATORY PILE is the University of Chicago pile rebuilt. The structure in center is the concrete shielding of the pile.

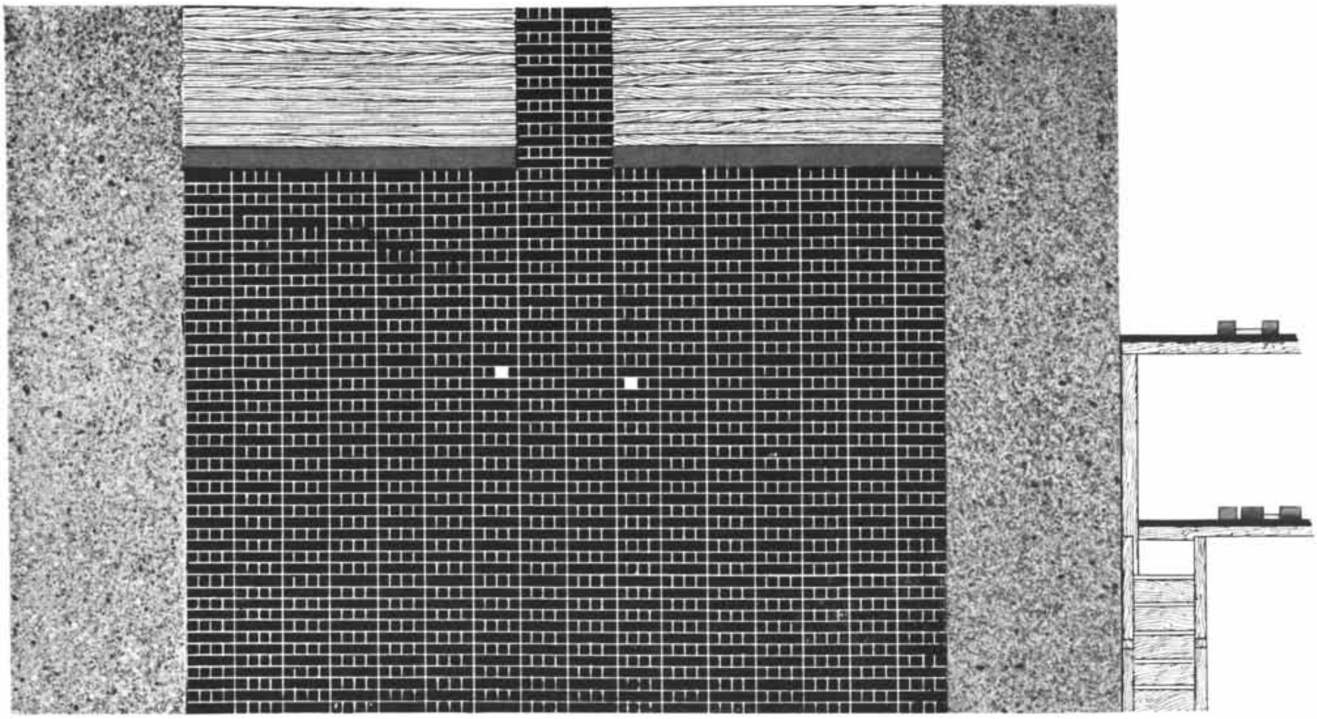
in diameter and about nine feet high, filled with about 6½ tons of heavy water, are suspended 120 uranium metal rods 1.1 inches in diameter and six feet long. The rods are sheathed in aluminum for protection against corrosion. They are arranged to form a square lattice with 5⅜ inches between their centers. This reactor is smaller than the graphite pile because heavy water is more effective than graphite in slowing neutrons and does not absorb them as readily. Its total weight of uranium is less than three tons, in contrast to the 52 tons in the graphite pile.

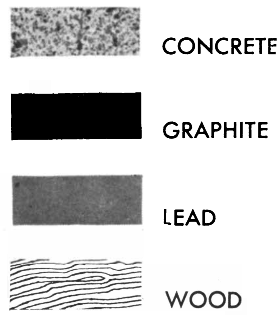
The heavy-water reactor tank is surrounded on its bottom and sides by a two-foot neutron reflector of graphite blocks. Around the reflector, in turn, are a four-inch casing of lead-cadmium alloy and then a shield of concrete eight feet thick. The reactor's top shielding consists of a layer of helium gas, a thin layer of cadmium metal, a one-foot layer of lead bricks and finally a four-foot layer of blocks of wood and steel.

Eleven small openings pierce the shield and reflector. These portholes, equipped with removable shielding plugs, are used to measure neutron intensity within the reactor, to insert materials for exposure to neutrons and to let beams of radiation emerge for experiments outside the reactor. There are also three large openings. One is a pocket roughly 30 inches square containing 20 hollow graphite receptacles in which materials can be placed for irradiation. Another is a graphite-plugged aperture five feet square which permits the passage from the reactor of a beam of slow neutrons. The third is a four-inch aluminum pipe inserted in the tank through the top. Into this pipe, known as the central experimental thimble, samples of material may be lowered for exposure to the most intense radiations of both fast and slow neutrons. When all the reactor's openings are used, 32 irradiations can be performed simultaneously.

To cool the reactor, the heavy water circulates between the tank and an external heat exchanger at the rate of 200 gallons per minute. The cooling system is capable of handling 300 kilowatts of heat. Normally the heavy water is at a temperature of 95 degrees Fahrenheit when it emerges from the tank; after it has passed through the heat exchanger, it is about seven or eight degrees cooler.

The operator measures and controls all the major aspects of the reactor's operation at panels in a nearby room. To start the machine he pushes a button: this lifts the 32-pound safety rods out of the heavy water. Other buttons control two motor-driven rods that regulate the reactor power level. To shut off the reactor the operator presses another button that causes the safety rods to fall back into the tank. If controls fail to function, if





NATURAL URANIUM-GRAPHITE REACTOR in which the first self-sustaining nuclear chain reaction was achieved is shown in this simplified cross section. The reactor was originally built at the University of Chicago and later rebuilt at Argonne National Laboratory. It is basically a large cube of graphite blocks, some of which contain small cylinders of uranium or uranium oxide. An outer layer of graphite blocks containing no uranium serves as a neutron reflector. The shaft of blocks sticking up from the top of the main cube in the cross section is the "thermal column," a means by which slow neutrons may be permitted to diffuse out of the reactor for experimental purposes. The wooden structure at the right supports control rods and stringers that may be inserted into the cube; the holes in the front of the cube permit the insertion of safety rods. The uranium cylinders are not shown.

there is an interruption in the electricity supply or if for any reason the power level rises too high, the safety rods automatically fall into the "in" position by gravity. As further provision for an emergency shutdown there is a large quick-opening valve through which the heavy water can flow out into a storage tank. Without the moderator, the chain reaction promptly stops.

The Water Boiler

The third declassified reactor is the famous "water boiler" at Los Alamos. This is a homogeneous reactor, meaning that the fuel is distributed uniformly throughout the moderator instead of being in lumps or rods. The fuel, a uranyl salt, is dissolved in heavy water, and this solution, called "soup" by the reactor scientists, is both the fuel and the moderator. As a chain reaction develops, the solution heats up; hence the name water boiler.

The first version of this reactor was a low-power model known as LOPO. It had no shielding and reached a power of only a twentieth of a watt. In December, 1944, LOPO was replaced by HYPO, a higher-powered model of six kilowatts which went critical with 1.8 pounds of U-235. Its fuel is "enriched"; that is, the uranium in the uranyl salt contains about one part of fissionable U-235 to six parts of U-238, instead of the 1-to-140 ratio in natural uranium.

The heart of this reactor is a one-foot stainless-steel sphere filled with the "soup," a solution of uranyl nitrate. Then comes a reflecting shell, or tamper, consisting of an inner layer of beryllium oxide and a thicker outer layer of graphite. Around this assembly is the shield: four inches of lead, 1/32-inch of cadmium and five feet of poured concrete (*see diagram on page 49*).

At the working face of the reactor a square tunnel pierces the shield. This tunnel is plugged with graphite to form a column for the passage of slow neutrons. The graphite column and the reflector have a number of ports for experimental irradiations. In addition there is a tube one inch in diameter that penetrates into the heart of the reactor itself. Through this tube, which Los Alamos workers call the "Glory Hole," materials can be thrust into the sphere for exposure to a very high flux of neutrons.

The operation of HYPO presents some special problems. Cooling is accomplished easily enough by circulating water, at the rate of about 50 gallons per hour, through a coiled tube in the central sphere. But the highly ionized atoms produced by fissions in the reactor decompose the water in the fuel solution into an explosive mixture of hydrogen and oxygen gas, at the rate of about half a cubic foot of gas per hour. Moreover, the radiations also produce a small volume of highly radioactive gases. Consequently the design has to provide a means for constantly diluting and flushing out these gases.

Under normal operating conditions the water boiler has a natural self-regulating action that prevents it from getting out of control. As the reaction rate and the temperature rise, the solution expands in volume, the U-235 atoms move farther apart and the reactivity per unit volume therefore declines. This automatically slows down the reaction and holds it within safe limits. HYPO has a safety control rod, nonetheless, and two regulating rods for accurate control of its flux. Since extremely accurate regulation requires almost continuous adjustment of the control rods and this can become tedious over long periods, the reactor has been provided with an automatic pilot that can hold the power at any desired level with an accuracy within a few tenths of one per cent. An experienced operator can bring HYPO up to full power in a few seconds. If cooled by water at about 45 degrees F., HYPO can run continuously at 5.5 kilowatts without exceeding a solution temperature of 185 degrees F.

HYPO is the smallest and most economical type of chain reactor. It has been used primarily for research experiments requiring a concentrated neutron source. The research reactor which the Consolidated University of North Carolina plans to build at North Carolina State College will be of this type.

The New Generation

So much for the description of the declassified reactors. Publication of the details may help citizens to begin to feel at home with these new machines of our civilization. But it must be remembered that the units described here were among the first built. By now they represent mere "taking-off points" for the better reactors that have been built since and for further improved ones that are under construction or envisioned for the future. The program for developing better reactors still faces many unsolved technical problems. We need materials that will stand very high temperatures and intense radiations and that will not absorb too many neutrons; we need more efficient shielding and control gear with very rapid response times; we need ways of attaining heat-transfer rates higher by an order of magnitude than those conventionally used in power plants; we need better ways of handling fission products in the reactor and of disposing of radioactive wastes. The national laboratories of the Atomic Energy Commission have been occupied with these problems since 1945. Much progress has been made toward solutions, but just how much is difficult to assess without some full-scale trials. During the coming year some of these trials will begin, as several reactors of new and advanced design come into operation.

The AEC has five major reactor projects under way. First there is the experimental breeder reactor, designed primarily to explore the possibilities of breeding; that is, producing more fissionable material than is consumed. This reactor will operate in the fast-neutron energy range. Construction and fabrication are practically complete and installation is beginning. The second is the materials-testing reactor, designed for the highest neutron flux yet attempted. As its name indicates, it will be used in the development of other reactors. Construction is well advanced. Third there is the slow-neutron ship-propulsion reactor, a land-based prototype of a reactor for propelling submarines. Construction is under way. Fourth is the ship-propulsion reactor designed to operate in the intermediate-neutron energy range, in which we have had no experience. This project replaces an earlier project for an intermediate reactor for both power and breeding. It is in an early stage of development and design. And fifth there is a homogeneous reactor, of moderate size, which will serve as a pilot model to spearhead further exploration of reactor designs of this type. It is under construction.

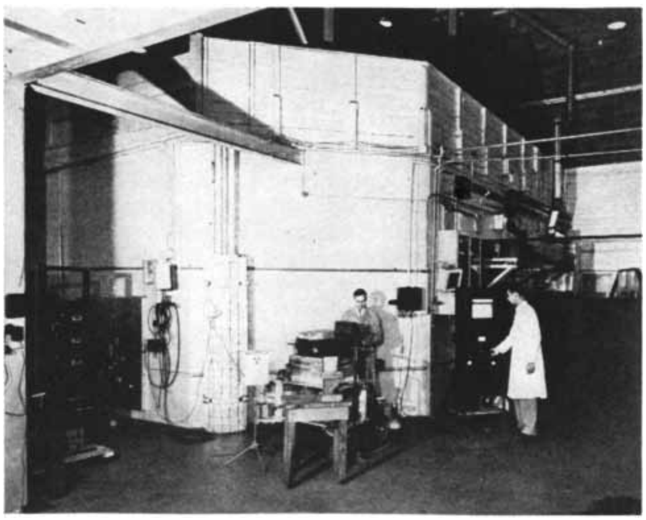
Now that actual construction of most of these reactors has started, we are acquiring, for the first time since 1942, an objective measure of the "state of the art" in reactor technology. We can see that the laboratories have done an adequate job of applied research and have provided the engineering designers with adequate "handbook" data. The designers in turn seem to have avoided gross miscalculations, at least as far as the early construction has gone. But final answers must wait until the present generation of reactors has been carried through the debugging stage and is in actual operation.

The Next Generation

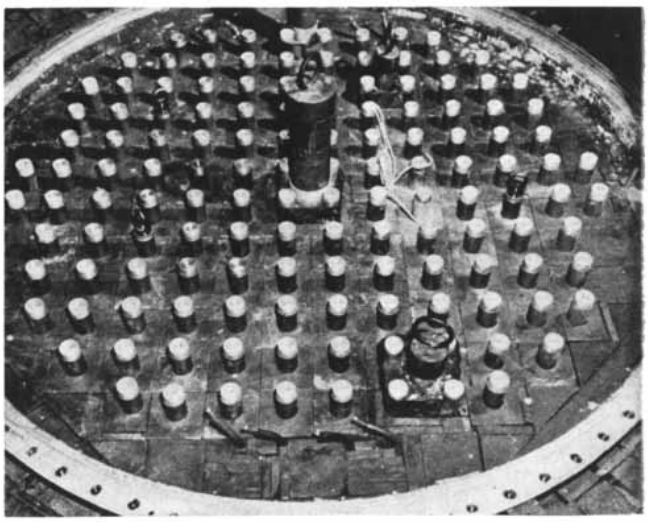
Already, as is not surprising, there is considerable discussion of the next generation of reactors. What types should be chosen for trial? There are all sorts of possibilities. With breeders and nonbreeders; high, low and intermediate neutron energy; high, low and medium temperatures; natural, slightly enriched and highly enriched fuels; homogeneous and heterogeneous fuel distributions; assorted moderators, coolants and corrosion-resisting coatings—with all these possible variations the number of permutations and combinations runs high. The problem is not to invent a reactor; the problem is to select one that will yield maximum returns. Remember that reactors are expensive. Small ones cost from $1 million to $5 million; large ones $25 million to $50 million or more.

We must start by considering what our reactor needs are. We know that we need reactors for producing fissionable material for military use if for no other. We believe we can probably use to advantage mobile power reactors for propulsion, if the cost in both dollars and fissionable material does not prove to be prohibitive. On the other hand it is clear that we can justify heavy commitments to reactors for industrial electric power only if and when the cost of this power bears a reasonable relationship to the cost under comparable conditions of power available from conventional fuels. These are the boundary conditions.

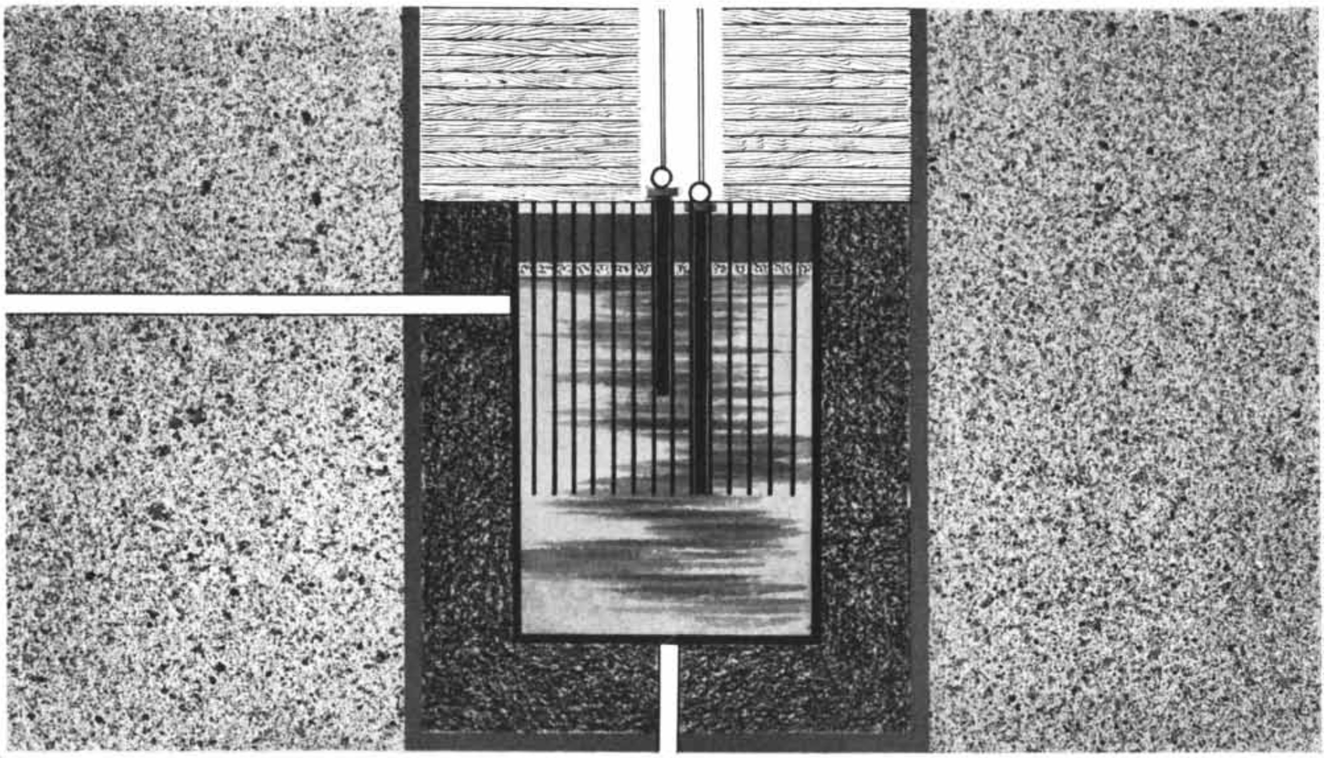
Unfortunately, to assess the need for



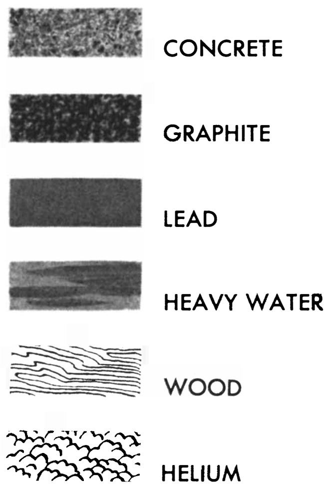
OUTSIDE of the heavy-water reactor at Argonne National Laboratory shows its concrete shielding. At the lower left is one of the graphite tunnels into the reactor.



INSIDE of the reactor shows the top of the tank containing the heavy water, with the ends of the uranium rods sticking up through a lead shield. Center: the "thimble."



