SCIENTIFIC AMERICAN

THE LAW CODE OF LIPIT-ISHTAR (PAGE 44)

FIFTY CENTS

June 1948

SAVE A CHILD—SAVE THE FUTURE

Photo by Roman Vishniac

You can help—you must help!

YOUR GIFT TO THE CRUSADE FOR CHILDREN WILL BE PART OF A UNITED EFFORT TO

Raise $60,000,000 for relief

AS you read this, millions of children are starving. Dozens will die before you finish.

To keep as many as possible alive and to help them to normal growth and normal thought, members of the United Nations are making a *unified* appeal for your help. *Every* country is doing what it can.

In the U. S. A. this appeal is called the Crusade for Children and twenty-six established relief agencies are represented. These agencies are making a *single* request for aid, and they will *share* your contribution.

Sixty million dollars are needed — now. There is no time to lose.

When you save a child, you save the future. So give what you can, and give *now!*

CRUSADE FOR CHILDREN

AMERICAN OVERSEAS AID—UNITED NATIONS APPEAL FOR CHILDREN

National Headquarters • 39 Broadway • New York 6, N.Y.

LETTERS

Sirs:

I should like, if I may, to express my gratitude for the long and detailed review which Professor Linton has given to my book, *The American People*, and for the confirmatory evidence he provides for a couple of the hypotheses therein. I am gratified that an anthropologist of Professor Linton's eminence should pay the book so much detailed attention.

He does however include a couple of criticisms which I should appreciate the chance of discussing. The more important point is the question of the validity of this type of analysis; but Professor Linton also devotes quite a lot of space to deducing, doubtless by the most scientific principles, the contacts I have had in the United States. He writes: "It appears that Gorer's American contacts have been almost exclusively with the members of two groups: middle-aged clubwomen . . . and the semi-Bohemian intelligentsia of New York and vicinity." As a matter of fact, Professor Linton has had a number of opportunities of exercising his scientific observation of my contacts at meetings of the American Anthropological Association, and smaller anthropological meetings in New York and New Haven; and I confess I am curious to know under which of these two categories he includes our professional colleagues. More seriously, I somewhat resent the slur on the generosity and hospitality of hundreds of Americans in every walk of life and every part of the United States who have entertained me and made me feel welcome; and I should not have thought it needed very abstruse calculations to understand why I did not fill several pages with the names and addresses of my hosts.

On the more technical level, Professor Linton makes his chief objection on the ground that "no statistical methods were employed at any stage in the study." It is true that I made no studies of distribution myself; but I did make fairly consistent use of the available statistical studies, as a background to my conclusions, and have referred to most of them in the preface or the footnotes. Because I was writing in the first place for an unspecialized British audience, I only included the most essential figures in my text, for such an audience is repelled by rows of figures and statistical tables. Interested specialists can easily discover the confirmatory figures by consulting the sources I quote, from *Statistical Abstracts* through such important sociological studies as Gunnar Myrdal's *American Dilemma* or the *Yankee City* series of Professor Lloyd Warner and his associates, to the ten years of the *Fortune* public opinion poll. In his reproofs, Professor Linton does not cite any authorities whom I should have consulted, and did not.

On a great number of the subjects with which I attempted to deal, statistical information is unfortunately not yet available. In the case of American childhood training, for example, I know of no studies of distribution; such excellent studies of child training and development in the contemporary United States as those of Drs. Gesell and Ilg present a wealth of detail from which a pattern can be abstracted, but no statistical evidence of the distribution of the customs they describe. I agree with Professor Linton that ideally all such statements should be backed by statistics; but the man who has reconstituted (from what slender sources!) the culture of the Comanche three centuries ago, and described the culture of the Marquesans on the basis of casual observations made nearly two decades earlier when he was devoting his attention to artifacts and after the society he was describing had almost completely disintegrated—such a man must surely acknowledge that the scientific ideals of anthropology cannot always be attained even in the primitive field, not even by one of the most distinguished and most lucid of living anthropologists. Admittedly, American culture is infinitely more complex than Comanche or Marquesan; but if the same criteria are applied to all three studies, where exactly are Professor Linton's statistics?