HEAVY-WATER REACTOR at Argonne National Laboratory is shown in a simplified cross section based on written descriptions released by the Atomic Energy Commission. In this reactor the neutrons produced by fission are moderated by heavy water instead of graphite. The heavy water is contained in an aluminum tank approximately six feet across and nine feet high. Suspended in the tank are 120 uranium rods. Around the tank is a layer of graphite to reflect escaping neutrons. Around the graphite is a layer of lead-cadmium alloy and a heavy shield of concrete. At the top of the tank is a layer of lead; beneath it is a thin layer of cadmium, and between the cadmium and the heavy water is a layer of helium. Toward the right side of the tank is a control rod. In the middle of the tank is the "experimental thimble," a device for inserting experimental materials into the reactor. Above the tank is a layer of wood and steel. The heat generated by the reactor must be dissipated; this is accomplished by circulating the heavy water through a heat exchanger (*pipes at left and bottom*). Among the details not shown by this cross section are two horizontal columns of graphite that pass through the concrete shielding. One of these is to insert experimental materials into the reactor; the other, to permit a beam of slow neutrons to pass out of it. The reactor can handle 32 neutron irradiations simultaneously.



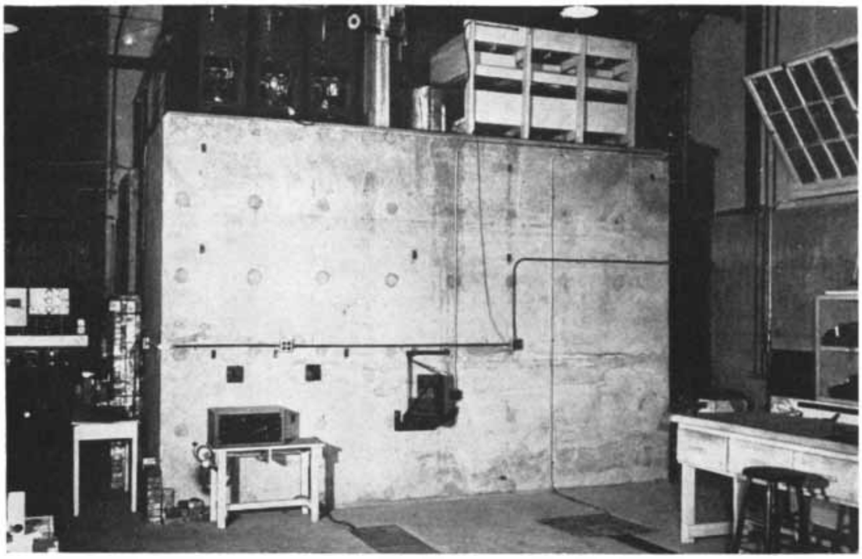
a given type of reactor we must know the cost, but costs, in turn, can only be determined by first building reactors. This is the circular argument in which we continually find ourselves. To break out of this vicious circle we use the fact that for the military needs the unknown economic factor is less compelling than it is for civilian needs.

A few other general conclusions can be drawn from experience. For example, with fissionable material in great demand for bombs, it is logical to concentrate on those types of power reactors that will at least partially replenish the fissionable fuel used up. Therefore we think of mobile military reactors which would produce plutonium as well as power. Eventually these reactors should breed, that is, manufacture more fissionable material than they consume. For civilian purposes also we should prefer reactors that produce fissionable material along with power, since breeding would reduce the cost of such power. Thus the difficulties are not separable into neat little problems which can be solved one at a time by themselves; the trend rather appears to be toward greater complexity with a pronounced interlock between fuel-producing, mobile-military and civilian power reactors.

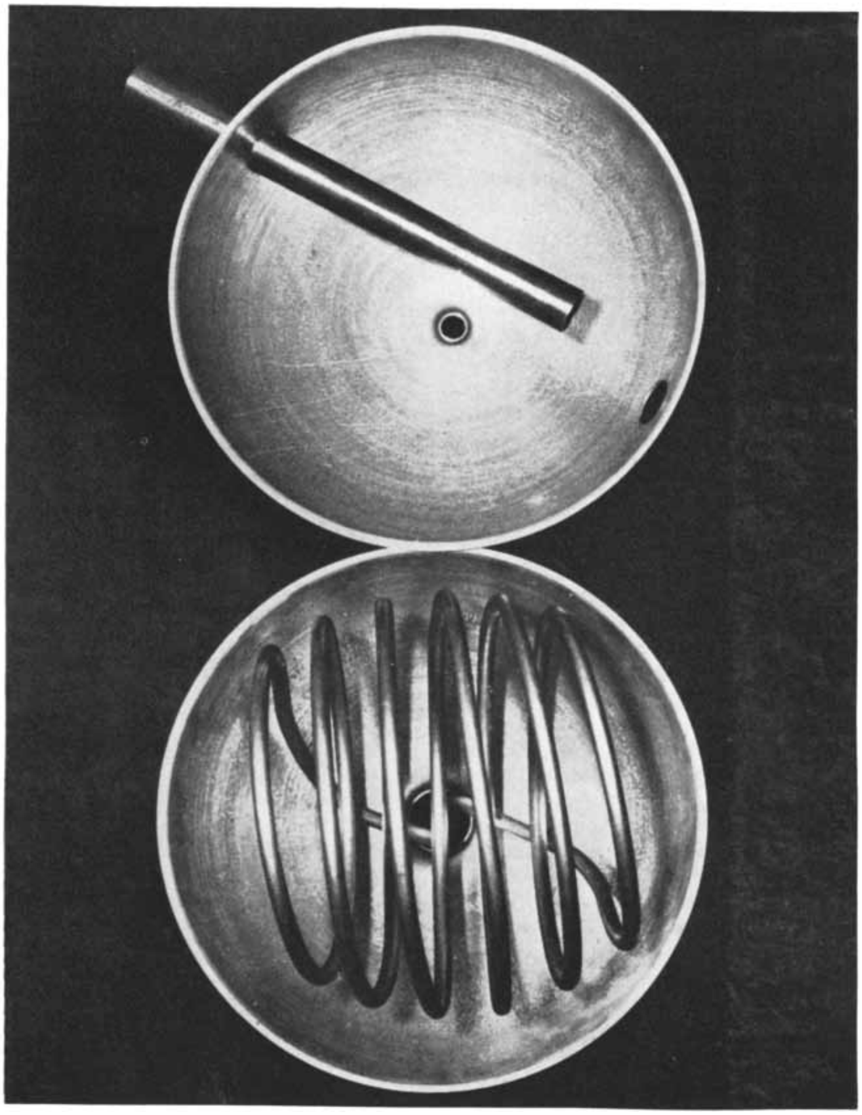
The economic factor insistently intrudes itself into what we would like to consider a purely technical problem. Critics of the U. S. atomic energy program assume that civilian atomic power could be made cheap and generally available if only those in authority had the will to do it. The assumption is that by another billion-dollar crash program like that of the Manhattan District the remaining necessary "secrets" could be uncovered and the real atomic era ushered in. Actually the atomic bomb problem and the civilian power problem have little in common except the language. They differ in kind rather than in degree.

The bomb project was almost uniquely "black and white": it was either a grand success or a colossal failure. The civilian power problem is quite different. Enough technical facts have long been known to assure us that electric power can be produced—if we are willing to pay the price. There is an analogy in the proposition of producing electric power from the winds or the tides. Our technical ability to tap these sources of energy is not questioned. But we don't utilize the wind and the tide because the power so produced would be more costly than that obtained conventionally from coal and oil.

The cost of construction of a nuclear power plant is still essentially unknown.



OUTSIDE of homogeneous reactor at Los Alamos is its concrete shielding. At left is a lead shield at the end of the graphite tunnel (*see opposite page*).



INSIDE of reactor is a steel sphere. The top hemisphere contains a tube into which experimental materials may be inserted; the bottom, a cooling coil.

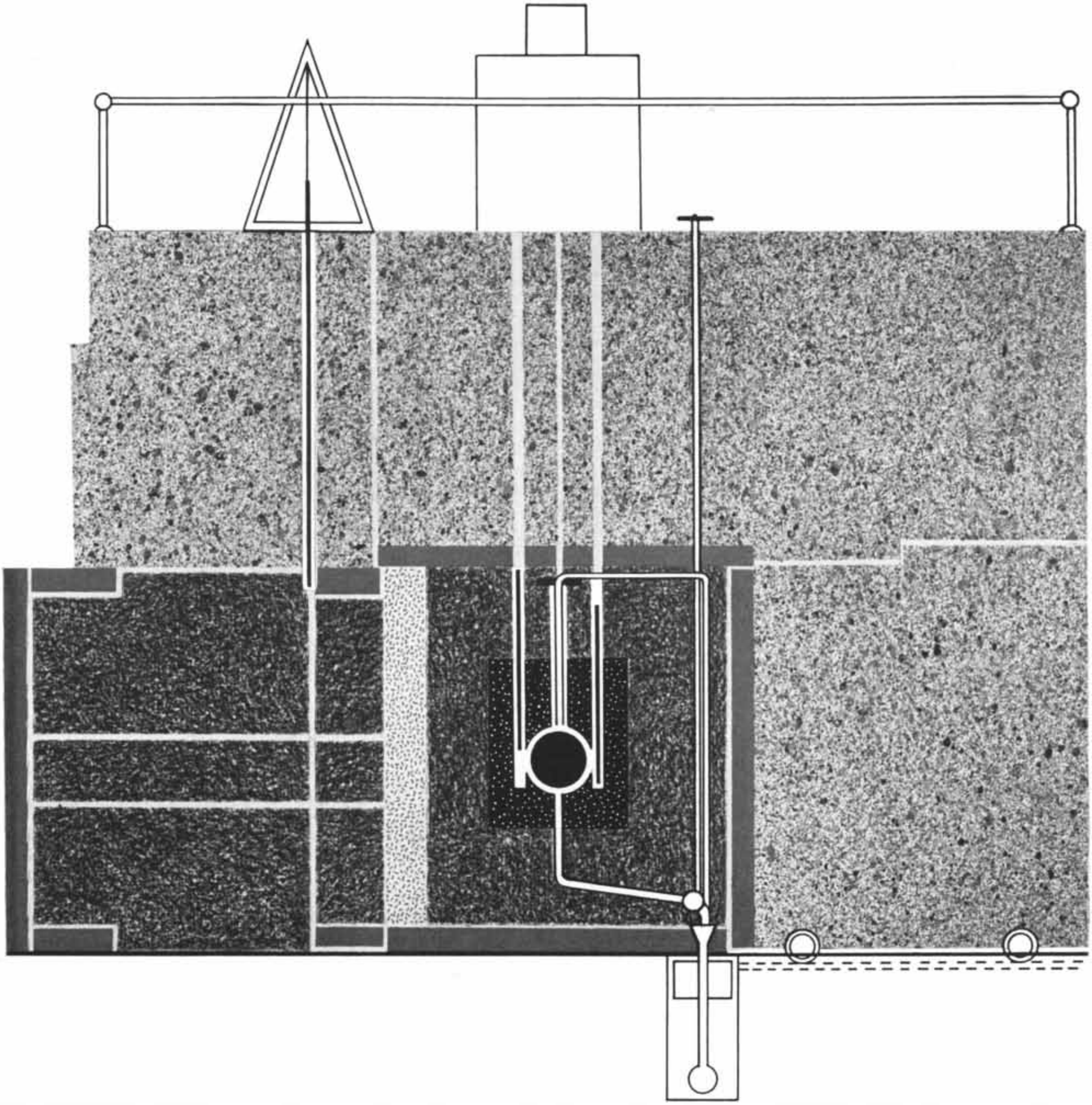
We have never even designed, much less built and operated, a reactor intended to deliver significant amounts of power economically. Our experience is that in this business estimates cannot be taken at face value and invariably turn out to be too low. My own approach has been to try to find the upper limit for the cost of a power plant, basing this estimate on the firmest available figures on the most nearly similar reactor either already built or under construction. Estimates based on the cost of low-temperature reactors for producing plutonium, on the assumption that they can be redesigned for operation at higher temperatures, cannot be taken seriously.

Yardstick

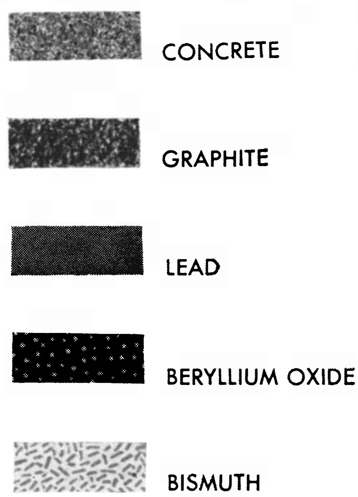
We are driven back to the slow-neutron ship-propulsion reactor now under construction as the best yardstick for the probable cost of a nuclear power plant. The cost of this mobile reactor has been estimated roughly as $1,400 per kilowatt-hour of installed electrical capacity. The corresponding cost of a conventional stationary coal-burning power plant is $100 to $150 per kilowatt-hour capacity. Now we know that many savings can be made in the $1,400 figure for the mobile nuclear plant. In a plant for civilian power it seems possible that we could avoid some of the high costs involved in developing a prototype reactor, in meeting the Navy's requirements of weight and space, in reprocessing fuels, in the lack of volume production, in the extreme military security precautions and in the extreme precautions for safety of personnel. If we could pick up a factor of two or three through savings in these items and through the technical improvements that will almost certainly come in a field as new as atomic energy, we would begin to close in on the competitive figure of $100 to $150.

The fuel costs are not negligible and are even more uncertain than construction costs. All fissionable material thus far manufactured has been produced by a government monopoly on a high-pressure basis in such a way that precise cost allocations simply cannot be made. Taking from the open literature the figure of $20 per gram for nuclear fuel, we get a fuel cost of one mill per kilowatt-hour, as compared with two mills for coal. The $20 figure is almost certainly low, and it seems likely that it will rise as the supply of high-grade uranium ore runs out. Hence it appears that fuel costs will be about the same for a power plant burning U-235 as for one burning coal, while the cost of the installation, and probably of its operation, will be considerably higher.

The civilian power plant need not, however, confine itself to producing power: it could also produce plutonium.



HOMOGENEOUS REACTOR, or "water boiler," at Los Alamos Scientific Laboratory combines fissionable material and moderator in one solution: a uranium salt dissolved in heavy water. The solution is contained in a one-foot steel sphere near the center of this simplified cross section. Around the sphere is a neutron reflector made up of a layer of beryllium oxide and a layer of graphite. Inserted in the beryllium oxide to the left and right of the sphere are the reactor's control rods. Within the sphere is a coil of pipe (*see photograph on opposite page*) through which water is circulated to cool the reactor. At the lower left in the cross section is a tunnel of graphite for experiments requiring exposure of materials to slow neutrons. For experiments requiring exposures to a high flux of fast neutrons materials can be inserted through the "Glory Hole" into the heart of the reactor. Hanging through the concrete shielding at the upper left is a cadmium curtain that can be dropped across the graphite tunnel. At the lower right is a concrete door that can be rolled out to permit access to the reactor. The homogeneous reactor was first built as a low-power apparatus without shielding; it was called LOPO. Later its power was stepped up and shielding was installed; it was then called HYPO. A reactor of this type is expected to be built by the Consolidated University of North Carolina for North Carolina State College.



The reactors now producing plutonium throw away their heat—hundreds of thousands of kilowatts of it. Suppose this heat could be put to some useful purpose, say the production of power, or even the distillation of sea water? What then is the economic picture?

Technically a reactor to produce both power and plutonium is not out of the realm of possibility, but scientists don't know much about such a reactor yet. If one can be made to work, much of the operating cost will be charged off to the production of the fuel, and the power may be provided at reasonable cost.

Enter Private Competition

It is my opinion that the fastest progress toward settlement of these issues will be made if we move toward the design, construction and operation of reactors on a competitive-bid, fixed-price basis, or otherwise utilize the profit incentive. Because of security and safety problems it will not be easy, but I believe that it can be done, if industrial people with the know-how and we in Washington have the will and the ingenuity.

Progress in the atomic energy field has brought both Government and industry to a point where each can see fairly clearly the real nature of the joint Government-industry effort that is required. In some respects only the problems to be solved are clear, but the problems have been identified sufficiently for both the Commission and industry to determine the most effective role each must play. Over the past few years the level of the Government's reservoir of technical knowledge has been substantially raised. In the meantime industry has expanded its competence in the field of atomic energy and begun to see its own role in terms of something more than job contracts.

During recent months the Atomic Energy Commission has received proposals from two industrial groups expressing willingness to bring their technical resources into the atomic energy program on a basis of new and greater responsibility. One proposal is from a group interested in the possibility of building reactors with its own capital and operating them to manufacture plutonium to sell to the AEC and electric power to sell to the industrial market. The other proposal is similar, though concerned principally with initial investigations. The Commission has replied that it welcomes these proposals and is ready to discuss arrangements for the first step, which would be a study of the state of reactor technology by representatives of the interested firms.

The Rocky Road Ahead

Suppose now that either out of AEC laboratories or from industrial contractors there emerges a design of a reactor producing plutonium and yielding electric power as a by-product. Will this finally usher in the atomic era? I am afraid not. The major charges will still be carried by the military need for plutonium. Only if and when civilian power can pay its own way, from the uranium mines to the waste-disposal dump, can it truly be said that the civilian atomic power problem will have been solved. In the meantime we would be less than prudent if we did not take advantage of every opportunity to make the operation of reactors economically practical by increasing emphasis on the use of by-products, whether military or civilian.

Assuming that it is desirable to have greater industrial participation—and by this is meant responsible, cost-reducing, competitive participation—we must anticipate certain serious problems. First and foremost will be the problem of shortage of personnel. A recent examination of the national scientific roster turned up a total of only 350 names of persons who list themselves as mathematical or nuclear physicists. Of these most are engaged in university teaching. So it is not surprising that we count our experienced reactor designers almost on our fingers, and these are committed and overcommitted by the present program. Nothing would cause more disruption than an irresponsible, uncontrolled proselyting of key men. The solution lies in a training program on an expanded scale.