Rather than indulge in this type of mutual recrimination, I should prefer to associate myself as emphatically as possible with Professor Linton's conclusion, in which he urges the "non-technical reader" to "think rather than believe." That would be, for me, the ideal result of my book. I present a series of interrelated hypotheses, nearly all of which are susceptible to statistical proof, disproof or modification; if the book succeeds in provoking researches, I shall feel that I have been justified in rushing in where professors fear to tread.

London GEOFFREY GORER

Sirs:

I have read the new SCIENTIFIC AMERICAN from cover to cover, and congratulate you most heartily upon it. The articles are on a high level—reached elsewhere, I think, only by the English magazine *Endeavour*. Keep this up and you will fill a badly needed place in this country. The only minor criticism that I have is that some of the illustrations in Professor Whipple's paper are a bit modernistic.

HENRY NORRIS RUSSELL

Princeton, N. J.

• The Board of Editors extends its thanks to Henry Norris Russell, whose articles on astronomy for many years enhanced the pages of the old SCIENTIFIC AMERICAN, and to other readers who have expressed their good wishes to the new SCIENTIFIC AMERICAN.

50 AND 100 YEARS AGO

JUNE 1898. "Prof. Dewar has recently liquefied hydrogen, which is an unprecedented feat. This invention was announced by cable to The New York Sun on May 11, and now fuller accounts of his experiments have been published. There is already controversy as to where the credit belongs for first bringing this element into control. The Polish scientist Olszewski forestalled the discovery a year or two ago by accurately determining the critical temperature and boiling point of hydrogen, but he did not succeed in reducing the gas to a liquid form in a really practical way, so that it could be examined and its properties tested."

"Undoubtedly the chief center of interest in the Spanish-American war lies just at present in the harbor of Santiago de Cuba, and, judging from present indications, this is likely to be the seat of the most active and important operations for some time to come. The rumors of last week, to the effect that Admiral Cervera's fleet was "bottled up"—to use the pet phrase of the day—by our fleet were confirmed by an official dispatch from Commodore Schley. The fleet was identified on Sunday, May 29, by the unprotected cruiser "Marblehead," which, acting under the orders of Commodore Schley, ran in close to the Morro Castle, and steamed past the entrance to the harbor in a westerly direction. Her officers had a good view of the interior of the harbor as far as Punta Gorda."

"The Governor of Massachusetts has signed a bill which substitutes electricity for hanging as the method to be followed by that State hereafter in putting to death condemned criminals."

"One of the questions periodically brought forth for discussion is the advisability of establishing a Department of Science, in which all of the scientific work of the general government shall be concentrated under one chief. It is said that each of our larger bureaus now prosecuting scientific inquiries has a director with an executive corps consisting of a chief clerk, private secretary and disbursing officer; that many have a special library, with a librarian and assistants; that not a few sustain laboratories with similar names if not identical functions, and that each is deprived of the support of the others, while all lack the strength that union alone can give. The corrective suggested for avoiding duplication of directors, chief clerks, librarians, etc., and the remedy for the dispersion of energy now volatilizing in so many workshops is to consolidate, to have one great Department of Science; in short, to centralize."

"A method of centrifugal casting has been recently introduced and described by which castings similar to the ordinary chilled castings can be produced in the following way: The mould is made to rotate, when a hard steel is poured in, which flies to the sides; soft steel is then poured into the hollow center, with the result that the casting produced has a soft core and a hard face."

"It has been observed in several instances that X rays have a peculiar action on the skin, causing it to get red and sometimes black, and also causing the hair to fall out."

"It is always the unexpected that happens. In November, 1896, a Spanish periodical, La Ilustracion Española y Americana, in an article about the capital of the Philippines, made the following statement: 'Even the strongest army would fail to capture Manila from the land, but the city has no protection of any importance against modern men-of-war.' The Spaniards did not consider until quite recently the possibility of an attack by a hostile fleet, and the hasty preparations made when such a contingency arose were not sufficient to remedy the inferiority of these fortifications."

JUNE 1848. "The America, the new steamer of the Cunard line, arrived at Boston on Tuesday evening last from Liverpool, making the passage in 10 days and 8 hours. She made the passage to Halifax in 8 days and 20 hours and to Boston in 10 days, having been detained 8 hours in the fog. This is the quickest passage that ever has been made to America."

"Miss Maria Mitchell, of Nantucket, discoverer of the Comet which bears her name, was unanimously elected an honorary member of the American Academy of Arts and Sciences, at their last general meeting. We believe that this is the first time such an honor has been conferred on any lady in this country."

"Two amputations were performed last week at the Bellevue Hospital of this City, the one that of an arm by Dr. Cox, one of the Assistant physicians; and the other, that of part of the foot, by Dr. Childs one of the visiting Surgeons. In both cases the patients were first rendered insensible to pain by the use of Chloroform diluted with four times its bulk of sulphuric ether, with which a sponge was moistened and held to the nostrils by a Resident Physician, Dr. Reese, who has had extensive experience in the use of both chloroform and ether, although this was the first time these agents had been used here in combination."

"The Electro Magnetic ore separator is a machine invented by Ransom Cook, Esq. late Superintendent of the Clinton County State Prison in this State, and employed for the separation of the magnetic ore at the mines in that place. The principle of this invention consists in charging successively by a battery different rows of magnets on a revolving cylinder, so that the magnets will lift magnetic ore from an endless web as it passes under the cylinder."

"The garden of the Empress of Russia on the island of Yelaguine has conservatories of glass which are upwards of two thousand feet in length. Eighteen columns support the roof; it is nearly eighty feet high, and upwards of one hundred in width."

"The stupendous project of uniting the waters of the broad Pacific with those of the Atlantic by a Railroad to the Bay of San Francisco, California, is one of great magnitude, but it is one which will, and must yet be carried into execution. A railroad will yet connect New York with San Francisco, and a line of steam vessels will cross the Pacific regularly, keeping up a continual communication with China and the United States."

"A remarkable telegraph race occurred in this city last week, when the Whig National Convention was in session in Philadelphia. The Jersey City wires were monopolized by the Whig Press, and our other papers had to bite their thumbs for news. But science was not to be baffled for news by a monopoly, so they dispatched a message via Albany and away round by Buffalo, Cleaveland, Cincinnati and Pittsburg, to Philadelphia. In fifteen minutes, over the same route, an answer was returned announcing the result of the second balloting for candidates for the Presidency. It is just as easy to stop the lightning as the enterprise of some of our papers."

These "sound jurors" record their preferences as they listen over test circuits.

Trial by "Sound Jury"

The engineer in the foreground talks over the test circuits which the other engineer sets up on a "circuit simulator."

THE COVER

The painting on the cover shows the fragments of baked clay that remain of the law code of Lipit-Ishtar (*page 44*), a Sumerian king who reigned in the nineteenth century B.C. Around the fragments are implements used in their translation by the archaeologist.

SCIENTIFIC AMERICAN, June 1948: Vol. 178. No. 6. Published monthly by Scientific American, Inc., Scientific American Building, 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 Director, SCIENTIFIC AMERICAN, 24 West 40th Street, New York 18, N. Y.

Subscription correspondence should be addressed to T. J. [illegible], Circulation Director. SCIENTIFIC AMERICAN, 24 West 40th Street, New York 18, N. Y.

Change of address: Please notify us six 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 ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Credits
9	Harris and Ewing
10-11	Irving Miller
14	W. A. DeMonbreun
15	David E. Scherman
16	Arthur Seymour
17	Roman Vishniac
19	Arthur Seymour
20-21	T. C. Schneirla
22	Roman Vishniac
23	American Museum of Natural History
26	University of California Radiation Laboratory
28-32	Irving Geis
33	C. F. Powell and G. P. S. Occhialini
34-35	Jon Brenneis
36-37	Top—Jon Brenneis; Bottom—University of California Radiation Laboratory
39	Jon Brenneis
41	Brown Brothers
42-43	(*l. to r.*) Haskins Laboratories, F. G. Wood, Jr., American Museum of Natural History, K. Chester
44	David E. Scherman
46-47	University of Pennsylvania Museum
48-49	U. S. Forest Service
50-53	Paul Landacre
55	William Auerbach-Levy