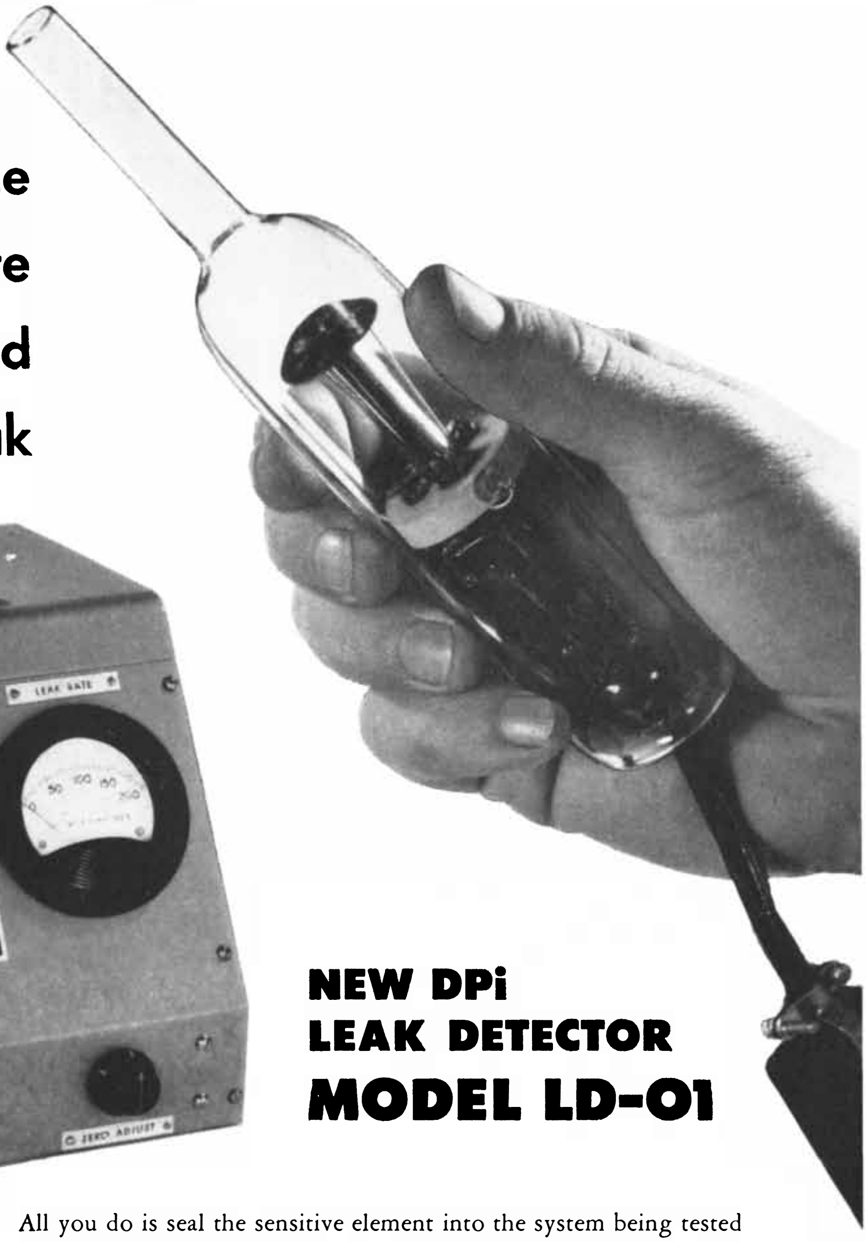
A second very serious problem will be that of unpredictable costs which may be introduced by government decree. These will be mainly in the fields of security, accounting for fissionable material and safety. A third problem is that the Government is reluctant to commit itself to long-term expenditures; yet in a development as ponderous as that of atomic energy, any privately financed industrial approach would have to be based on firm plans for 5, 10 or more years.

Another knotty problem is the question of how to distribute the opportunity to play an active part in this field fairly among the many interested parties. One is reminded of the early days of radio when lawyers argued furiously that each citizen, or group of citizens, had a constitutional right to an equal share of the radio-frequency spectrum. The fact that the extent of the available spectrum was limited by natural law somehow did not seem to register.

Finally, there is the category of legal problems, some of which will require Congressional action. Additional complications may arise from developments in the United Nations concerning an international inspection system for atomic energy.

Lawrence R. Hafstad is Director of the Division of Reactor Development of the U. S. Atomic Energy Commission.

here's a simple device to locate almost any kind of leak



NEW DPi LEAK DETECTOR
MODEL LD-01

All you do is seal the sensitive element into the system being tested and bring the interior a little below atmospheric pressure. Then you direct a small jet of harmless Freon Gas at suspected spots and watch the meter. It's as simple as that, and sensitivity is high enough even where one-millionth of atmospheric pressure is to be maintained.

It works like this: The sensitive element contains a heated platinum anode and a cold cathode with relatively low voltage between them. The tendency of hot platinum to emit positive ions is enormously stimulated by infinitesimal traces of halogens or their compounds. The circuit to accomplish all this uses only three standard radio tubes and operates from your 115-v a-c lighting circuit.

For full information write *Distillation Products Industries,* Vacuum Equipment Department, 751 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

DPi

high vacuum research and engineering

Also . . . high vacuum equipment . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry

Shakespeare The Physicist

A little-known investigation by Sherlock Holmes reveals that the Bard anticipated wireless, relativity and the atomic bomb

by Banesh Hoffmann

I HAVE NOT often known Sherlock Holmes to jest. But Holmes and I have both become more mellow, and a growing humour and warm sentiment have enriched our latter years.

As we lingered over breakfast at our annual reunion last Christmas, Holmes, who had been unusually silent, idly fingered some books that he had brought to the table. I glanced curiously at the titles. "Well, Holmes," I said, "what is the case to be this time?"

"I am afraid, my dear Watson, that I have no case to tell you this Christmas," he replied. And then, seeing my disappointment, he hastened to add, "But I have something just as good."

"Literary research has always attracted me," he continued with a mischievous twinkle in his eye. "For in no other field does the art of detection find such free rein. I am embodying the results of my recent investigations in a little monograph that may have important influence on Shakespearean scholarship. My discoveries suggest the need for a complete revaluation of Shakespeare's works. For they imply that his writings conceal, beneath a cloak of poetry and drama, unparalleled feats of clairvoyance and prognostication."

I was about to protest, but he stilled me with a gesture.

"The first hints of this startling possibility came no more than a few decades ago. With the advent of wireless broadcasting, men began to look for hidden meanings in *The Tempest,* their attention roused by the prophetic name of the character Ariel."

"But the spelling is wrong," I burst out.

Holmes frowned at the interruption. "Surely you are aware that Shakespeare, like other Elizabethans, was notoriously careless in his spelling. . . . Scholars pointed out that the play was full of magical happenings that often bore uncanny resemblance to the modern miracle of wireless; so much so that Ariel might well be the personification of wireless itself. They persisted in their researches and soon came upon a striking passage that they felt could not be easily laughed away.

"I have here Caliban's speech in Act 2, Scene 3 of *The Tempest,* telling of the magic performed by Ariel and Prospero. Permit me to read a little of it:

Be not afeared; the isle is full of noises,
Sounds and sweet airs, that give delight and hurt not.
Sometimes a thousand twangling instruments
Will hum about mine ears, and sometimes voices. . . .

"Why," I cried, "this is extraordinary. It is wireless to the life. A modern could hardly have described it more aptly. Even the announcer is there."

Holmes chuckled and went on: "My own recent discoveries, which are concerned mainly with the *Sonnets,* bring the strongest possible support to the thesis of the early researchers. Listen, for instance, to the beginning of *Sonnet 12:*

When I do count the clock that tells the time
And see the brave day sunk in hideous night. . . .

"It reads like poesy pure and simple. But I shall now point out to you unmistakable indications that these lines refer to Einstein's theory of relativity."

"My dear Holmes!"

"You think it unlikely? Did not Einstein arrive at his theory by rejecting the notion of absolute time? Did he not reason in terms of the behavior of clocks moving relative to one another? Did he not, in the words of Shakespeare, *count the clock that tells the time*? In one small line Shakespeare has packed the essence of the theory of relativity."

"Surely it is rather farfetched," I murmured dubiously.

"Oh, yes. One line alone can easily be dismissed as a coincidence. But once we realize that the sonnet refers to the theory of relativity the significance of the second line is immediately clear. How was Einstein's theory tested? Was it not during a total eclipse of the sun, with *the brave day sunk in hideous night*? If this is still a coincidence it is by now an enormous one."

"Holmes," I laughed. "I am convinced."

"My dear Watson, I have hardly begun to present the evidence. Shakespeare's 64th sonnet describes the present atomic situation so aptly that every line of it can be understood as a message for today."

He paced nervously up and down as I read the following:

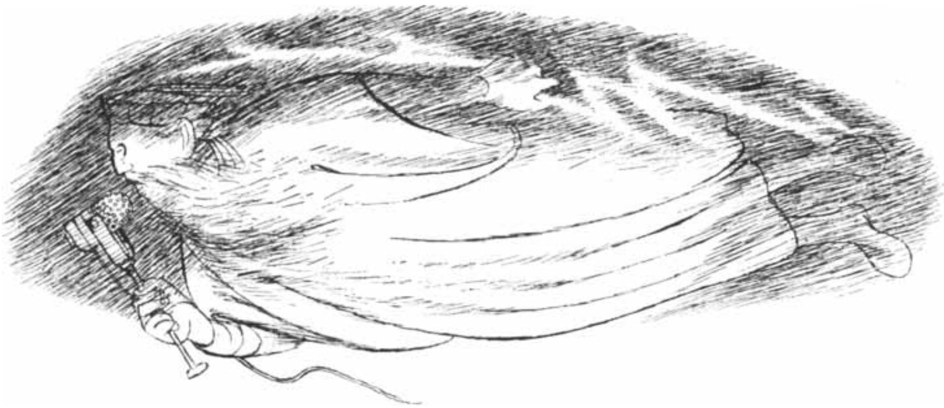
When I have seen by Time's fell hand defaced
The rich proud cost of outworn buried age;
When sometime lofty towers I see down-razed
And brass eternal slave to mortal rage;
When I have seen the hungry ocean gain
Advantage on the kingdom of the shore,
And the firm soil win of the watery main,
Increasing store with loss and loss with store;
When I have seen such interchange of state,
Or state itself confounded to decay;
Ruin hath taught me thus to ruminate,
That Time will come and take my love away.
This thought is as a death, which cannot choose
But weep to have that which it fears to lose.

I was puzzled. "There is nothing here about the atomic bomb. Are you sure this is the one you meant?"

"Certainly. How does it begin?"

When I have seen by Time's fell hand defaced

"Just so. In view of the 12th sonnet we have just discussed, we may take



Prospero

Time to refer to relativity and thus to Einstein's famous equation $E=mc^2$. For the correct continuity we must skip to the third line: *When sometime lofty towers I see down-razed.* These are the steel towers that supported the atomic bomb in the first bomb test in New Mexico in July of 1945. Truly the *lofty towers* were *down-razed* by $E=mc^2$. It is, of course, hardly necessary to add that the word *sometimes* means that the test occurred in the summer time."

"Hardly necessary at all," I murmured.

"How does the second line go?"

The rich proud cost of outworn buried age

"Ah, yes. This seems obscure at first. But only if we do Shakespeare the injustice of assuming that he did not foresee the modern method of estimating the age of the rocks. This is done by examining the by-products of their decaying radioactive constituents. If Shakespeare knew of this, was it not the height of poesy for him to speak of uranium deposits as *outworn buried age*? The *rich proud cost* needs no further explanation. We are all taxpayers. Kindly read the fourth line."

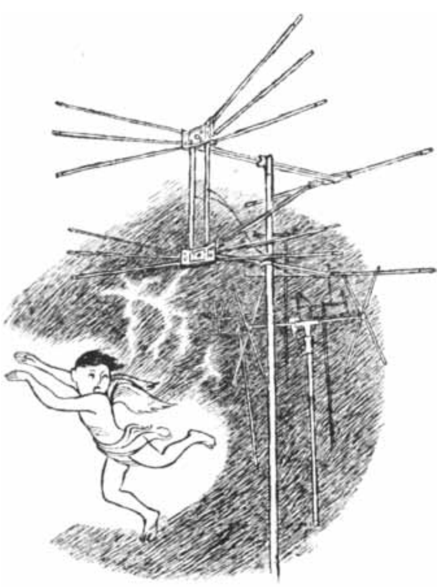
I read the cryptic words: *And brass eternal slave to mortal rage.*

"Now, Watson, this is something recherché. Observe closely. The key to its meaning is the pair of words *slave to*. This is an ingenious contraction, formed by combining two v's into one. Separate them out and we have the phrase *Slav veto,* which refers unmistakably to the behaviour of the Russian delegation to the United Nations. The *Slav veto* is here characterized as *brass eternal* and we are told that it engenders in us *mortal rage.*"

"I am delighted to find Shakespeare on our side in the cold war," I remarked.

"The next three lines are to be taken together," said Holmes.

When I have seen the hungry ocean gain



Ariel

Advantage on the kingdom of the shore,
And the firm soil win of the watery main

"This has to do with the Bikini bomb tests, which sent a shower of radioactive water over the island of Bikini, a *kingdom of the shore* from which the king and his subjects had previously been removed. The island was not obliterated. The *firm soil* won over the *watery main.* You see how admirably it all fits? What is the next line?"

Increasing store with loss and loss with store

"That is an easy one. As you see, it foretells the *increasing store* of atomic bombs in stockpiles, the words *loss and loss* being, of course, an oblique reference to Los Alamos, where the bombs were first designed. I see you are enjoying my little monograph."

"Indeed I am. It is positively delightful. I have never known you more brilliantly entertaining. But how do you explain the next line?"

When I have seen such interchange of state

"Ah. This is one for the specialists. It is a highly technical reference, showing how thoroughly Shakespeare understood the nature of modern atomic theory. Atomic physicists will recognize *interchange of state* as the purest quantum theory. And as if this were not enough indication, Shakespeare goes on, in the following line, to talk of *state itself confounded to decay.* This clearly refers to the radioactive decay of an atom, which is associated with a change in the quantum state of the nucleus.

"The next line, *Ruin hath taught me thus to ruminate,* with its ominous opening word, tells subtly of the hydrogen bomb. For some reason Shakespeare decided to make the reference obscure. Perhaps he was unable to decide whether a hydrogen bomb could be made to work or not. Be that as it may, the reference is definitely there, if one will but look for it. Observe the innocent word *hath.* If we write it *H at H,* it succinctly expresses the idea of hurling hydrogen nuclei at hydrogen nuclei, which is one way of causing nuclear fusion. To explode an H-bomb one needs a fission bomb, and Shakespeare suggests this, too. Split the word *ruminate—rumina* is an almost perfect anagram of uranium, and *te* gives the first and last letters of two hundred and thirty-five, the explosive isotope.

"The next line is a melancholy one:

That Time will come and take my love away.

"Here *love* refers to the American monopoly of the atomic bomb, which was indeed our love. And time has already come and taken it away. *This thought is as a death,* Shakespeare goes on to say. Could one put it more tragically? And what of the final line: *But weep to have that which it fears to lose*? Does it not sum up the awful dilemma of modern man? We do not want the atomic bomb. We should all sleep far more soundly did it not exist. Certainly we weep to have that which we fear to lose."

There was a moment of silence. Holmes reached for another book. "Since we began with *The Tempest,* it is fitting that *The Tempest* have the last word. If you still entertain doubts as to Shakespeare's prophetic powers, ponder this dire prediction of atomic destruction. It is from Act 4, Scene 1:

The cloud-capp'd towers, the gorgeous palaces,
The solemn temples, the great globe itself,
Yea, all which it inherit, shall dissolve
And, like this insubstantial pageant faded,
Leave not a rack behind.

I could not suppress a sigh.

"Cheer up, Watson. Perhaps men will be wise and it will not come to that. Perhaps, after all, Shakespeare is not the prophet I have made him out to be. I trust you have enjoyed my Christmas fable despite its sombre ending. Indeed, I perceive that you have, for you have let your breakfast get cold. Have some warm eggs, Watson."

"Thank you, Holmes. But no more bacon."

Banesh Hoffmann is associate professor of mathematics at Queens College.

Cataclysmic Evolution

Many plants (e.g., wheat, cotton, tobacco) evolved suddenly by a process involving the doubling of chromosomes. The same process is artificially induced to create useful new species

by G. Ledyard Stebbins, Jr.

TWO GRASSES, blue wild rye (*left*) and squirrel-tail grass (*right*), were crossed to produce a hybrid (*center*). The hybrid was sterile, but when its chromosomes had been doubled with colchicine, it became fertile.

AS A RULE the origin of new species is a slow, gradual process. It takes many generations, and sometimes eons of time, for a new kind of organism to arise by the usual evolutionary method of mutation, favorable mating and natural selection. But there is a certain type of evolution in the plant kingdom that telescopes the transformation into one or two steps. In a single generation or two an old species or pair of species suddenly gives rise to a brand-new plant, strikingly different from its parents and capable of breeding true to type in its new form. The occurrence of this cataclysmic type of evolution is by no means uncommon: it was responsible for the origin of cultivated wheat, oats, cotton, tobacco, sugar cane, and probably, in the remote past, of apples, pears, lilacs, willows and many other plants.

The process that causes this abrupt creation of a new species is the accidental doubling of a plant's set of chromosomes. Occasionally, for example, a species of rose that normally has 14 chromosomes may produce an abnormal offspring with 28, or a tobacco species with 24 chromosomes may yield one with 48. Most cases of doubling, however, arise not from such a single species but from hybrids, or crosses between two species. In any case, the double-chromosome descendant is definitely a different plant from the original. It meets the all-important test that marks a truly new species: it can reproduce itself indefinitely, but it cannot mate with the original species, or if it does, the offspring from the mating are sterile.

The story of the discovery and elucidation of this phenomenon, which has given man a tool of great potential usefulness, covers a half-century in time and involves a host of investigators in all parts of the world. Early in this century the Belgian botanists Élias and Émile Marchal, examining certain mosses under the microscope, observed that some of them had double the usual number of chromosomes. At about the same time in England the geneticist R. Ruggles Gates discovered the same curious circumstance in an evening primrose. In Japan Masuto Tahara noticed another interesting fact: in the various species of the chrysanthemum family the chromosome numbers were all multiples of nine—namely, 18, 36, 54, 72 and 90.

What did these facts mean? The first to suggest a plausible answer was Öjvind Winge of Denmark. On the basis of Tahara's series of chrysanthemum chromosome numbers he worked out an ingenious hypothesis. To follow his reasoning we must review some facts concerning chromosomes.

EVERY species of plant or animal has a certain characteristic number of chromosomes in each body cell. When body cells divide, during the growth of a young organism, each new cell receives exactly the same allotment of chromosomes. What happens is that in a dividing cell each chromosome splits into two identical halves—one for each of the two daughter cells.

But sex cells—which in a plant are the pollen and eggs—behave differently from body cells. They are formed by cell divisions of a special kind, called meiosis. In meiotic division the chromosomes do not split; hence the sex cells come to have only half as many chromosomes as the body cells from which they originated. (The full number is restored when a pollen cell and an egg cell unite at fertilization.) During the process of meiosis the chromosomes in the sex cells pair off; each seeks a mate with genes like its own and takes a position beside it. Ordinarily it finds its match from the opposite parent; that is, a chromosome derived from the male parent of the plant mates with a chromosome from the female parent of the plant. In the final meiotic division the mates are separated, one set of chromosomes going to one daughter cell and their mates to the other.

These facts explain why a hybrid between two parents of different species is generally sterile. To form functioning sex cells the chromosomes must find mates that are very like themselves in genetic composition. When two different species are crossed, the chromosomes that the hybrid receives from one parent may differ greatly from those it gets from the other, so that pairing of the chromosomes is difficult or impossible. As a result the meiotic cell divisions are much disturbed, and those sex cells that do emerge have abnormal, disharmonious combinations of chromosomes.

Winge analyzed Tahara's series of chrysanthemum chromosome numbers in the light of this knowledge. Suppose the various species of chrysanthemums had arisen from a single original species by successive doublings of the chromosomes. Then the series of numbers should run 18, 36, 72 and so on. But the actual numbers were 18, 36, 54, 72 and 90. How could a species with 54 chromosomes have been formed? Certainly not by doubling 18 or 36. If it was created by chromosome-doubling, it must have come from a plant with 27 chromosomes.