SCIENTIFIC AMERICAN
Established 1845

CONTENTS FOR JUNE 1948 VOLUME 178, NUMBER 6

ARTICLES

THE NATIONAL SCIENCE FOUNDATION by Alfred W. Jones
To assure its leadership in science, the U.S.—Congress and the President approving—is about to launch a large-scale program of basic research in science. A review of the new Foundation's job and some future problems. **7**

HISTOPLASMOSIS by Martin Gumpert
Millions of Americans appear to be afflicted with a strange new fungus disease that has sprung up suddenly out of the biological underworld. It produces lesions like those in tuberculosis, which confuses diagnosis. **12**

THE ARMY ANT by Theodore C. Schneirla and Gerard Piel
Social scientists have learned much from this jungle creature. New studies of the regimented insect's amazingly well-knit social organization convey some interesting lessons in the nature of group behavior and social suicide. **16**

THE ULTIMATE PARTICLES by George W. Gray
In his investigations of the elementary units and forces in the microcosm of the atom, the physicist is approaching the ultimate frontiers of physical reality. Presenting a comprehensive summary of his knowledge to date. **26**

THE BIOLOGY OF OLD AGE by Florence Moog
Death is not a universal rule of nature. The durability of living tissue in bacteria, fishes and plants suggests that physiological researches may result in considerably lengthening the present effective span of human life. **40**

"IF A SLAVE GIRL FLED . . ." by Francis R. Steele
From four small fragments of an ancient Babylonian tablet. Archaeologist Steele has reconstructed a law code older than the great Hammurabi's, thereby adding a century and a half to the known history of codified law. **44**

WHITE PINE by Donald Culross Peattie
The fascinating saga of North America's noblest and most valuable tree, which played a little-sung but important part in the rise of the British Empire, in the American Revolution and in the construction of the U.S. **48**

SRINIVASA RAMANUJAN by James R. Newman
The biography of a self-taught Hindu boy, one of the great mathematical geniuses of the twentieth century, whose "profound and invincible originality" has left a memorable imprint upon modern mathematical thought. **54**

•

DEPARTMENTS

LETTERS **1**
50 AND 100 YEARS AGO **2**
SCIENCE AND THE CITIZEN **24**
BOOKS **58**
THE AMATEUR ASTRONOMER **60**
BIBLIOGRAPHY **64**

yesterday we have received your recent "CARE" package. Once more the unpacking of these very useful foods has been a joy
My greatest thanks for the parcel you have sent to me with CARE.
I already received two.
Par cette lettre je vous remercie d'un nouveau colis que vous avez eu la bonté de m'envoyer
All the wonderful foods in your CARE package are still scarce here. It is impossible for you to imagine how des-
PAR AVION
It's MORE FOOD for LESS MONEY
Send
CARE
Food Packages Abroad... $10.
INSURED · GUARANTEED DELIVERY
DUTY FREE · RATION FREE
NON-PROFIT · GOVERNMENT APPROVED
CONTENTS:
1 lb. Braised Beef
2 8 oz. tins of Liver Pâté
2 8 oz. tins of Corned Beef Loaf
2 lb. Shortening
1 lb. Chocolate
2 8 oz. tins of Cocoa
2 lb. Whole Milk Powder
8 oz. Egg Powder
1 lb. Apricots
1 lb. Raisins
7 lb. Flour
2 lb. Sugar
1 lb. Coffee (For Britain, ½ lb. tea)
2 3 oz. Bars of Soap
¼ oz. Yeast
CARE Cooperative for American Remittances to Europe, Inc., 50 Broad St., New York 4
CARE Food Packages may be sent to: Austria, Belgium, Bulgaria, Czechoslovakia, Eire (Ireland), Finland, France, Germany (American, British and French Zones and all of Berlin), Great Britain, Greece, Hungary, Italy, Netherlands, Poland.
Prompt Delivery Depends on Clear, Correct Address. PLEASE PRINT
Enclosed is ten dollars for each CARE package
☐ Check ☐ Money order
To Be Delivered To:
Your Name and Address
(Name)
(Street and Number)
(Street and Number)
(Town and Country)
(signature of sender) (Date)
(City and State)
A RECEIPT, SIGNED BY THE BENEFICIARY YOU NAME, WILL BE RETURNED TO YOU

SCIENTIFIC AMERICAN

JUNE 1948 VOL. 178, NO. 6

THE NATIONAL SCIENCE FOUNDATION

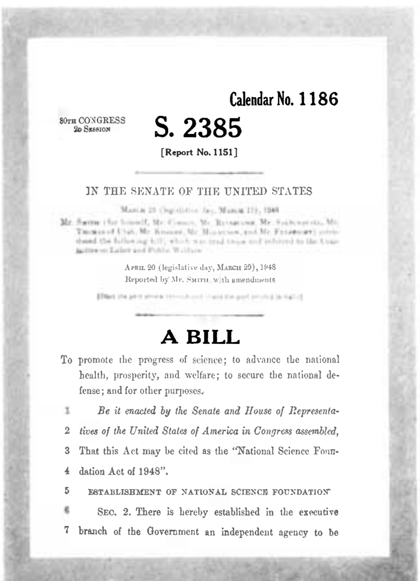
Its momentous responsibility will be to assist the fundamental research which is essential to human progress

by Alfred Winslow Jones

ON MAY 5 the Senate passed, by a unanimous voice vote, the long-awaited legislation in behalf of basic science. By the time this article appears in print the House may have acted and the President may have signed the bill. If so, there will be set up in Washington a National Science Foundation with unique responsibilities and powers. Almost everyone concerned will be happy about the outcome of a long. irksome debate, and reasonably satisfied with the compromises reached on the many issues that had to be resolved to bring the Foundation into being.

The Foundation will do its job mainly by making research grants and loans to non-profit institutions and by giving scholarships and fellowships to individuals. It will support research for the armed services after consulting with the Secretary of Defense. It may set up commissions for special jobs and may establish divisions for dealing permanently with particular branches of science. The chief emphasis is on the natural sciences, but "other sciences" also may be assisted, which is as near as the present legislation comes to including the social sciences. Here, almost surely, is a realm for ardent future discussion within the Foundation.

The spacious powers given to the Foundation are to be further defined and exercised by a 24-man board of persons "eminent in the fields of the basic sciences. medical science, engineering, education. or public affairs," serving part-time and appointed by the President. To execute


Calendar No. 1186

80TH CONGRESS 2D SESSION

S. 2385

[Report No. 1151]

IN THE SENATE OF THE UNITED STATES

APRIL 20 (legislative day, MARCH 29), 1948
Reported by Mr. SMITH with amendments

A BILL

To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Science Foundation Act of 1948".

ESTABLISHMENT OF NATIONAL SCIENCE FOUNDATION

SEC. 2. There is hereby established in the executive branch of the Government an independent agency to be

SENATE BILL, embodying changes which caused 1947 veto, passed May 5.

the policies and decisions of the board, the Foundation will have a full-time $15,000-a-year director, also appointed by the President. According to the present budget figures, the Foundation will have $20 million to spend during its first year. As it learns how to spend money, its appropriations should grow from year to year, reaching a figure that Presidential adviser John R. Steelman projects as $100 million after 10 years.

U. S. scientists are almost unanimous about the need for large-scale Federal aid to basic research. Without it American scientific work would move more and more toward the periphery of application, leaving a less and less adequate ratio of basic work going on at the center—except, for a time, under military auspices. The ultimate result might be a hollow shell of mere technology, followed by the decline of technology itself.

The reasons are familiar enough. The practical Yankee genius has always tended toward the making of tools and the mass production of goods, at the expense of the essentially speculative enterprise of basic or pure science. The main sponsors of American science have been industry, the government, the universities and the foundations. Industry, by and large, wants practical results for the money it spends. The people in charge of government agencies and the legislators who make the appropriations have followed the bent of industry. All of the agencies listed on the next page have sponsored chiefly applied science. This leaves the universities and foundations as the main traditional promoters of basic research. They have done the best they could, but their funds have been limited and the pull upon them by industry for applied studies has been strong.