Now it was easy enough to see how a 27-chromosome chrysanthemum might arise by hybridization. Suppose a chrysanthemum species with 36 chromosomes hybridized with one having 18 chromosomes. The combining egg and pollen cells of the two species would have half the full number of chromosomes, or 18 and 9, respectively. When the two combined, the result would be $18+9=27$, and the hybrid would carry this number of chromosomes in its body cells. This hybrid, as we have seen, would ordinarily be sterile, since its chromosomes would not match. However, Winge suggested, suppose by some accident the hybrid should produce offspring with a doubled set of chromosomes. Then each chromosome would have a duplicate, and they could easily mate. Hence this offspring, with 54 chromosomes, should be fertile.

Winge's ingenious theory suffered from the weakness that, so far as he knew, no sterile hybrid had ever actually been converted into a fertile species by doubling its chromosome number. But soon after he published his hypothesis other botanists pointed out that just such a phenomenon had been observed, although Winge apparently was unaware of it. Miss L. Digby of London University had noticed that a certain sterile hybrid primrose growing in Kew Gardens suddenly became fertile when its usual quota of 18 chromosomes was doubled to 36.

TWO botanists at the University of California, Roy E. Clausen and T. Harper Goodspeed, proceeded to perform a critical experiment which clearly verified Winge's hypothesis. They crossed the cultivated tobacco species (*Nicotiana tabacum*) with a distantly related wild species of tobacco (*Nicotiana glutinosa*). The resulting hybrid was vigorous but almost completely sterile. By means of careful hand-pollination Clausen and Goodspeed managed to obtain a few seeds, from which they raised several second-generation plants.

These plants turned out to be highly fertile, as Winge's theory predicted. But they also furnished a more convincing confirmation. On the basis of the Mendelian laws of heredity, one would expect the plants to resemble one or the other of the original parents—*N. tabacum* or *N. glutinosa.* This is so because in normal Mendelian heredity the parental characteristics are not changed but simply sorted out to the offspring; chromosomes carrying the father's genes pair with those from the mother, and whether a second-generation offspring shows the traits of one or the other depends on the dominance relations in the particular combination of genes. If Winge's hypothesis was correct, however, when a hybrid doubled its chromosomes the two members of a pair would not come from the father and the mother. Both would be derived from a single original chromosome in the hybrid; they would be the two duplicates of this chromosome created when the hybrid doubled its set. Consequently Winge's theory predicted that the second-generation offspring would have traits not just like those of the paternal or maternal species but somewhere between.

This indeed proved to be the case in Clausen's and Goodspeed's tobacco plants. All of them resembled their hybrid parent much more closely than they did either of the original parental spe-

PRIMULA FLORIBUNDA, a species of primrose, has 18 chromosomes in the nucleus of a root cell.

P. VERTICILLATA has 18 chromosomes. Some of them appear to be double because they are dividing.

P. KEWENSIS, hybrid of ***P. floribunda*** and ***P. verticillata,*** also possesses 18 chromosomes. It is sterile.

P. KEWENSIS in which the number of chromosomes has doubled possesses 36 chromosomes. It is fertile.

cies. They differed from the first-generation hybrid chiefly in their more robust appearance and somewhat larger flowers.

Counts of the chromosomes also confirmed the theory. *N. tabacum* has 48 chromosomes in its vegetative (body) cells and 24 in its pollen and egg cells, while *N. glutinosa* has 24 and 12, respectively. Examination of the first-generation hybrids under the microscope showed that their vegetative cells had 36 chromosomes, that is, 24 plus 12. And the fertile new species produced in the second generation had 72 chromosomes in their vegetative cells, as Winge had predicted they would have.

How did the chromosome-doubling occur? From a careful study of chromosome behavior during pollen formation in the first-generation hybrid, Clausen and Goodspeed concluded that the doubling was caused by accidents during the abnormal cell divisions of the sex cells. In short, this tobacco hybrid behaved in every respect as Winge had predicted.

MEANWHILE botanists had accumulated many more facts about chromosome-doubling as a method of plant evolution. Multiple series of chromosome numbers like that in the chrysanthemums had been found in roses, wheats and several other groups of plants. Experimenters had succeeded in doubling the chromosome numbers artificially in tomatoes and nightshades. During the decade from 1925 to 1935, as the phenomenon became widely known, geneticists began to experiment in breeding new plants by this method. The Russian cytologist G. D. Karpechenko synthesized a fertile new species that was a cross between the radish and the cabbage. Unfortunately it combined the worst features of both—it had the harsh leaves of the radish and the tough root of the cabbage—so it was worthless as a vegetable. Other workers in Germany, the U. S., the U.S.S.R. and Sweden produced a true-breeding doubled hybrid of wheat and rye which may eventually be a valuable crop plant. The Swedish geneticist Arne Müntzing, working along this line, is breeding a grain which, it is hoped, will combine the high milling and baking qualities of wheat with the ability of rye to grow in poor soils.

By artificial chromosome-doubling under controlled conditions Müntzing and others have also succeeded in producing some species of plants that already exist in nature; in other words, they have reproduced in the laboratory the natural process of the origin of these species. One of the most interesting cases concerns a certain comparatively new species of marsh grass.

Two old species of marsh grass have long been known. One is *Spartina stricta,* a European plant once widespread along the coasts of northern Europe; the other is an American kind, *Spartina alterniflora.* Early in the 19th century some seeds of the American marsh grass were accidentally brought by transatlantic ships to Bayonne, France, and Southampton, England. In 1870 botanists discovered at Southampton a new type of marsh grass which was intermediate between the European and the American species. Shortly afterward a similar plant was found in France. The new species was named *Spartina townsendii*—Townsend's marsh grass. By 1907 it had become common along the coasts of southern England and northern France. It was then planted artificially in Holland to help support the dikes and keep out the ocean, and has since been used for similar purposes in many parts of the world. Townsend's marsh grass is more vigorous and aggressive than either the European or the American species, and in fact has in many places completely crowded out the original European marsh grass.

Experts on grasses pronounced the new plant a hybrid between the European and the American species, but they were much puzzled by its unhybrid-like behavior: it was rather fertile, producing in some localities a large amount of seed, and plants grown from these seeds bred true to type. In 1931 the Canadian geneticist C. Leonard Huskins found the way out of this dilemma by counting the chromosomes of all three of the species involved. The European marsh grass proved to have 56 chromosomes, the American species 70, and Townsend's 126. The fact that the latter number was the sum of the first two, that Townsend's was first found in the only places where the European and American marsh-grass species had grown together, and that the new plant was fertile, true-breeding and intermediate in appearance—all this added up to convincing evidence that it had sprung from hybridization between the two old species and doubling of the chromosome number.

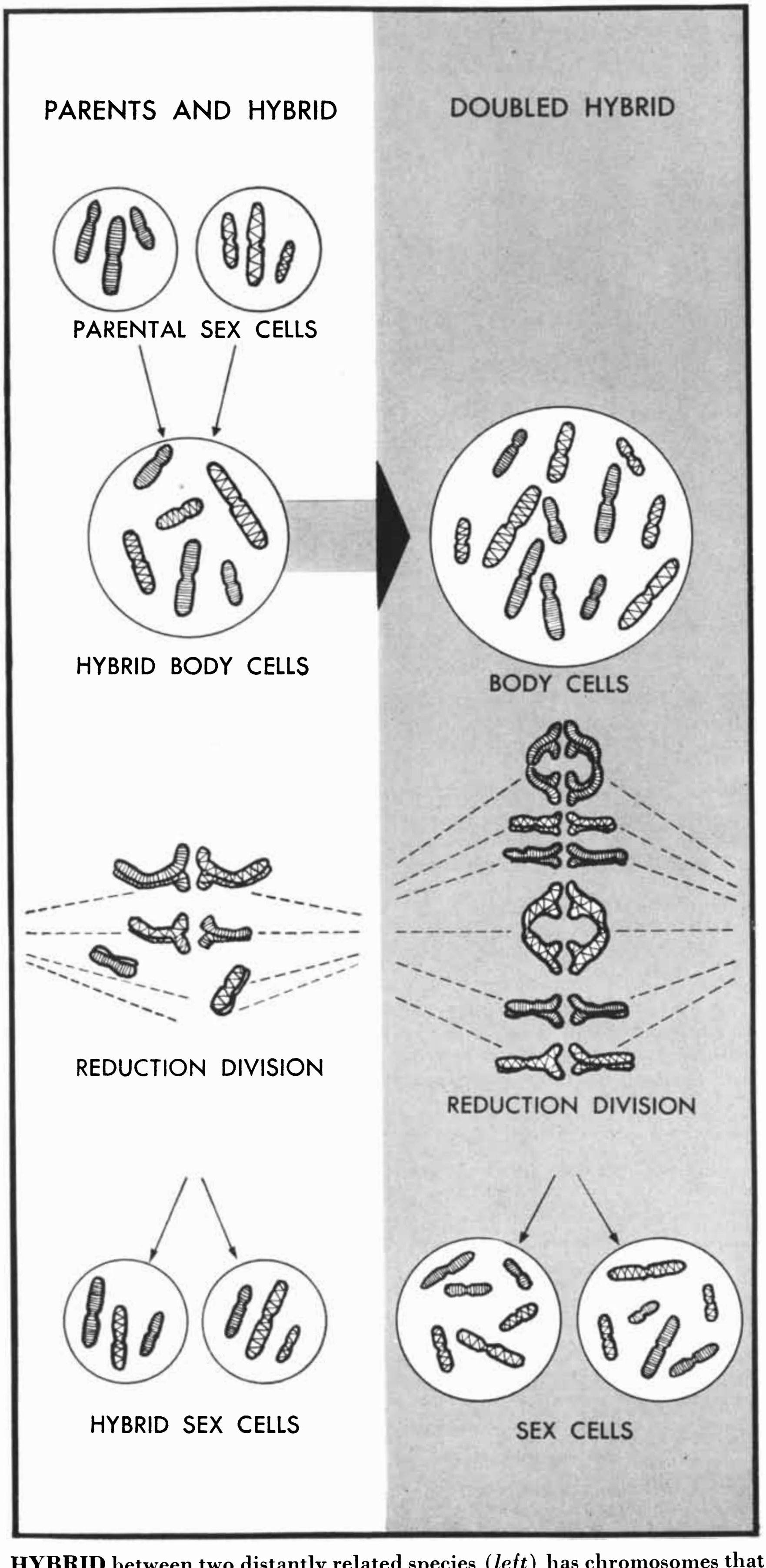
FOR a number of years experiments in chromosome-doubling suffered from the difficulty that there was no sure method for doing it artificially. In 1937 this bottleneck was removed. Albert F. Blakeslee and Amos G. Avery of the Carnegie Institution Laboratory and, independently, Bernard Nebel of the New York Agricultural Experiment Station found that colchicine could perform the trick. Colchicine is an alkaloid derived from the roots of the autumn crocus. When applied in very weak concentrations to dividing cells, colchicine permits the division of the chromosomes but prevents the separation of the daughter chromosomes to opposite poles of the mitotic spindle. This effectively blocks the completion of cell division and produces cells with twice the normal number of chromosomes. The concentration of colchicine and the method of treatment vary considerably according to the plant being treated. Through the work of scores of investigators in many countries a great variety of plant species have now been converted into new forms with this drug.

When a nonhybrid plant of some well-established species such as corn, tomatoes or snapdragons has its chromosome number doubled, the new plant differs from its undoubled progenitor in certain definite characteristics. It usually has thicker leaves and stems; its flowers are generally larger and have firmer petals; its seeds are larger. It grows more slowly and therefore usually blooms and sets fruit later. Most important, it is likely to be more or less sterile. For this reason chromosome-doubling of nonhybrid plants is of little practical value for grains, in which the seeds are harvested, though it has given us useful varieties of certain leaf crops such as clover and of snapdragons and other garden flowers.

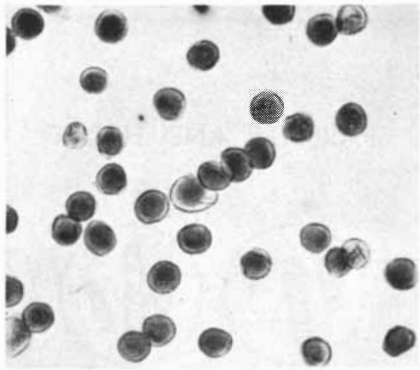
It is in the treatment of hybrid plants that colchicine has been most useful. Investigators have employed the technique for two purposes: 1) to study the evolutionary ancestry of plant species, and 2) to produce new species which may be of value to man. In the first category some striking results have already been obtained. One of the most interesting has to do with the origin of wheat.

About 1920 T. Sakamura in Japan and Karl Sax at Harvard University independently discovered that the cultivated wheats include species with three different chromosome numbers. The primitive, small-grained "einkorn" wheat of southeastern Europe and southwestern Asia has only 14 chromosomes in its vegetative cells. The "emmer" wheats, grown in northern Europe and the northern U. S. as stock feed, have 28 chromosomes. The bread wheats have 42 chromosomes. Both botanical and archaeological evidence points to the 14-chromosome wheats as the oldest and most primitive and the 42-chromosome species as the most recent. Furthermore, the behavior of the chromosomes suggests that the 28- and 42-chromosome groups originated as doubled hybrids from species having lower chromosome numbers.

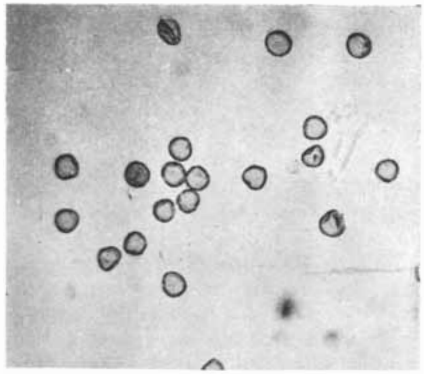
At about the time that Sakamura and Sax made this discovery the British wheat expert John Percival put forward the bold hypothesis that the bread wheats originated from hybridization between emmer wheats and goat grass, a common weed which often grows around the edges of wheat fields in the Mediterranean region. After colchicine became available, several cytologists undertook to test Percival's theory by experiment. From emmer wheat and a particular species of goat grass named



HYBRID between two distantly related species (*left*) has chromosomes that cannot work harmoniously in reproduction. If the chromosomes of the same hybrid double (*right*), the duplicate chromosomes work harmoniously.



BLUE WILD RYE (*see photograph on page 54*) has pollen grains that are plump and filled with material.



HYBRID between blue wild rye and squirrel-tail grass has pollen grains that are empty and without function.

Aegilops squarrosa, E. S. McFadden and Ernest Sears of the U. S. Department of Agriculture and Hitoshi Kihara of Japan produced doubled hybrids which looked very much like primitive forms of bread wheats. Furthermore, they passed the acid genetic test: hybrids between them and bread wheats were fertile and had normal chromosome behavior. This is proof that the bread wheats actually arose from hybrids between emmer wheats and *Aegilops squarrosa.* This goat grass grows in the region of the ancient Babylonian civilizations where the bread wheats are believed to have originated.

The remarkable fact about the wheat story is that the combination of chromosomes of a moderately useful plant, emmer wheat, and those of a completely useless and noxious weed produced the world's most valuable crop plant. This example should tell us that we cannot always predict in advance whether a particular hybrid will be worthless or a priceless new addition.

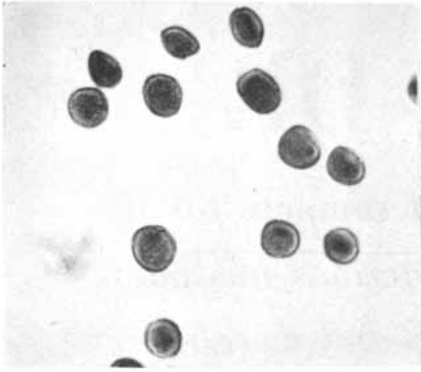
THE STORY of the cataclysmic evolution of other plants, notably cotton, has been worked out in a similar manner. Thanks to the experimental method made possible by colchicine, the origin of these doubled hybrids can be established with greater certainty than can any other process of evolution. Moreover, this method enables us to reconstruct the beginnings of plants that are not well represented in the fossil record, and to work out the distribution of plant species in past geological ages when conditions were very different from what they are now.

A striking example of such a deduction concerns the blue-flag iris of the northeastern U. S. (*Iris versicolor*). Edgar Anderson of the Missouri Botanical Garden proved that this species, which has 108 chromosomes, is a doubled hybrid derived from a blue-flag iris of the Mississippi Valley (72 chromosomes) and an arctic iris found in central Alaska (36 chromosomes). This means that the two parent irises, now widely separated, must once have lived close together. During the last ice age, when glaciers covered the northern end of the Mississippi Valley, there must have been many areas directly south of the ice sheet in which conditions were not very different from those that now prevail in central Alaska. The Alaskan iris could have grown together with the Mississippi Valley species in those areas, and the blue-flag iris of the northeastern states probably originated there. When the ice retreated, the new species was better adapted to occupy the newly opened regions than either of its parental species. At present this northeastern blue flag is the only common one in the formerly glaciated areas.

A similar origin has been demonstrated for the small cranberry, which appears to be a doubled hybrid between the large cranberry of the eastern states and a small-berried species found in the Rocky Mountains, Alaska and Eurasia.

In the case of cotton and some members of the grass family, the original parents or nearest relatives are now so widely separated that they do not even occupy the same continents. For example, of the two parental species that gave birth to a common brome grass of the western U. S. one is now confined to North America and the other is strictly South American. It must be assumed that the South American species once existed in North America also. This assumption is supported by fossil evidence concerning some of the grasses. Maxim Elias of the Nebraska Geological Survey has found a large number of fossilized grass seeds in the North American plains in strata apparently 5 to 25 million years old. Some of these fossils are closely similar to the seeds of grasses belonging to a genus now abundant on the pampas of Uruguay and Argentina but almost absent from North America.

There are two species of rice grass in the woodlands of eastern North America which are doubled hybrids that came from parents now separated by thousands of miles of ocean: one parent today is found only in North America and the other in eastern Asia. Evidently certain species of rice grass now con-



SAME HYBRID in which the number of chromosomes has been doubled has normal, functional pollen grains.

fined to Eurasia once existed in North America. Evidence from fossils has shown the same to be true of various species of forest trees.

The use of doubled hybrids as keys to past distribution patterns is still in its infancy, but the results obtained to date show that here is a really powerful tool for obtaining new evidence to unravel the past.

Up to the present the principal interest in doubled hybrids has been scientific rather than practical. But their practical possibilities have already been recognized in such work as the combination of wheat and rye to produce a hardier grain and in other projects. Doubled hybrids involving bread wheat and certain wild species of wheat and related grasses are serving as bridges by means of which certain particular characteristics, such as disease resistance, can be transferred from these wild species to bread wheat. Similarly, through doubled hybrids genes for resistance to the tobacco-mosaic disease have been transferred from useless wild species to valuable cultivated varieties of tobacco. This method of obtaining disease-resistant varieties of crop plants can be widely used.

Beyond this, botanists may be able to combine in one doubled hybrid the valuable qualities of two or more wild plants now useless by themselves, and so create new species of value to man. This is particularly true in the case of forage plants, where vigor of growth and adaptability to a variety of environmental conditions are more important than the quality of the product. Many wild plants that grow in very dry or very cold habitats originated as natural doubled hybrids. Increased knowledge of species of this type should make it possible for plant breeders to synthesize useful plants that can thrive in these severe conditions.

G. Ledyard Stebbins, Jr., is professor of genetics at the University of California.

THE IMITATIVE DRUGS

The fact that a counterfeit molecule will compete for the place of a natural one in biochemical reactions has made possible a rewarding study of drug action and metabolism

by Richard O. Roblin, Jr.

SINCE the days of Paul Ehrlich, whose discovery of "606" in 1909 was the beginning of modern chemotherapy, chemists and biologists have been intrigued and baffled by the problem of explaining how drugs exert their therapeutic effects. It is now generally agreed that many of them act by interfering with the normal metabolism of cells. The fascinating ways in which they do so, and the light that these discoveries have shed on the processes by which cells normally grow and reproduce, are the subject of this article.

It was a brilliant investigation by two workers at Cambridge University in England that started biochemists on this fruitful track. Paul Fildes and D. D. Woods were members of a school of biochemistry at Cambridge which, under the stimulus of the late Marjorie Stephenson, had devoted itself to studying metabolism in bacteria. In the late 1930s Fildes and Woods set out to try to explain, in terms of bacterial metabolism, how the new sulfa drugs worked.

It had been observed that in the test tube sulfanilamide was less effective against bacteria in some culture media than in others. Certain media appeared to contain a substance that interfered with the antibacterial action of the drug. In 1940 Woods located this substance in an extract from yeast cells. He found that the extract could check the action of sulfanilamide against bacteria if its concentration in the medium was increased in proportion to the increase in the drug.

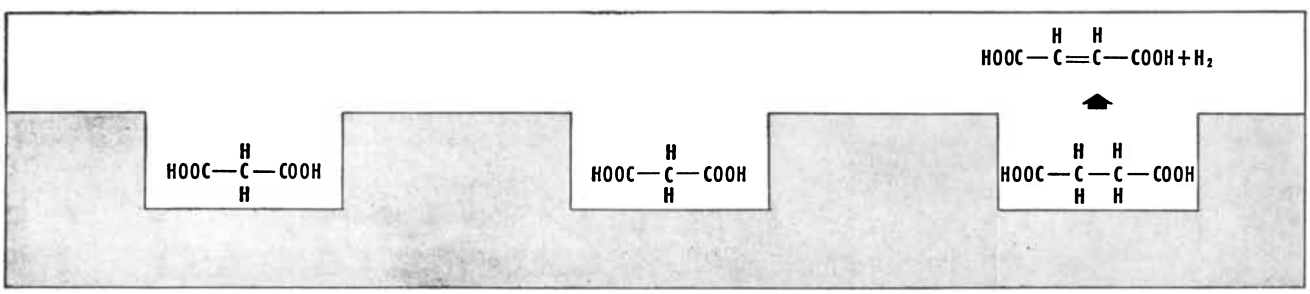
What seemed to be going on was a kind of competition between the substance in the yeast extract (*i.e.*, a food element) and the drug. The more drug was added, the more food was needed to counteract it. By some chemical legerdemain the sulfanilamide appeared able to deprive bacterial cells of this food substance and starve them to death. Only when extra amounts of the substance were supplied in the medium did the bacteria have a fair chance to survive.

This sort of phenomenon was not altogether unknown in biochemistry. Something very like it had long been observed in the study of enzymes, the catalysts that assist cell metabolism. There is a certain enzyme, for example, that removes two hydrogen atoms from succinic acid and converts it to fumaric acid—a reaction important in the respiration of plant and animal cells. The enzyme has on its surface active centers, or "hot spots," which specifically attract succinic acid molecules. The centers are not so specific, however, that they cannot attract very similar molecules, such as malonic acid, whose essential difference from succinic acid is that it has one less carbon atom. But malonic acid spoils the party. It cannot be converted to fumaric acid, so no reaction occurs when it occupies a hot spot on the enzyme. Furthermore, its occupancy of this spot blocks any succinic molecule from taking it. When a mixture contains succinic and malonic acid molecules, both compete for the hot spots on the enzyme. In this game of musical chairs malonic acid interferes with the conversion of succinic acid to fumaric acid in proportion to its relative concentration in the mixture. It is, in other words, an antagonist to the metabolite, succinic acid.

NOW this situation involves only a single isolated enzyme. Woods was dealing with living cells, which are much more complex: in them metabolism is actuated by whole systems of enzymes working in concert. But it seemed probable that the metabolism of a living cell could also be disturbed by the same process. If some antagonist blocked the action of one enzyme in the enzyme complex, it might retard the cell's metabolism.

The antagonist in this case was sulfanilamide. Woods' problem was to identify the metabolite, presumably very similar to sulfanilamide in chemical structure. This substance was already partly isolated in his yeast extract. He set out to determine which component in the extract was the active factor. The very first substance he tried, para-aminobenzoic acid, proved to be the correct one. Para-aminobenzoic acid is now known to be a constituent of the vitamin folic acid. And sulfanilamide is very closely related to it in every respect, including its chemical name—para-aminobenzenesulfonamide. Woods concluded that the antibacterial action of the drug was based on the fact that it acted as a competitor and antagonist to para-aminobenzoic acid in the organisms' metabolism.

At first Woods' ideas were received with considerable skepticism, because



ENZYME MOLECULE (*depicted in gray tone*) normally acts on succinic acid (*lower right*). Malonic acid, which chemically resembles succinic acid, combines with enzyme but no reaction occurs (*left and center*).

para-aminobenzoic acid was not then recognized as a vitamin and no bacteria were known which required it for growth. This situation was soon remedied, however, by experiments which proved that several strains of bacteria were unable to grow in its absence. When, several years later, para-aminobenzoic acid was shown to be a part of the folic acid molecule, the picture was complete. It is now generally recognized that the sulfa drugs exert their antibacterial action by preventing the functioning of the enzyme responsible for the incorporation of para-aminobenzoic acid into the folic acid molecule. That is, the sulfa drugs prevent the bacteria from making the folic acid they require for normal growth and reproduction.

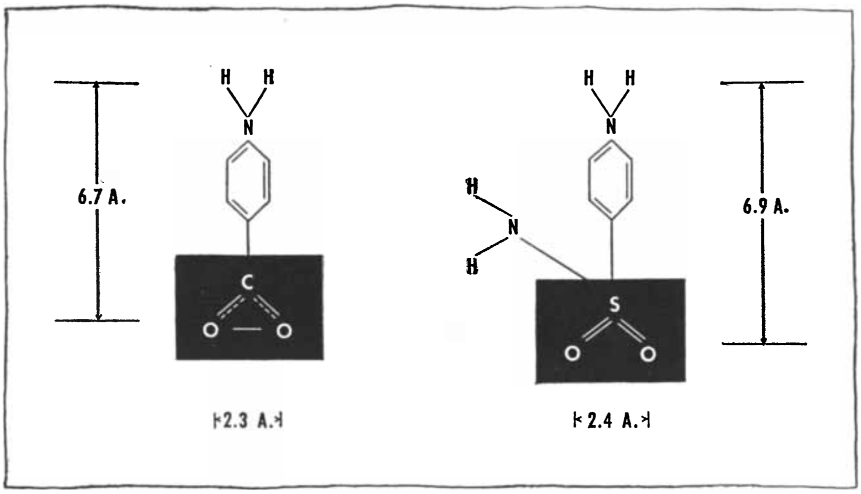
There are a few strains of bacteria that do not synthesize folic acid themselves; they must find this vital nutrient ready-made in their food. In these cases, as one might anticipate, the bacteria are unaffected by the sulfa drugs. It is fortunate that the bacteria which are incapable of making their own folic acid from para-aminobenzoic acid are few and harmless; otherwise, the sulfa drugs would be of little practical value in the treatment of bacterial infections.

One might reasonably ask at this point: If the sulfa drugs prevent the production of folic acid, why do not patients who take the drugs suffer a deficiency of this vitamin? The explanation seems to lie in the fact that animals, including man, are unable to make their own folic acid but obtain it from the foods they eat. Like the few harmless bacteria, they are not affected by the blocking action of the sulfa drugs on metabolism.

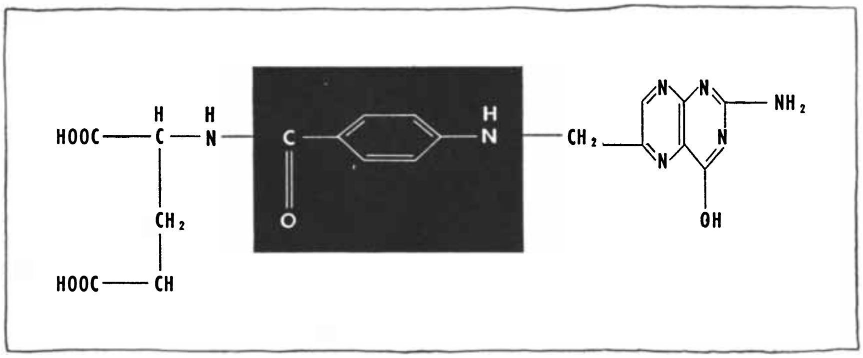
WHILE Woods was concentrating on a solution of the problem of how the sulfa drugs act, Fildes visualized some of the broader implications of Woods' findings. He suggested that it might be possible to design new drugs to order by synthesizing substances closely related to important metabolites, such as the B vitamins. Up to that time the search for new antibacterial agents had been on a purely empirical basis. Many investigators were attracted to the more rational approach suggested by Fildes. It was, however, easier said than done.

Workers in this country and Europe uncovered a number of antagonists to metabolites. Substances chemically related to the B vitamin pantothenic acid were found to prevent the growth of certain bacteria and to cure a fatal streptococcic infection in rats. But compared with the sulfa drugs, the pantothenic acid antagonists were not particularly useful, for they prevented the growth of only a few types of the important disease-producing bacteria.

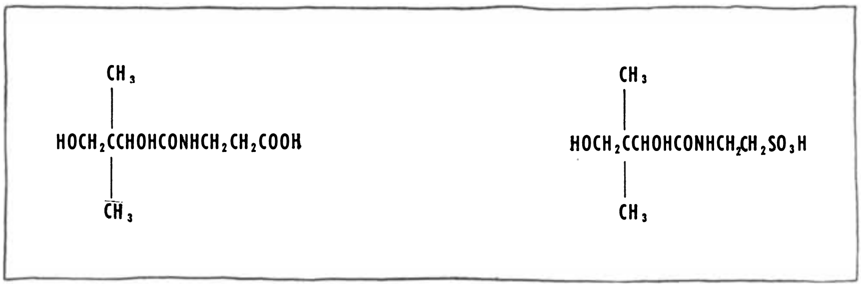
This investigation disclosed a new wrinkle that had not been anticipated.



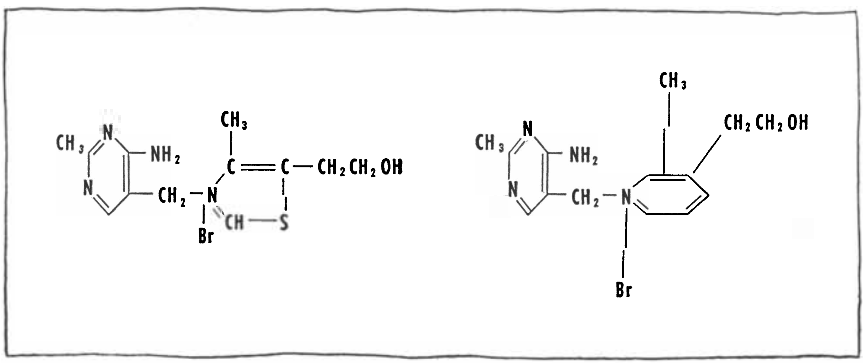
PARA-AMINOBENZOIC ACID (*left*), a natural product, and sulfanilamide (*right*), a synthetic drug, so closely resemble each other that they compete.



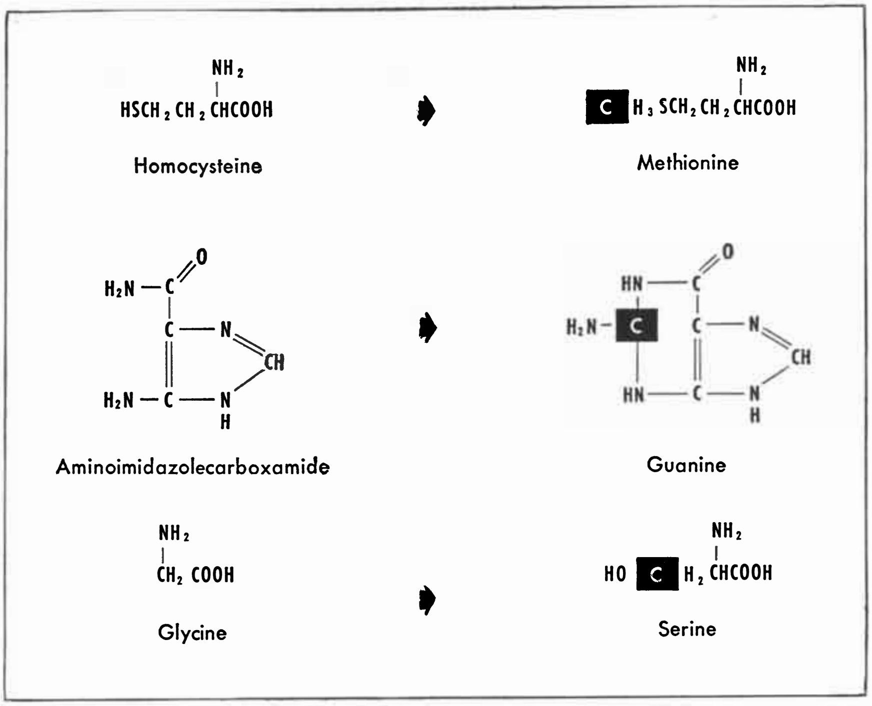
FOLIC ACID is needed by all bacteria and made by most. Sulfa drugs interfere with process incorporating para-aminobenzoic acid radical (*rectangle*).



PANTOTHENIC ACID (*left*) has a structural analogue in pantoyltaurine (*right*). These two substances are also antagonists in bacterial metabolism.



THIAMINE (*left*) is required for bacterial growth. Its antagonist pyrithiamine (*right*) prevents growth of those bacteria that cannot make their own.



THREE METABOLITES (*right*) **plus thymine can replace para-aminobenzoic acid. They may thus be regarded as the products of reactions requiring para-aminobenzoic or folic acid. Each reaction adds one carbon atom (*black*).**

In the case of the sulfa drugs all bacteria, whether or not they produced their own para-aminobenzoic acid, were susceptible to the drugs as long as they were able to make folic acid. In the case of the pantothenic acid antagonists, however, only the bacteria unable to make pantothenic acid for themselves were affected. Apparently those that synthesized their own vitamin utilized it in such a way that the enzyme involved was not vulnerable to inhibition. Vitamin B_1, the beriberi vitamin, was later found to follow the same pattern. Only bacteria that required an outside source of the vitamin were inhibited in growth by a specific antagonist. When it was given to animals, which also require an outside source of the vitamin, the antagonist produced a vitamin deficiency which was soon fatal unless the animals were fed extra rations of vitamin B_1.

Thus, as is so frequently the case, Nature proved to be more subtle than man had anticipated. She had several unsuspected road blocks erected in the way of a rational approach to the synthesis of new chemotherapeutic agents. Another of these blocks was encountered in studies of antagonists of the amino acids, those important building stones of the cell proteins. One of these antagonists was a substance called methoxinine, closely related to the amino acid methionine. As in the case of antagonists to the vitamins, methoxinine prevented the growth of various bacteria in a synthetic medium, and the addition of an excess of methionine to the medium allowed the organisms to grow normally. But a simple calculation showed that overwhelmingly large amounts of methoxinine would be required to produce any effect on the growth of bacteria in the body, which normally has an excess of methionine.

HENCE the investigation of metabolite antagonists has not yet led directly to the development of new therapeutic agents of much practical importance. As new metabolites are found, however, the study of their antagonists may well yield new and powerful drugs. In the meantime, the metabolite antagonists have proved of great value in other directions, particularly in tracing the course of complex metabolic processes.

One of the substances that has been most effectively studied in this way is folic acid. This vitamin is very useful in the treatment of many secondary anemias. Why does the body need it, and how does it normally use it? An investigation employing the sulfa drugs as a tool has supplied part of the answer.

Before the discovery of para-aminobenzoic acid, it was known that the antibacterial action of the sulfa drugs could be overcome to a limited degree by several other substances, including the amino acids methionine and serine, some purines such as guanine, and a substance called thymine. These substances are not chemical competitors of the sulfa drugs as is para-aminobenzoic acid; they have no chemical resemblance to the drugs. Individually they appear to prevent the antibacterial action of the sulfa drugs over a relatively narrow range of concentrations; collectively they can do so over a wide range of concentrations. Investigations established that if bacteria are provided with all these factors, they can grow without the para-aminobenzoic acid or folic acid that normally must be supplied in their food. Ordinarily folic acid is essential for the synthesis of these amino acids and purines. But if all of them are supplied preformed, the cells of course no longer have any need for folic acid.

Another interesting finding developed from the discovery of a mysterious substance that accumulated in cultures of bacteria containing sulfa drugs. This substance was not found in sulfa-free cultures. It was identified as amino-imidazolecarboxamide. It looked very much as if the material were an intermediate substance that was stopped short of conversion to the final product because of the presence of sulfanilamide. The addition of one more carbon atom to the molecule could result in the production of a purine such as guanine. This observation suggested that folic acid is required to catalyze this particular step in the manufacture of guanine by living cells; when the formation of folic acid is blocked by the presence of a sulfa drug in the culture medium, this step cannot be completed and the unfinished intermediate substance accumulates in the medium. An examination of the widely different reactions catalyzed by the folic acid-containing enzyme indicates that they have one feature in common: all involve the addition of one carbon atom to the intermediate.

THE accumulation of so much information about the functions of folic acid in such a relatively short time would hardly have been possible without the help of the sulfa drugs. Similar studies with other antagonists have greatly increased our knowledge about the functions of other cell catalysts. Thus the discovery of the mechanism of action of the sulfa drugs has provided new tools for the investigation of some of the fundamental reactions by which cells grow and reproduce. The subtle and specific manner in which metabolite antagonists block one particular reaction makes them especially valuable for studies in living cells.

As is frequently the case in biochemistry, a few isolated observations on a particular problem (the action of drugs) have led to the development of a more general concept with implications far beyond the original objectives. A better understanding of the function of various metabolites may in turn lead to the discovery of more useful new drugs, and so complete the cycle.

Richard O. Roblin, Jr., is Director of the Chemotherapy Division in the Stamford Research Laboratories of the American Cyanamid Company.