As a consequence we have been notoriously dependent on European science for basic findings and even for development work, since Europeans, supported by their governments. have been by far the more

GOVERNMENT AGENCIES AND LABORATORIES IN SCIENCE

Department of Agriculture

Office of Experiment Stations
Bureau of Animal Industry
Bureau of Dairy Industry
Bureau of Plant Industry, Soils and Agricultural Engineering
Bureau of Entomology and Plant Quarantine
Bureau of Human Nutrition and Home Economics
Bureau of Agricultural and Industrial Chemistry
Agricultural Research Center, Beltsville, Md.
Forest Service
Soil Conservation Service
Production and Marketing Administration
Farm Credit Administration

Department of Commerce

National Bureau of Standards
Civil Aeronautics Administration
Weather Bureau
Coast and Geodetic Survey

Department of the Interior

Geological Survey
Bureau of Mines
Fish and Wildlife Service
Bureau of Reclamation

Navy

Office of Naval Research
- Planning Division
- Naval Research Laboratory
- Special Devices Center

Bureau of Aeronautics
Bureau of Yards and Docks
Bureau of Medicine & Surgery
Bureau of Ships
- David W. Taylor Model Basin
- Navy Electronics Laboratory

Bureau of Ordnance
- Naval Ordnance Laboratory
- Naval Ordnance Test Station

Army

Army Technical Services
- Quartermaster
- Signal Corps
- Ordnance
- Chemical
- Engineers
- Medical
- Transportation

Air Force

Wright Field
Patterson Field
Cambridge Field Station
Ladd Field
Muroc Army Air Base
Watson Laboratories
Alamogordo Army Air Field
Boca Raton Army Air Field
Eglin Field
Olmsted Field

Federal Security Agency

National Institute of Health
U. S. Public Health Service
Food and Drug Administration

National Advisory Committee for Aeronautics

Langley Memorial Aeronautical Laboratory
Ames Aeronautical Laboratory
Flight Propulsion Research Laboratory

The Smithsonian Institution

Research Division

Atomic Energy Commission

Research Division

Federal Works Agency

Public Roads Administration

Federal Communications Commission

Engineering Department

Federal Power Commission

Bureau of Power

Veterans Administration

Medical Research Division

Treasury Department

Bureau of Printing and Engraving
Bureau of the Mint
Coast Guard

Federal Loan Agency

Office of Rubber Reserve

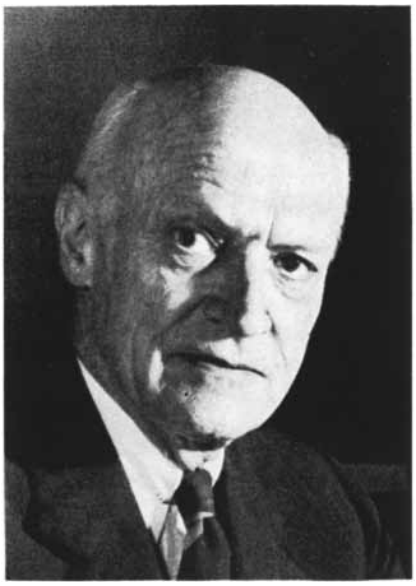
adventurous pioneers at the frontier of knowledge. To cite one of many illustrations: Of the 149 Nobel prize winners in physics, chemistry and medicine since 1901, 123 were born and received all their early training in Europe, and only 22 were U. S.-born and trained. (Two awards went to Canada, and one each to India and Argentina.) As between Europe and the U. S., this is out of all proportion to national wealth and the application of scientific findings.

The war has obviously left Europe unable to maintain its old contributions to the international fund of pure science. If private American efforts could fill the gap, there would be no problem, but actually they are failing to maintain even the traditional insecure position of pure science in this country. In 1929 the funds laid out for scientific research by universities and foundations (the most accurate measure we have for the support of basic research) amounted to only 15 per cent of a national research budget of about $170 million. By 1939 the ratio had shrunk to 10 per cent and, although the dollar total of university and foundation research funds had increased to $35 million, a substantial part of this outlay included income from research contracts with industrial concerns, which represented a diversion from pure to applied science.