THE SQUID

Largest, fastest, most vicious and probably most beautiful of the animals without backbones, it possesses a nervous system that is uniquely useful to the modern physiologist

by H. B. Steinbach

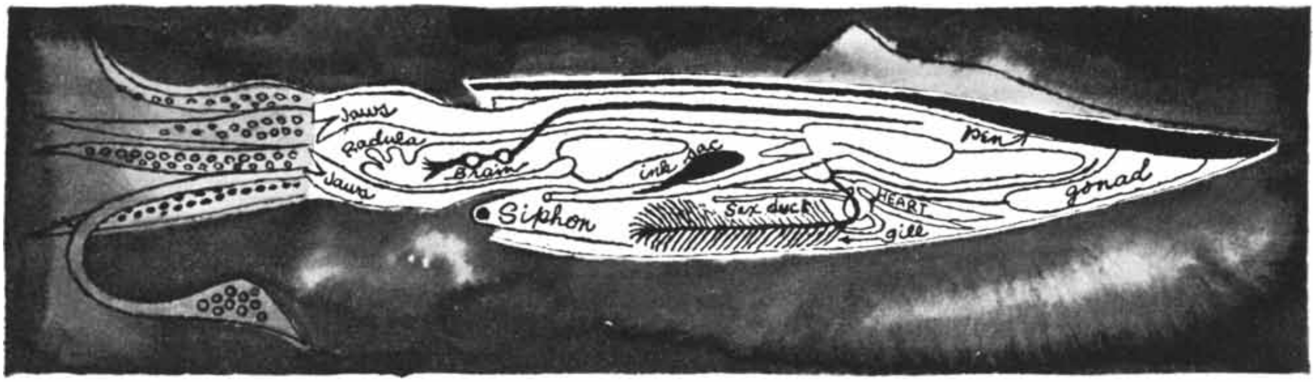
SQUID are an animal prototype of modern jet-propelled instruments of destruction. They are the largest, fastest, most vicious and probably the most beautiful of all animals without backbones. Closely related to the quiet and peaceful clam, oyster and snail, the squid has managed during long periods of evolution to modify the basic body features of the mollusk make-up to attain a speed and activity never possible for its sluggish relatives. Squid have copied the more masterful vertebrates in the details most calculated to promote the destructive aspects of the struggle for existence. Functionally streamlined with a backbone type of supporting skeleton, they have accurate vision and rapid control of body movements, remarkable tearing and rending devices and no signs of a conscience.

In recent years these animals have become scientific news-makers because of their extraordinary nervous system. They gain their speed of action and reaction from the fact that they have comparatively thick nerve fibers, conducting nerve impulses rapidly. Vertebrates have developed fast nerves by a different device: an insulating coat around the delicate nerve fiber. This is a perfectly sound method of speeding the passage of nerve impulses, but it makes the nerve most inconvenient to study. A nerve fiber in man is only a few thousandths of a millimeter in diameter, and a two-inch length weighs about a hundred thousandth of a gram (a paper match weighs a tenth of a gram). Squid, on the other hand, have some nerve axones nearly a millimeter in diameter, and a two-inch length weighs several hundredths of a gram—enough to do a lot of chemistry with.

Squid have been known under a variety of names for as long as there is a written history of biology. They are still sometimes called calamaries, from the Latin word for pen, because the skeletal structure simulating the vertebrate backbone resembles an old-fashioned penholder. Of crustacean flavor but tougher in texture, they are eaten in a variety of dishes and are a favorite bait of many fishermen. Some squid have delicate arrays of luminous organs; all show fascinating color changes. In size squid range from creatures only a few inches long to the giants of the deep waters.

THE giant squid, which dwarfs the octopus, is a direct relative of the mythical sea monsters. The long tentacles of a 50-foot squid resting on the surface of the ocean, mixed with a little imagination and fear, certainly give basis for many of the stories of sea serpents. But stories of the giant squid are far more numerous and exciting than are authentic records of them. Lack of recent information regarding the largest giants may relate to the decline of the whaling industry. Giant squid are known to live in deep cold waters and to be a favorite food for whales. When whales were plentiful off our shores, giant squid were reported frequently; the presumption is that they were seen more often then because the whales chased them to the surface.

From an old scientific report one can conclude that a respectably large giant would be 55 feet long, including its tentacles. The body itself, according to this report, is 20 feet long and 12 feet in circumference. The giant's eyes are ovals six inches by nine inches. Its horny, parrotlike beak has jaws five inches long. These data were assembled from measurements of incomplete specimens brought in by fishermen. Not long ago a special expedition to the Humboldt Current off South American shores managed to land with rod and reel some in-



INTERNAL ORGANS of the squid are contained in a muscular mantle. When the mantle contracts, water squirts from the siphon at lower left center and the squid moves in the opposite direction. The mouth of the squid is surrounded by tentacles. Where the octopus has eight tentacles, the squid has 10: eight short and two long.

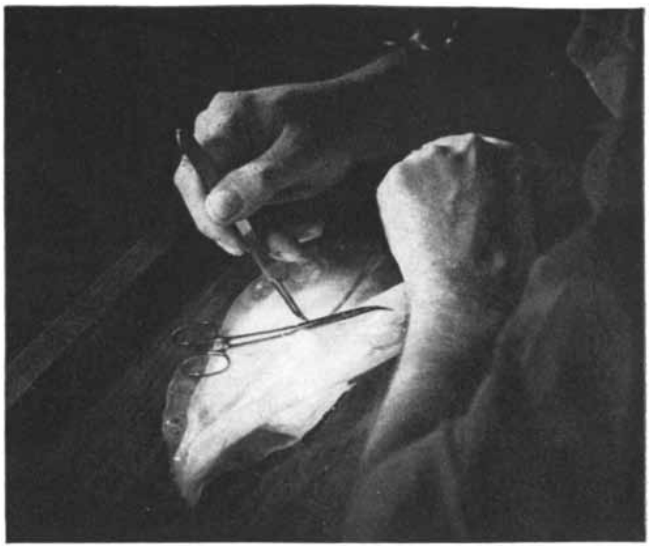
tact giant squid somewhat smaller than these. They were some nine feet long and weighed more than 100 pounds. Their tough beaks bit through piano-wire leaders used as tackle, and their supply of black ink bathed the fishing boat in slimy fluid.

Norwegian fishermen used to tell many tales of the giant kraken. Allowing for a certain amount of pardonable Norwegian fancy, the more conservative accounts of this animal, coupled with the known geographical distribution of giant squids, make it probable that the kraken was actually a squid. One story relates that the Bishop of Nidaros, wishing to conduct a seaside service, mistook the back of a sleeping kraken for a rock. He erected his altar on it and proceeded with his sermon. The kraken, awaking, was so impressed with the Bishop's eloquence that he stayed quiet until the close of the services. The good man then dismounted his altar and the kraken swam gently out to sea. Other stories tell of kraken with backs rising as high as a ship out of the sea. A variation of the story is that fishermen sometimes found the water only 20 to 30 fathoms deep in places where they expected to find 80 to 100 fathoms; deducing that the kraken was sleeping on the bottom beneath them, they would stay and fish until the water became less shallow, which was a sign that the kraken was rising toward the surface and the time had come to row rapidly for the safety of the shore.

SQUID belong to the division of mollusks known as cephalopods—the "head-footed" animals. Their arms and tentacles protrude from the head (most of which is really the foot to the zoologist) at the forward end of the animal. An octopus has eight arms; the squid has 10—eight muscular arms and two longer tentacles. The arms and tentacles are all equipped with suckers, sometimes bearing serrated rasping edges. Within its pharynx the squid carries another aid to the destruction of prey: the radula. This consists of a flexible file-like device that can be thrust against the body of the victim and pulled back and forth like an oscillating ditch digger. Usually, however, the squid simply bites into prey with its sharp jaws and cuts out wedge-shaped portions of flesh to be swallowed whole.

A narrow neck connects the head with the long, arrow-shaped body, designed for high speed. The main bulk of the body is a large mantle cavity surrounded by the muscular outer wall. This cavity, not comparable to the body cavity of vertebrates, constitutes the pressure chamber for the jet-propulsion of the animal. Its outlet is through a short muscular tube in the neck called the siphon. The muscular mantle, contracting strongly on the cavity full of water, can

GIANT SQUID reach a length of more than 50 feet. This illustration, adapted from an old engraving, shows a scene that is thought to have been more common when whales were sufficiently numerous to chase squid to the surface.



GIANT AXONE is dissected out of a squid. At left the mantle of the squid is cut open; the tentacles have been removed. In center the mantle is opened and a strip containing the axone cut away. At right the ends of the strip

squirt a strong stream out through the siphon. According to Newton's third law of motion, when the siphon squirts in one direction the squid will zoom in the opposite direction. The siphon can be bent backward or forward at will, so the animal swims equally well forward or backward. To change direction completely requires only a slight movement of the relatively small siphon. Hence trying to catch a squid by hand even in a tank somewhat resembles the pursuit of a flight of fancy by a poet.

Within the mantle cavity is the usual quota of visceral organs. Near the anal end of the digestive tract, just back of the siphon, is a special ink sac which secretes a thick, black, gummy fluid that can be ejected into the mantle fluid and thence out in a thick cloud into the ocean. This constitutes a fine smoke screen, and the ink may also be toxic to some forms of prey. When stalking food the squid holds its arms close together and extended forward, using them as a rudder. As it darts at its prey, the arms suddenly reach out in a writhing deadly circlet. It is uncanny to watch the care and skill with which a squid can stalk another animal, and chilling to see the speed with which the attack is finally launched.

Within the skin of the squid are the structures responsible for its colorful and mobile beauty. These consist of many sacs of pigment, chromatophores, in three basic colors—red, brown and yellow. Each sac is equipped with strands of muscle fibers. When the fibers contract, they spread the sac and show the color; when they relax, the pigment is concentrated to a fine point and the color practically disappears. A very slight disturbance, such as shadows moving across the eyes, can cause the squid to change color rapidly. When seriously disturbed or chasing one of the opposite sex, the common squid genus named *Loligo* alternately glows red and pale white, with a whole gamut of intermediate shades and variations.

The sexual behavior of the squid is enthusiastic and complicated. It was the indefatigable Aristotle who first studied and reported on the sex life of this animal. The mating process is hard to follow in detail because of the speed of movement of the animals. The male, after an elaborate and lusty courtship, seizes the female with his arms and, with a graceful motion of a tentacle, produces a packet of spermatophores from his mantle cavity. He deposits these in a buccal pouch just below the female's mouth or, sometimes, thrusts them far back into her mantle cavity. The spermatophores are marvelous little structures whose action is not well understood. In essence they are sacs filled with sperm, and each sac has a neck with a triggerlike device at the orifice. Inside the neck is a perfectly formed coil that looks like the spring of an air gun. Pressure on the trigger causes the discharge of the sperm.

WHILE squid have many unique features worthy of close study, it is on the internal nervous system that current scientific attention is focused. This system consists roughly of the brain, a series of ganglia in the head region connected by nerve fibers to paired, star-shaped ganglia in the fore part of the mantle, and various nerves leading to and from these regions.

It was the zoologist L. W. Williams, of Harvard University, who first noted in 1909 the giant size of the squid's nerve cells and fibers. He remarked: "The very size of the nerve processes has prevented their discovery, since it is well-nigh impossible to believe that such a large structure can be a nerve fiber." Perhaps no one really did believe it. At any rate, no further attention was paid to the giant nerve fibers of the squid until they were redescribed with more precision and detail in 1933 by J. Z. Young of Oxford University. Young recognized the great potential value of these structures to workers in physiology. For many years physiological, chemical and electrical investigations had been carried out on ordinary nerves, but their small size was a serious handicap. Here in the squid were fibers so large that they could be dissected free from connective tissue and small fibers. Protoplasm could be studied in pure form and nerve membrane investigated directly.

The squid usually used for laboratory work are those of the common *Loligo* genus, a variety ranging from a few inches to a couple of feet in length which is fairly plentiful in the waters near the Marine Biological Laboratory at Woods Hole, Mass. There is a stretch of nerve fiber from the star-shaped ganglia to the muscles of the mantle that is particularly easy to work with and is therefore used as the standard experimental material. This stretch of whole nerve can be tied at either end, cut loose and lifted to a tray on a dissecting microscope for isolation of the single giant axone. The common squid has a single axone per nerve; the northern squid has several smaller ones.

After small fibers and connective tissue are stripped from the giant axone, the structure can be seen clearly with the naked eye as a nearly transparent, turgid cylinder about the size of a small pencil lead. It may be used at once for electrical measurements, chemical analyses and so on or may be placed in sea water in the icebox, where it will retain its ability to respond normally to a stimulus for many hours.

THE greatest interest has centered on electrical measurements. Many years ago the German physiologist Emil Du Bois-Reymond noted that an electrical

are tied with thread. The photographs are continued on next page.

potential difference existed between injured and uninjured regions of muscle and nerve. This injury potential, he suggested, was due to the fact that the injury established a contact between the negatively-charged inside of the fiber membrane and the positively-charged outside. From Du Bois-Reymond's idea others developed the theory that impulses are conducted along a nerve fiber by the movement of an action potential; that is, a potential created by the stimulation of a nerve (or muscle) which makes the region of nerve fiber responding at any one time negative to a neighboring quiet spot. According to the theory the stimulation results in electrically breaking the membrane, thus allowing the inside and outside charges to neutralize each other. It was thought that an injured spot and an active spot were electrically similar, and that the action potential was in a sense a transient injury potential. This depolarization theory satisfied the then known facts and was widely accepted for many years.

Around 1940 Alan Hodgkin and A. F. Huxley in England and Kenneth Cole and H. J. Curtis at Woods Hole developed techniques for inserting fine electrodes into living giant axones and then measuring both injury and action potentials. Measurements by this method showed that the two potentials were greatly different in magnitude: the action potential was sometimes as great as a tenth of a volt, while the injury potential rarely was above five hundredths of a volt. Clearly this was inconsistent with a theory that could allow the action potential to be as large as the injury potential but never larger.

The source of this extra energy for the action potential is not yet understood. The most plausible explanation has been suggested by Hodgkin and his colleague Bernhard Katz. They suggest that the injury potential is in effect an electrical

INDEX OF ADVERTISERS

APRIL 1951

GIANT AXONE is finally removed with the strip (*left*). It is then placed

measurement of the difference in potassium concentration inside and outside the nerve cells, and that the excess of the action potential over the injury potential represents the reverse gradient of sodium. This suggestion is compatible with the results of chemical studies, which indicate that cells spend a fair amount of energy getting rid of sodium that has leaked into them. This active excretion of sodium ions may be the basis for the energetic changes in the nerve membrane during conduction.

WHILE most physiologists have used the squid's giant fibers as a convenient means of studying how a nerve conducts an impulse in animals in general, the British investigator Young, who discovered their usefulness for this purpose, has been one of the few to speculate about the importance of the giant fibers to the squid itself. Theory predicts, and measurements confirm, that fibers of large diameter conduct impulses much faster than those of small diameter. Thus the squid saves a few thousandths of a second in reaction time—a saving that may be of considerable significance to an animal moving so fast. Moreover, its giant fibers are of different sizes; those that must carry impulses to the rear parts of the mantle are thicker, and therefore faster, than the ones that conduct impulses a shorter distance. As a result all parts of the mantle contract in close unison. Young points out that this method of coordination would not be effective for the human body, because of its complicated multiple muscular system. Whereas in the squid a single fiber activates a large portion of the body, in vertebrates single fibers control only small muscular units. In this way the human nervous system allows much more delicate and variable control of the parts of the body.

Fascinating and elaborate new gadg-

under low-power microscope (*right*) and its fatty material trimmed away.

ets are being built to refine the study of squid nerves as a means of exploring the nature of the nerve impulse. A small portion of a squid can keep several scientists and a roomful of vacuum tubes happy for hours. The work must be done, however, where the squid are, because squid, for all their ferocity, are very delicate animals. They will not live long in stale sea water. Nor can they tolerate rough handling. Bruises are usually fatal: an opaque spot, a sign of the death of cells, forms around each abrasion, and the opacity, for reasons not understood, spreads rapidly. Moreover, during capture squid get excited and leap into the air, and air gulped into the mantle cavity can also lead to their death.

Nearly all the work with squid is done in the Marine Biological Laboratory at Woods Hole and in the marine laboratories at Plymouth, England, and Naples, Italy. At Woods Hole local fishermen cooperating with the scientists have learned how to capture squid in good condition. This Laboratory now uses dozens of squid per day during the summer season.

ALL of man's thoughts and actions, his neuroses and psychoses, depend upon the functioning of the nervous system. Fundamental advances in treating nervous disorders and in understanding normal functions will depend upon what we can find out about the processes that occur within a few thousandths of a second in the confines of a thin axone membrane. Thus squid are important to human welfare. Their nerves may eventually tell us a great deal about our behavior.

H. B. Steinbach is professor of zoology at the University of Minnesota. He was author of Animal Electricity, *which appeared in the February, 1950, issue of this magazine.*

BOOKS

A biography of the brilliant, many-sided and contradictory John Maynard Keynes

by James R. Newman

THE LIFE OF JOHN MAYNARD KEYNES, by R. F. Harrod. Harcourt, Brace and Company ($7.50).

AUTHORIZED biographies are apt to be decorously dull, but R. F. Harrod's life of John Maynard Keynes is a rich and absorbing work. Himself a leading British economist, Lord Keynes' pupil and friend, Harrod comes to his difficult task equipped with background, understanding and sympathy. The sureness with which he handles his material, his sense of moral principle, the dignity of his style, even its faintly old-fashioned academic flavor, make this a cumulatively impressive and often moving study.

The request to undertake the biography came from Keynes' brother Geoffrey, a successful surgeon and literary scholar. The private papers and letters on which much of the book is based were made available to Harrod by Keynes' parents, his widow and his many friends. (His father, the noted logician and political economist John Neville Keynes, outlived him by three years, dying in 1949 at the age of 97; his mother, whose small volume of family reminiscences, *Gathering Up the Threads*, has just appeared, is still living, aged 92.) I had, under the circumstances, expected the book to be an encomium. It is, but it is also much more. Harrod's affection and admiration are strongly displayed on every page; nor is it likely that Keynes' theories will ever win a stouter protagonist. Still, an honest attempt has been made to present the material from which the reader might form a balanced judgment about the man and his achievements.

It is as a chronicle of Keynes' career and an analysis of his economic doctrines that the book best achieves its purpose. Harrod gives an account of the intellectual and social climate that enveloped Keynes in his home, at Eton and at Cambridge; of the brilliance and the antics of the "Bloomsbury Circle"; of the revolution in 20th-century economic thought; of Keynes' achievements as a mathematician, civil servant, banker, pamphleteer, Cambridge don, college bursar, speculator, government spokesman and adviser, art patron, political scientist, biographer, essayist and editor. Where Harrod fails is in telling us about the man himself. Keynes' foibles and inconsistencies are not concealed, yet of the emotions that moved him, the aspirations that drew him we are told almost nothing; we are always outside looking in. To be sure, there were obstacles in the way of a franker portrait. In a contemporary biography reputations must be spared and libels avoided. Although Keynes could be outgoing and friendly, he was aristocratically reserved as to his inner feelings. At any rate, Harrod seems incapable of cutting deep. "The biographer," he writes, "must pause at the threshold and must not seek to pry among the inner eddies of his subject's emotions. The secrets of the heart must remain secret."

Keynes was dazzling in his versatility,

Keynes

energy and sheer intellectual power. His record as a student was extraordinary. It was his many-sidedness that distinguished him even more than his individual achievements. At Eton he enjoyed good health, played fiercely at Rugby, rowed, frequented the rare-book stalls, wrote Latin hymns, was an outstanding mathematical scholar, read prodigiously, played Malvolio in *Twelfth Night*, made a speech on the thesis that "women are more fitted to rule than men," won almost every calf-bound prize volume that was offered, and generally overawed his tutors as well as his fellows. Nevertheless he made friends. At Cambridge the competition was stiffer; it soon became apparent that while he was a fine mathematician he would never be a great one. His métier lay elsewhere, and while he searched for it he took full part in the rich intellectual and communal life of the university—the seances of undergraduate societies, the debates at the Union, the sharp controversy with men of mettle on any and every subject, preferably deep. He was admitted to the select group known as the "Apostles." This secret society, founded in the 1820s, had had Alfred Tennyson, William Kingdon Clifford, William Harcourt, James Clerk Maxwell and Henry Sidgwick as members; shortly before Keynes was invited to join, Frederick Maitland, Walter Raleigh, J. M. McTaggart, Alfred North Whitehead and Lowes Dickinson had belonged. It was bound by common intellectual tastes, common studies, common literary aspirations. Clifford described its agenda as "solving the universe with delight." With Lytton Strachey, Duncan Grant, Leonard Woolf, Thoby Stephens and Clive Bell, Keynes formed lasting friendships. G. E. Moore influenced his ethical thought. He attended the lectures of Alfred Marshall, and was decisively persuaded by him "to give up everything for economics."