More recently universities and foundations have suffered from lower yields on their investments and from higher costs of research, and the universities have had more students and hence greater deficits. During the war the nation's proportion of development expenditures, other than those of industry and the Federal government, shrank to 4 per cent; it now stands at about 8 per cent. Of the $2.5 million which Columbia University, for example, had this year for physical research, only $16,000 was from University funds, the rest coming from the government, most of it from the Atomic Energy Commission.

JUST AS critical is the manpower shortage. Curtailment of education during the war cut the maturation of new scientists by half. The grievous loss may be estimated as some 20,000 graduates, including 3,000 doctors of science. Those who have been graduated are under an almost irresistible pull from industry. If it were not for a new interest in basic science on the part of the armed services, the plight of fundamental research would be cause for even greater alarm.

The war itself brought an almost total inhibition of basic research in the U. S. Virtually to a man, the scientists of the U. S. were brigaded under the command of the Office of Scientific Research and Development for the most massive campaign of applied research ever organized. The more than 2,000 projects to which they were assigned spent $300 million directly and guided the spending of hundreds of millions more. Two of the



SENATE BILL was introduced by Senator H. Alexander Smith of New Jersey, who also was its 1947 sponsor.

projects, the atomic bomb and radar, began as hopes and developed into billion-dollar enterprises by the end of the war.

The stupendous achievements of the OSRD shortened the war and saved countless lives, but its aftereffects must now be reckoned with. During the war the armed services received from the scientists imaginative and efficient new devices and techniques useful in almost every branch of operations. The war, therefore, endeared science to the military mind and even won it over to the need for basic research. The military is now determined that there shall be no postwar

HOUSE BILL for the Foundation was sponsored by Representative Charles A. Wolverton, of New Jersey.

divorce. Under military auspices, science in general, and even some branches of pure science, are now being maintained in a style to which they have never before been accustomed.

The best measure of the government's and the military's present involvement in scientific work is the Federal budget estimate for research for the fiscal year beginning July 1. The grand total is likely to be about $825 million, an increase of almost 25 per cent over this year and 15 times as much as was spent in any year before the war. Of this staggering sum, over $650 million is for the Army, Navy, Air Force and for the military work of the Atomic Energy Commission and the National Advisory Committee for Aeronautics.

A rough indication of the proportion of government funds which is being allocated to pure and applied research, respectively, was given in the so-called Steelman report, issued by the President's Scientific Research Board, John R. Steelman, chairman. Analyzing research expenditures in the fiscal year that ended in mid-1947, the report estimated that some $570 million out of a total of $625 million went for applied and developmental studies. For the armed services the figures were $465 million out of $500 million. Of the $100 million spent by the four civilian agencies with the largest research budgets—Agriculture, Commerce, Interior and the NACA—about $85 million was spent on nonbasic work, chiefly background research, that is, fact-gathering, compiling, surveying and the like.

Since the end of the war scientists have been actively debating the role of the military in the scientific affairs of the country. Some are contented enough, and see no serious threat to the integrity of their work. Others are extremely unhappy —alarmed about the fatal blight of secrecy, about dismissals on mere suspicion of unreliability, about the inevitably limited objectives of the Army and Navy. They are afraid of the intrusion of others into their work and afraid that military-sponsored basic science will be cut off in favor of applied efforts when the now copious funds may be curtailed—at a time when the universities will have become dependent on military contracts.

Most scientists are grateful for the stopgap aid they have had, but many are now eager for other sponsorship. The body of scientific opinion appears to be opposed to an entire new department with a Secretary of Science (as was once proposed) but in favor of a civilian, independent agency. Specifically, through the National Science Foundation they look for a good, solid compromise between the old days of freedom and poverty and the wartime binge of regimentation and inexhaustible funds.

The new agency has been at least three years in the making. The New Deal, the war and the work of the OSRD under Vannevar Bush provided the impulse. Then developed a serious struggle over important details. In July of 1945, the creation of a "National Research Foundation" was urged by Bush in his report, "Science, the Endless Frontier," written in answer to the request of Franklin Roosevelt. The following October, Senate committee hearings began on three bills. One of the two important ones, the Magnusson bill, followed faithfully the recommendations of the Bush report and put control of the Foundation in the hands of a part-time board appointed by the President. The Kilgore bill incorporated additional ideas by providing for strict patent controls in the interest of the government and in giving control and responsibility to a presidentially appointed director, advised by a board of scientists. This matter of administration became the most hotly contested point in the subsequent debate. In July of 1946, a compromise Kilgore-Magnusson bill (S. 1850) passed the Senate, but was killed in the House. The compromise, which seemed to represent a majority view among scientists, leaned too far toward the Kilgore position to be acceptable to the Bush people.