At Cambridge and ever after Keynes was hospitable to ideas that were bold, sweeping, revolutionary. The makeshift and the ambiguous left him "with a feeling of irritation and disgust." There was a streak of iconoclasm in him. "To tease, to flout, finally perhaps to overthrow venerable authorities—that was a sport which had great appeal for him." His intellectual predisposition vied at times with his practical traits, but on the whole they harmonized and reinforced one another. He was once dubbed Pozzo, for the Corsican diplomat Pozzo di Borgo, "not a diplomat of evil motive or base conduct, but certainly a schemer and man of many facets."

It is not possible in this review even to sketch Keynes' extraordinary career, but a glance at some of his writings may serve to illustrate his varied interests and capacities. His first book, *Indian Currency and Finance*, is a work of prime quality in its practical application of the "esoteric monetary principles" expounded by Marshall to the complex problems of Indian exchange. Even those who have no use for the later Keynesian theories regard it as a classic. *Treatise on Probability*, which occupied all his "spare time" for five or six years, is a fascinating book: learned, clear, provocative in its philosophical speculations.

"The book as a whole," wrote Bertrand Russell, "is one which it is impossible to praise too highly. . . ." It was greatly approved by Whitehead, though he had criticized it severely and constructively in manuscript. Today its mathematics are not regarded as beyond reproach. Writing under the joint influence of Moore's *Principia Ethica* and Whitehead and Russell's *Principia Mathematica*, Keynes made a sharp attack on the frequency theory of probability. Following Russell's views, he adopted a proposition rather than an event "as that which carries the attribute of probability." Moore's basic doctrine that the "good" is an indefinable, intuitive concept finds an echo in Keynes' similar judgment regarding the concept of probability. Keynes was attracted to the skepticism of Hume, according to which it is impossible to prove that because two events, X and Y, occur in conjunction there is a causal connection between them; he found it necessary to invent a rescuing hypothesis, that of Limited Independent Variety. With this it is assumed "that the experienced properties of things arise out of a finite number of generator properties," whence there is a finite probability, however small, in favor of a connection between any two properties. Evidence for the validity of the hypothesis is to be found, Keynes argued, in experience. For all its merits the *Treatise* is not a profoundly original work, but it amply exhibits Keynes' erudition, his powers as a logician, his method of assault upon a problem by concerting theoretical and practical weapons. It is notable also for an elegance of style and wit not to be found in other treatises on this formidable subject—except for the writings of such masters as Laplace and Poincaré.

The Economic Consequences of the Peace, which Keynes wrote at white heat a short time after severing his connections as a British Treasury official at Versailles, was the book that first brought him fame. The core of its argument was that security against German aggression could not be assured by crushing the German economy, that the proposed reparations would not be met voluntarily and could not be enforced, and that no durable peace could be erected upon a foundation economically so unsound. It was an impeccably reasoned brief, but its main impact was polemic. The portraits of Clemenceau, Woodrow Wilson and Lloyd George are unforgettable; the castigation of the Allies for their hypocrisy and shortsightedness made a worldwide impression. The book had a large audience, vehement critics and stalwart defenders. Although its influence among contemporary governments and politicians is uncertain, it undoubtedly affected public opinion and helped shape the later appraisal of the entire fumbling tragedy of Allied peacemaking and its catastrophic consequences. *The Economic Consequences* was a work of somber prophecy, of bitterness, magnanimity and courage; it incurred "great odium in official circles" and cast Keynes "for many years in the wilderness." But the very fact that the official world "could no longer use him" was both emancipation and challenge. His greatest achievements, which lay ahead, were his response.

Keynes' major contributions to economic thought are most fully and systematically expressed in his *Treatise on Money* and the later *General Theory of Employment, Interest and Money*. The central doctrine of the *Treatise* is that there is no necessary link between savings and investment. "The decisions to undertake capital outlay are made by one vast class of people in the community and the decisions to save by another." There is nothing to bring these decisions into line, yet if investment runs ahead of savings, conditions of inflation or boom ensue; if savings run ahead, there is an opposite tendency. "This opened up quite new lines of thought. Hitherto, the economist, as such, had tended to encourage economy and thrift in all circumstances. If Keynes' doctrine was correct, it was most desirable to do so in times of incipient inflation—but not at all times. On the contrary, in times of depression and unemployment it was desirable to encourage spending and lavishness." To forego the "immediate enjoyment of consumption" may sometimes help to increase wealth, "but it should be obvious that mere abstinence is not enough by itself to build cities or drain fens." Thrift, in other words, is not an absolute virtue for either individuals or governments; it may do good or it may do harm. Usually, Keynes said, it does harm. In the *General Theory* Keynes was primarily concerned with analyzing the causes of unemployment. Here again he departed from traditional economic theory (in fact, Harrod remarks, he "went out of his way" to stress differences and find weaknesses, to criticize "revered names"). Keynes denied, subject to certain qualifications, that high wages caused unemployment, or that lowering them would raise the level of employment. In these difficult theoretical works and in some of Keynes' more popular economic writings (*e.g.*, *How to Pay for the War*) are to be found the ideas which have so vastly influenced students, practical men, theoreticians and governments; which have shaped financial policies and altered the circumstances of millions of men and women to whom even Keynes' name is unknown and his thought incomprehensible.

Savage in writing and debate, Keynes could also be magnanimous and delicate of understanding, with "a kind of critical intuition only to be paralleled by that of some of our greatest historians and scientists." He delighted in paradox, in argument for its own sake, in cultivating the "appearance of omniscience," in playing the prophet. When the necessary statistics were available he had them at his fingertips; when they were not, he would guess at them, a fact he would admit with disarming candor. He would crush an opponent with a converging series of arguments or run him through with a single rapier thrust; in either case he was tempted, one suspects, to restore the victim to life only to show him how Keynes could have defended the opponent's side of the case. His assaults on accepted views of reparations, birth control, *laissez faire*, the salaries of university dons, the gold standard, Communism, painting, protectionism, the virtues of thrift, sprang from honest intellectual conviction. Yet often he had the accompanying desire to demonstrate that the idols of the time were hollow, its great men dolts. While he never lacked courage to espouse unpopular causes, he could accommodate himself to existing circumstance. Harrod attempts to show that there were no real inconsistencies in Keynes' attitude toward major economic issues, but the proofs are not altogether convincing. He adopted new views, or reinstated the old when he believed them to be true views. (He answered those who reproved his inconsistencies: "I seem to see the elder parrots sitting round and saying: 'You can *rely* on us. Every day for thirty years, regardless of weather, we have said, "What a lovely morning!" But this is a bad bird. He says one thing one day and something else the next.' ") Though Keynes had strong prejudices, he would not permit them to harden and imprison him; he saw too well both sides of a question to commit himself irrevocably to one. This is perhaps one of the side-meanings of the word "clever" as it was so often applied to him. "No one in our age," Harrod says somewhat regretfully, "was cleverer than Keynes nor made less attempt to conceal it."

He was a great man. Of this there can be no doubt, whatever judgments time may pronounce on the validity of his doctrines. "For good or ill—and there are those to whom Keynes' influence appears catastrophic—the world is a different place on his account. . . ." (I quote from the review of Harrod's book in *The Economist*.) He advanced new ideas, yet more of his energy was spent in tearing down the old; the critic outweighed the creator..He did not regard the interplay of economic forces as a sacred process not to be tinkered with, but urged instead that it be planned and regulated to improve the condition of men everywhere. Yet regimentation or any threat to personal freedom was abhorrent to him. He was at one time a free trader, "indeed the fallacies of Protection had aroused his especial fury"; not long thereafter he embraced Protectionism and described the route of escape from "our present difficulties" prescribed by the free traders as "a peregrination of the catacombs with a guttering candle." To be a dissident, a radical in purely intellectual matters, was as ingrained in Keynes as in matters of culture to be "a true Burkean conservative." He was both rude and kind, a fierce controversialist and, as Henry Morgenthau said, "a gentle soul." He condemned the predominance of the money motive, and he made a fortune as a speculator. He was "keenly alive to great social evils," a progressive, a reformer, and he had no sympathy with socialism. He had a "strong vein of pacifism," expressed the view that "only individuals are good, and all nations are dishonorable, cruel and designing," and he did not spare himself in his country's service in either war. He died too soon. "Ministers of good things," said Richard Hooker, "are like torches, a light to others, waste and destruction to themselves."

HENRY GROSS AND HIS DOWSING ROD, by Kenneth Roberts. Doubleday and Company ($3.00). Henry Gross' dowsing rod locates water when waved over maps and photographs as well as the ground, judges the depth, flow and potability of the water, distinguishes bonded from blended whiskey and answers yes-or-no questions over a wide range of other topics. The author assures his readers on the first page that "this is not a scientific book," and with that statement there can be no quarrel whatever.

REFLECTIONS OF A PHYSICIST, by Percy W. Bridgman. Philosophical Library ($5.00). These collected essays are concerned with specialized topics such as the author's well-known concept of operational analysis, first broached in *The Logic of Modern Physics*, and also with subjects of broader interest; for example, scientific freedom and the function of science. Bridgman writes with sharpness and, even on technical matters, with agreeable irony.

OXFORD JUNIOR ENCYCLOPAEDIA, VOL. II, NATURAL HISTORY; VOL. IX, RECREATIONS. Oxford University Press ($8.50 each). The most recent additions to this new Oxford encyclopaedia are handsomely produced and the main articles are not only clear but so literate and interesting as to make the work attractive to adults as well as children. The encyclopaedia is primarily intended for British children, so that while it will prove invaluable to the school library it must be regarded as supplementary to its U. S. counterparts.

CONCISE HISTORY OF ASTRONOMY, by Peter Doig. Chapman and Hall, London ($5.25). A clear, incisive, unpretentious account by the editor of *The*

Journal of the British Astronomical Association of the development of the theories and instruments of astronomy and of its leading figures from Hipparchus and Ptolemy through the 20th century. Useful for the student and the general reader.

HISTORY OF BIOLOGY, by Charles J. Singer. Henry Schuman ($5.00). Revised edition of a standard work, originally published in 1931, by a distinguished historian of science. Singer's critical survey of the development of biological problems is well illustrated, clearly written and demands only a minimum of scientific training for its comprehension.

THE FOUNDATIONS OF ARITHMETIC, by Gottlob Frege. Philosophical Library ($4.75). This is the first English translation of a classical work which first appeared in Germany in 1884 but lay comparatively neglected until Russell and Whitehead at the beginning of this century called attention to Frege's attempt to place mathematics on a secure logical foundation, and acknowledged their indebtedness to him for ideas brilliantly elaborated in their own writings (*e.g.*, Russell's *Principles of Mathematics* and Whitehead and Russell's *Principia Mathematica*).

NATURAL REGIONS OF THE U.S.S.R., by Lev S. Berg. The Macmillan Company ($10.00). An authoritative work on the natural geography of the entire Soviet Union issued under the auspices of the American Council of Learned Societies as part of its series of Russian translations. Professor Berg is an outstanding scientist whose writings and field researches are internationally known. This study is generally regarded as his most valuable contribution to physical geography.

THE ATOM AT WORK, by Jacob Sacks. The Ronald Press Company ($4.00). A refreshingly straightforward and clear account for the general reader of what's what in atomic energy, emphasizing research and constructive aspects and relegating weapons to their proper minor place. The best book of its kind since Selig Hecht's excellent *Explaining the Atom.*

THORNDIKE-BARNHART COMPREHENSIVE DESK DICTIONARY, edited by Clarence L. Barnhart. Doubleday and Company ($2.75). A new, well-designed, inexpensive work by the editor of *The American College Dictionary.* It is shaped in large part by the important researches in lexicography of the late Edward Lee Thorndike, noted Columbia psychologist. With its simple, uncluttered definitions this should prove an exceptionally valuable reference book for the student and the general reader.

What GENERAL ELECTRIC People Are Saying

E. L. AUYER
R. T. HOLLAND

Apparatus Department

JET NOISE: Since its inception the noise problem associated with turbojets has received considerable attention from the public as well as from industry. Noise control at test facilities has shown some excellent results, but noise control on an installation appears to be impractical. Since absolute measurements are always subject to question because of variation in methods of measurement and interpretation as well as variations between individuals concerning discomfort encountered, it is well to compare a known familiar noise with the new unknown noise.

The public is generally familiar with the noise level associated with conventional aircraft as the aircraft passes overhead. Therefore noise measurements on the ground were made as a piston engine aircraft passed overhead and also as a turbojet airplane passed overhead. Identical methods and measuring equipment were used for both tests, and both types of aircraft were operated at normal cruise power settings.

The results . . . indicate that noise levels for the turbojet were actually much lower than the noise levels of the piston aircraft. In addition the ground observer is subjected to the turbojet noise for only 20 seconds, while the piston aircraft noise persisted above background level for 70 seconds. In both cases the aircraft were flown directly overhead at an altitude of 1000 feet. The same pattern existed for the test made at 5000 feet.

Institute of Aeronautical Sciences
New York, New York
January 29, 1951

★

T. W. DRIESCH

Apparatus Department

MOTOR BRAKE: After man had invented the wheel, he was immediately confronted with the problem of bringing to a stop whatever the wheel moved. . . . With the advent of the machine age, it became more important to develop brakes to retard and stop revolving machinery, and the first hand brake resulted. . . . The later use of electric power, in the form of motor drives with ever-increasing speeds and horsepower, demanded brakes of greater capacity and reliability. Electricity then took the place of muscular effort.

During the past 50 years, designs have been developed with a multitude of variations in shoe or band arrangements, with one or more springs, and with numerous links, levers, and pins. The majority of those brakes had only one magnet and used a system of mechanical linkages to multiply the force of the magnet to release the shoe pressure.

The major objectives in the development of the new brake described in this article were: (1) to reduce the number of wearing parts, (2) to obtain faster operation, (3) to simplify the means of making adjustments, and (4) to have fewer parts. . . . These objectives aim at decreased maintanence. Other advantages include improved performance and appearance.

General Electric Review
February, 1951

★

A. H. HEMKER

Apparatus Department

FARM POWER: The fact that farmers are dependent on electricity more and more has brought to focus the last year or two a question: What do you do when the power goes off? . . .

Take a dairyman who is milking, say 50 cows. How does he milk them if his milking machine won't run? In some cases this may even be a physical impossibility. Think of the inconvenience on any farm if the water pump doesn't work. If the power interruption is of long duration, what about the farm freezer? Many farm homes are considerably electrified, and probably the most important electric item in the farm home is the electric motor that runs the oil burner or stoker that keeps the home comfortable.

Take the poultryman who may have chicks under the brooder or who heats the brooder house with an oil or stoker heating plant. Take the poultryman with a thousand layers or more who lengthens the working day of his layers by having lights in his poultry house. A few interruptions in this light cycle would throw his complete flock off production and might even put them into a molt.

Another example of the importance of electricity is the truck garden or greenhouse operator who has electric heat in his benches or who depends on automatic heat with his stoker to heat his greenhouse. Loss of power in these cases might mean a loss of considerable money.

A standby electric power generator is the answer to the above questions, but I believe it is necessary that we take a sensible view of the farmer's requirements, even though a farm may have 20 or 30 kilowatts of connected load. It isn't necessary that he protect himself for his possible maximum use. . . . I believe a three-kva generator will take care of most farmers' emergency needs. . . . I believe in most cases it would be silly to saddle the farm with a complete engine-generator set when the use of it may average only once a year. . . . All farmers have a prime mover which is used nearly every day. . . I am speaking, of course, of the farm tractor.

American Society of Agricultural Engineers
Chicago, Illinois
December 18, 1950

You can put your confidence in—

GENERAL ELECTRIC

THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

When an engineer designs a bridge, unlike an amateur astronomer designing a telescope mounting, he does not proportion the parts by guesswork, or even trust to experienced judgment. Instead he applies mathematical stress analysis, which grinds out exact and dependable answers. This standard method of engineering was used on the mounting of the 200-inch telescope by engineers Mark Serrurier, Jesse Ormandroyd and others. Can this method also be used on the smaller telescopes that amateurs build?

No exposition of the engineer's method as applied to telescopes has ever been published. Writers, including the present one, have merely urged the use of massive, rugged mountings to avoid vibration at the eyepiece. This advice has not been accepted by all amateurs, many of whom follow the good American tradition of ignoring precept unless the reasons for it are explained, understood, believed and liked. In the exposition that follows, the amateur telescope maker Roelof Weertman of Beaver, Pa., explains step by step the engineer's approach to the design of a typical telescope mounting by stress analysis. Thus the beginner may now design his mounting scientifically, while the more advanced amateur may check his telescopes by this method and find out whether he is an unsuspected engineering genius. Weertman writes:

As an example for stress analysis we may choose the familiar beginner's 6-inch $f/8$ reflecting telescope.

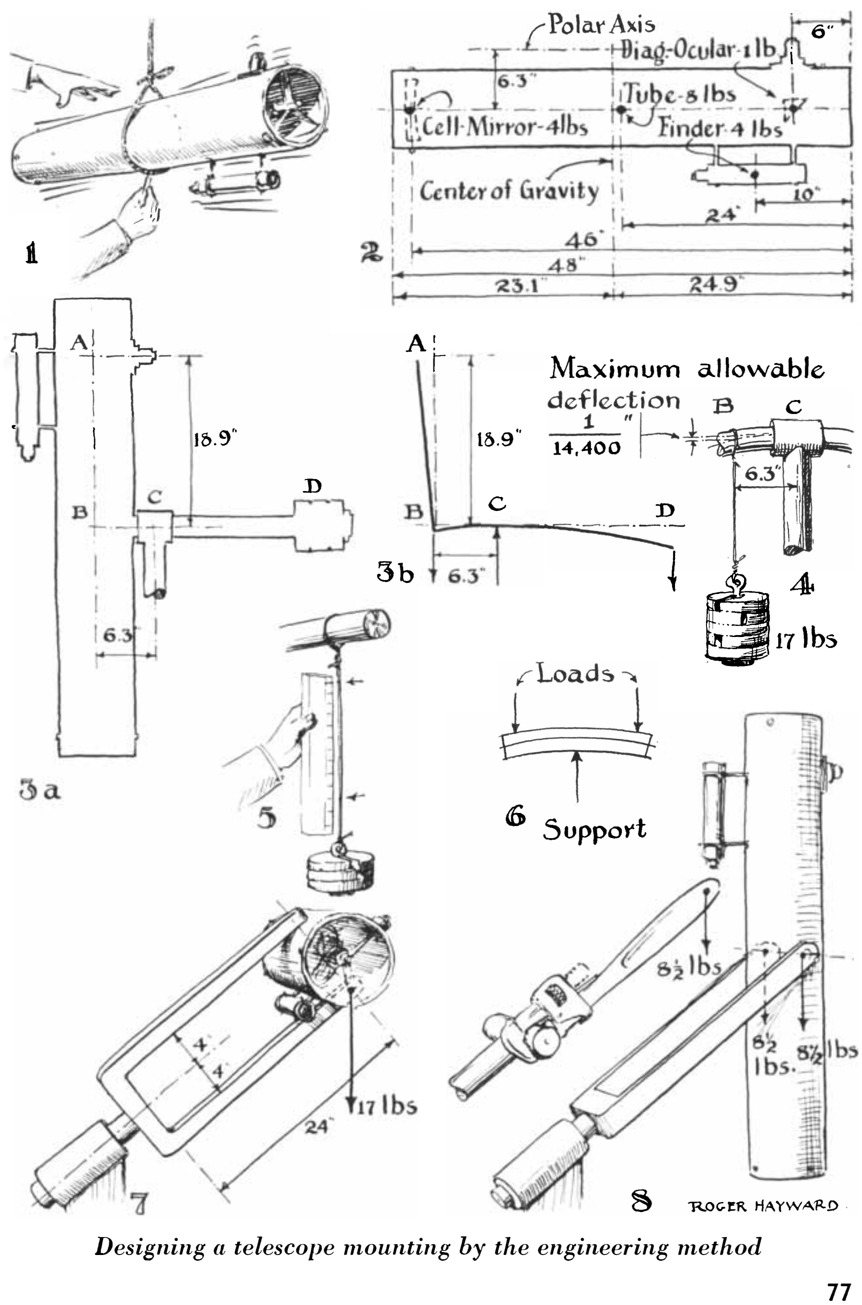
First, find the point of balance of the tube unit. This may be done quickly by the method shown at 1 in the illustration at right, but the alternative method shown at 2, though consuming more time, will have more interest, and while we are at it, we may as well be scientific even if it kills us. (The method has other uses.) Weigh the assembly parts of the telescope—tube, cell with mirror, diagonal support with eyepiece, and finder—and record their weights. Then assemble the entire unit and, as shown by the large dots at 2 in the illustration, mark on the tube the approximate center of mass of each part and complete a layout like the one shown. Now tabulate for each unit the product of its weight and its offset distance from the right-hand end of the tube. For example:

Tube alone	8 lbs. ×	24 in.	192 in.-lbs.
Diag.-ocular	1	6	6
Cell-mirror	4	46	184
Finder	4	10	40
Add it up	17 lbs.		422 inch-lbs.

Dividing the total inch-pounds by the weight of the telescope will give the balancing point of the assembly. In the example, if we correctly estimated the balancing points of the individual parts, this point will be 422/17 = 24.9 inches from the right end of the tube.

The next and most important step is to design the axes. If these are too thin the telescope will vibrate with every zephyr and force the user to stop observing until it settles down. Little puffs that we are ordinarily unaware of nevertheless shake solid objects microscopically. These "microshakes" are magnified as many times as the telescope magnifies, and thus the image of the star may dance like a flea on a fiddlestring. Ordinary standards of rigidity are a poor guide for telescopes.

What then is the maximum vibration that can be tolerated at the eyepiece of the telescope? Here we must take into account the resolving power, first of the eye, and then of the telescope. I have



Designing a telescope mounting by the engineering method before me an architect's scale with a ⅛-inch section at one end which is divided into 12 parts. These 1/96-inch divisions can be clearly resolved by the eye, and so can the narrower spaces between them which are about 1/400-inch wide. At 10 inches, which is assumed in optics as the standard viewing distance giving best vision for close objects, this width subtends an angle of about one minute. And a one-minute angle is commonly regarded as the resolving power of the human eye, though this varies somewhat with circumstances.

The six-inch mirror of the telescope, much wider than the pupil of the eye, should resolve the images of two equally bright stars about one second apart. Enough magnification is used on the telescope to raise the one-minute resolving power of the eye to the one-second resolving power of the telescope.

There is no way to eliminate vibration completely. We are interested only in reducing its amplitude to a point where the crosswise motion of the image at the eyepiece will be smaller than the resolving power of the eye, and therefore unnoticeable. In our example this is one second of angle. What does this mean in terms of inches at the eyepiece? Knowing the angle subtended by the moon, we may measure the width of its image in the eyepiece, and then simple calculations give the answer: 1/4800-inch. If in the case shown at 3a in the illustration on the preceding page, the tolerance at the distance A, that of the eyepiece, is 1/4800-inch, then the tolerated deflection at B, at one third that distance, is one third that amount, or only 1/14,400-inch.

The declination axis BD is attached to the polar axis C, and BC is an overhang. The 17-pound weight of the tube is attached to the polar axis at the median point B of the tube. Now we can state the problem in fresh form, as at 4 in the illustration. We have a 17-pound load at B, hanging from the end of the round declination-axis shaft held at C: in other words, a cantilever beam. And now we come to the main question: How thick shall we make this declination axis, and the polar axis which requires equal thickness?

Merely to support the telescope even a small steel wire would be amply strong, but it would not be nearly stiff enough. Its "elastic limit" would be far exceeded. To illustrate the meaning of elastic limit, we may take a piece of wire as thick as that in a paper clip, with a cross-sectional area of about .0022-square-inch, and mark it at two points exactly 10 inches apart, as at 5 in the illustration. Now hang, say, 67 pounds from a loop below the measured section. The original 10 inches will stretch to perhaps 10.01 inches. Add, say, 20.1 pounds. According to calculation the wire will now measure 10.013 inches. Remove all the weights. The marks once more measure just 10 inches apart. Now carefully hang the same weights again so that the marks return to the 10.013-inch separation, and add 13.4 pounds more, bringing the distance to perhaps 10.015 inches, an elongation of the original 10 inches by .015-inch, or .0015-inch per inch. Now when we remove the 100.5 pounds we discover that the distance between the marks does not return to the former 10 inches, but remains 10.015 inches. Without breaking, the wire has lost its ability to return to its original length; we have exceeded its elastic limit.

Next we divide the original cross-sectional area, .0022-square-inch, by the 100.5 pounds weight hung on the wire, obtaining a quotient of 45,681 pounds per square inch, which we round off to 45,000 pounds. Dividing the 45,000 pounds' stress per square inch by the .0015-inch elongation, we get a quotient of 30 million. This is the "modulus of elasticity," called E for short. For steels E generally equals 30 million.

Now we refer again to the drawing at 4 in the illustration, in which the weight of the telescope tube is shown hanging from the end of the declination axis beyond its attachment to the polar axis. The formula for deflection is $D = Wl^3/3EI$. D is the maximum deflection, which in our example is not to exceed 1/14,400-inch; W is the load, which in our example is 17 pounds; l is the length of the overhang of the declination axis, or 6.3 inches; E is the modulus of elasticity, here 30 million; and I is the "moment of inertia."

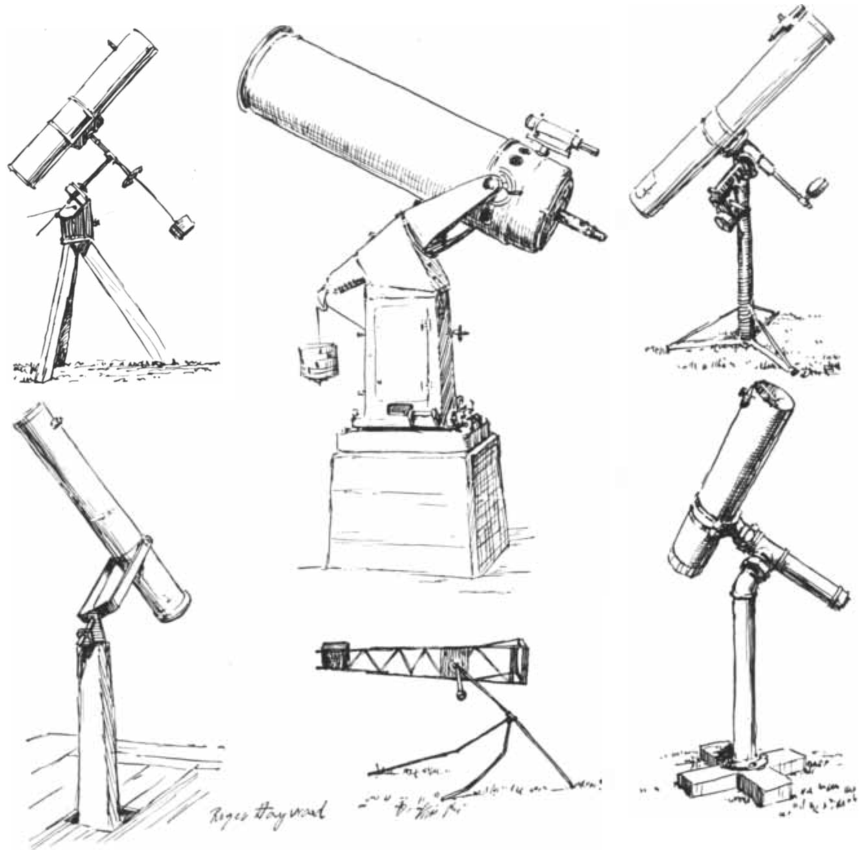
Inertia expresses the reluctance of a material to change its shape under deformation by an outside force. When we bend a rod or beam, as shown at 6, the fibers of the material on the concave side are compressed and those on the convex side are stretched. In a certain plane about halfway between the sides the fibers are neither compressed nor stretched; this is the neutral axis. As we depart from this axis the fibers are subjected to stresses that increase as the square of their distance from it. The inertia of any fiber is its area in square inches times the square of its distance from the neutral axis; this gives a square times a square, or a fourth power. The moment of inertia, I, of the whole beam is the sum of the inertia of all the fibers. In engineering language, "The moment of inertia I is the sum of the products obtained by multiplying each of the elementary areas of which the section is composed by the square of its normal distance from the neutral axis."

Now we return to the main argument. Since in the above equation we know all the quantities except I, we can solve for I as follows:

$$\frac{1}{14{,}400} = \frac{17 \times 6.3 \times 6.3 \times 6.3.}{3 \times 30{,}000{,}000 \times I}$$

Then I equals .6801 inch^4.

If we look in an engineer's handbook we find that $I = .6801$ inch^4 for a shaft



Contrasts in mountings: three adequate, three inadequate

1 15/16 inch in diameter. This is therefore the diameter our two shafts should have if they are to be solid. If we prefer, we may substitute two-inch pipe, which has 2⅜-inch external diameter. The gain in diameter will about compensate for the loss of the central section.

What if we wish to double the aperture of the telescope and make a 12-inch $f/8$? The instrument will not only be twice as long, but will also be doubled in its other two dimensions, making it eight times as heavy. Its overhang will likewise be doubled, and so the polar-axis shaft will be loaded with eight times the former weight at twice the former distance, or 16 times as much as on a six-inch telescope. Yet the tolerated deflection at the eyepiece will remain exactly the same as before, 1/4,800-inch, and, everything being proportional, we still have a tolerance of $(2 \times 18.9)/(2 \times 6.3) \times 1/4{,}800 = 1/14{,}400$-inch at the junction of the two axes. Substituting in the formula for D, we find that I now equals 43.52 inches^4. This calls for shafts 6 7/16 inches in diameter.

And now for the forked mountings. When the fork is in the position shown at 7 in the illustration the tube is supported practically on one tine. This tends to bend it at two places: at the elbow and at the junction with the polar axis. It becomes a cantilever. Since the tube with eyepiece moves as a whole, the tolerance is 1/2,400-inch total maximum deflection, and I may be found by multiplying the weight of the telescope by the cube of the length of the fork tine and dividing the product by three times the modulus of elasticity times the maximum deflection. Thus we have $(17 \text{ pounds} \times 24 \text{ inches} \times 24 \text{ inches} \times 24 \text{ inches}) / (3 \times 30{,}000{,}000 \times 1/4{,}800)$. Solving for I, the answer is 12.54. From tables in the engineer's handbooks we may choose any shape or cross section we desire that gives 12.54 for its least dimension.

A round bar with a 4-inch diameter or a square bar 3½ by 3½ inches would suffice equally well. If other shapes are used, the value of I required should be in the direction of the bending, and the tables of elements of sections in the handbooks should be consulted.

A different situation arises when the fork is in the position shown at 8 in the illustration. Here there is torsion on the cross-member of the fork. Half the weight of the telescope, or 8½ pounds, is applied at a distance of 24 inches, giving 204 inch-pounds of twist in either half of the cross-member. The formula is $\theta = Tl/E_sI$, where θ, an angle expressed in radians, is $pi \times d \times$ the arc of twist, divided by 360 degrees $\times$ 60 minutes $\times$ 60 seconds. T is the twist, l the length, E_s the shearing modulus of elasticity, and I the moment of inertia (which for a solid round shaft of diameter d is equal to $.098d^4$). Substituting and solving for d, we find that the cross-member, if round, must be 1 15/16 inch to 2 inches thick.

THE preceding analysis by Weertman is offered as the opening of a campaign to change the design of the amateur's mountings from an art, as at present, to something approaching a science, and with the aim of including an analysis in a future printing of *Amateur Telescope Making*. Space in that book for not more than 1,730 words may be found by discarding the matter now on pages 157 to 159. No prize is offered for the best exposition of mounting design by engineering stress analysis other than the mention of the author's name in a by-line in that book; such mention would, however, embalm the winner as one of the classic granddads of the hobby. The analysis should not be aimed at the engineer or the long-haired advanced amateur but at the beginner, who is the one most given to building what Weertman correctly calls "pantywaist contraptions mounted on hairsprings and jelly."

THE drawing on the opposite page shows some outstanding mountings, both bad and good, that amateurs have built. They were drawn from original photographs without caricature and without change in the proportions of the axes. In the mounting in the upper left-hand drawing the lower portion of the polar-axis shaft has a diameter of only ⅝-inch, and the lower extension of the declination-axis shaft, carrying a heavy counterweight, is only ⅝-inch in diameter. The builder of this mounting was a student in a famous engineering school!

The fork mounting in the lower left-hand drawing was made by folding a length of ⅝-inch strap iron, and would sag excessively.

The polar axis of the mounting in the lower central drawing consists of ½-inch pipe, mounted on its crane-fly legs of slightly larger pipe. Whether this mounting deserves to steal away the prize from the first of the three remains a question.

These, of course, are extreme cases. Examples of adequate or more than adequate mountings are shown in the remaining drawings.

The 12-inch Cassegrainian in the center, designed by Russell Porter, has an adequate fork of sweet proportions.

The instrument in the upper right-hand drawing, built by F. L. Prescott of Dayton, Ohio, is adequate throughout.

The mounting in the lower right-hand corner, built by H. I. Linn of Oakland, Calif., carries a six-inch telescope on 3½-inch pipe fittings which include a heavy steam-pipe saddle used as the saddle for the tube. Despite the ruggedness of this mounting it required no machine work.

IN THE article on erecting eyepieces on page 70 of the March issue, formula 5 should be corrected to $a = [m(O+y)/F] + y$.

BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful. The lists are not intended as bibliographies of source material for the articles. The references selected will provide supplementary information.

THE CENSUS

POPULATION OF CONTINENTAL UNITED STATES BY REGIONS, DIVISIONS AND STATES: April 1, 1950; Series PC-3. *1950 Census of Population, Preliminary Counts*, U. S. Department of Commerce, Bureau of the Census.

PARADOXES OF THE MISSISSIPPI

SUMMARY OF THE GEOLOGY OF THE LOWER ALLUVIAL VALLEY OF THE MISSISSIPPI RIVER. Harold N. Fisk. War Department, Corps of Engineers, U. S. Army, Mississippi River Commission, Vicksburg.

THE SUTTON HOO SHIP-BURIAL

THE EXCAVATION OF THE SUTTON HOO SHIP-BURIAL. C. W. Phillips in *The Antiquaries Journal*, Vol. XX, No. 2, pages 149-202; April, 1940.

THE SUTTON HOO SHIP-BURIAL. T. D. Kendrick, Ernest Kitzinger and others in *Antiquity*, Vol. XIV, No. 53, pages 1-87; March, 1940.

REACTORS

ENGINEERING ASPECTS OF NUCLEAR REACTORS: I, II, III, IV. L. A. Ohlinger in *Nucleonics*, Vol. 5, No. 6, December, 1949; Vol. 6, Nos. 1, 2 and 3, January, February and March, 1950.

THE SCIENCE AND ENGINEERING OF NUCLEAR POWER, Vols. I and II. Clark D. Goodman. Addison-Wesley Press, Inc., 1947 and 1949.

CATACLYSMIC EVOLUTION

VARIATION AND EVOLUTION IN PLANTS. Chapters 8 and 9. G. Ledyard Stebbins, Jr. Columbia University Press, 1950.

THE IMITATIVE DRUGS

RECENT ADVANCES IN THE STUDY OF BIOLOGICAL COMPETITION BETWEEN STRUCTURALLY RELATED COMPOUNDS. D. W. Woolley in *Physiological Reviews*, Vol. 27, No. 2, pages 308-333; April, 1947.

THE SQUID

FUSED NEURONS AND SYNAPTIC CONTACTS IN THE GIANT NERVE FIBRES OF CEPHALOPODS. John Z. Young in *Philosophical Transactions of the Royal Society of London*. Series B, Biological Sciences. Vol. 229, No. 564, pages 465-503; May 25, 1939.


Wherever chemical quality counts...
Specify
BAKER & ADAMSON
B&A
QUALITY
STANDARD OF PURITY
REG. U. S. PAT. OFF.
Reagents
For Research Laboratories
For Industrial Laboratories
For Chemical Control
For Product Planning and Development
For Educational Laboratories
BAKER & ADAMSON Reagents and Fine Chemicals
GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 RECTOR STREET, NEW YORK 6, N. Y.
Offices: Albany • Atlanta • Baltimore* • Birmingham* • Boston • Bridgeport* • Buffalo* • Charlotte* Chicago* • Cleveland* • Denver* • Detroit* • Houston* • Jacksonville • Los Angeles* • Minneapolis New York* • Philadelphia* • Pittsburgh* • Providence* • St. Louis* • San Francisco* • Seattle • Yakima (Wash.)
In Wisconsin: General Chemical Company, Inc., Milwaukee, Wis.
In Canada: The Nichols Chemical Company, Limited • Montreal* • Toronto* • Vancouver*
SETTING THE PACE IN CHEMICAL PURITY SINCE 1882
* Complete stocks are carried here.

Photo by Roy L. Miller

Here are some good examples...

A SURE sign that our teachers are doing a good job today is the genuine interest most youngsters take in their schoolwork. Our schools are doing their best to provide better equipment, too. The plastic-top desks you see here are good examples. They are virtually indestructible—can be counted on to stand up under *decades* of use!

These plastic-top desks have been welcomed by school authorities wherever they have been installed. So they will withstand rough treatment without being marred or stained, these laminated desk tops are surfaced with a MELMAC® Resin, a development of American Cyanamid Company. Being smoother, they are easier to write on and keep clean, and need practically no maintenance. All these characteristics also aid in sound school budget planning. Similar MELMAC-laminated surfaces have given years of trouble-free service on drug store and restaurant counters, in kitchens and dinettes.

Here is still another example of how Cyanamid Chemistry helps to make things worth more—by making them last longer.

AMERICAN *Cyanamid* COMPANY

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

Materials for the Plastics Industry . . . one of the many industries served by Cyanamid