Last year Senator H. Alexander Smith of New Jersey introduced S. 526, which passed both the Senate and the House. This bill leaned just as far toward the Bush position, but was supported by many scientists who had come to feel that it was about the best they could get. The Smith bill was regretfully vetoed by the President on the ground that it set up an impractical type of administration with the power in the hands of a board rather than a single director.

The 1948 Smith bill (S. 2385), which will pass in the closing days of the 80th Congress—or, failing that, the similar bill that clearly should be made a law in 1949—is a reasonable enough compromise, though it is still administratively not what the President hoped to get. The chief executive officer of the National Science Foundation will be appointed by the President, to be sure, but he will be fully governed and guided by the Foundation's legislative body, its 24-man board of eminent scientists and others. To this board is left the final decision on most of the controversial matters that have been fought over for the last three years.

THE FOUNDATION will decide just how wide a geographical distribution to give its grants and contracts. It will decide to what extent it can hold as public property patents resulting from work in which it takes part, and how far it will have to go in allowing patent rights to those with whom it makes contracts. It will decide whether or not to set up its own executive committee. It will prescribe its own rules and regulations. It may acquire real and personal property. It may receive funds donated by others. It may publish freely in the field of science.

The Foundation must clear security matters with the Secretary of Defense, and it may not go into atomic research without the permission of the Atomic Energy Commission. It is authorized to cooperate in international scientific research but any such activity "shall be exercised in such a manner as is consistent with the foreign policy objectives of the United States as determined by the Secretary of State, after consultation with the Director."

The greatest of the Foundation's considerable powers is that of deciding just what jobs to tackle. Certain obvious divisions—1) Medical Research, 2) Mathematical, Physical, and Engineering Sciences, 3) Biological Sciences, and 4) Scientific Personnel and Education—are suggested by Congress, but even these are not insisted upon.

With the probable passage of this legislation, the scene shifts. The Foundation itself now becomes the focus of arguments as to what it should do and how it should do it. The most vital and difficult single issue will be whether or not the Foundation shall undertake work in the field of social science.

Such a venture is admittedly fraught with difficulties. The social sciences differ from the physical and biological sciences more than the latter differ from each other. By the accepted standards of scientific work, the social sciences are less mature. Experimentation in them is usually impossible. Those who operate with social data are forced into more complex and higher abstractions and into many areas where measurement is impossible. Social science has ill-defined limits. At the end of its spectrum farthest from the biological sciences, its lines tend to blur into an area (from the scientific point of view) of mere heat—the warm, disorderly, ethically supercharged humanities.

A more serious difficulty stems from the deep and stubborn cleavage between pure and applied effort in social science. As James Bryant Conant has pointed out, there was a time when such a condition did not constitute a detriment to any branch of science. Until perhaps 100 years ago, science was almost entirely pure, and technology was in another realm. But now, the sphere of science has become so completely integrated that a scientific effort which remains endlessly pure, with no eventual application, is not thought of as science at all but as some sort of recondite, priestly discourse.

TO A DEGREE, this is what has happened to social science. Frightened away from the periphery of application by the fierce heat of controversy that is engendered there by conflict of interests, some "social scientists" take refuge in "pure" effort that is not, nor ever will be, called into practical play. Many an able social scientist spends his time endlessly gathering facts which are not really gathered to be used, because their use would get the user into trouble.

ORGANIZATION of the Foundation is depicted on the basis of the Senate bill introduced by Senator Smith. Its power is principally in the hands of the 24-man board, although the President appoints the director. Many of the organizational details have been left to the discretion of the Board.

Pure and applied social science can serve special interests admirably, but the National Science Foundation is being set up to serve the general interest. Can it do so in the field of social science? The difficulties will loom so large that it will take a board of 24 (or at least a majority of 13) brave men to make the effort.

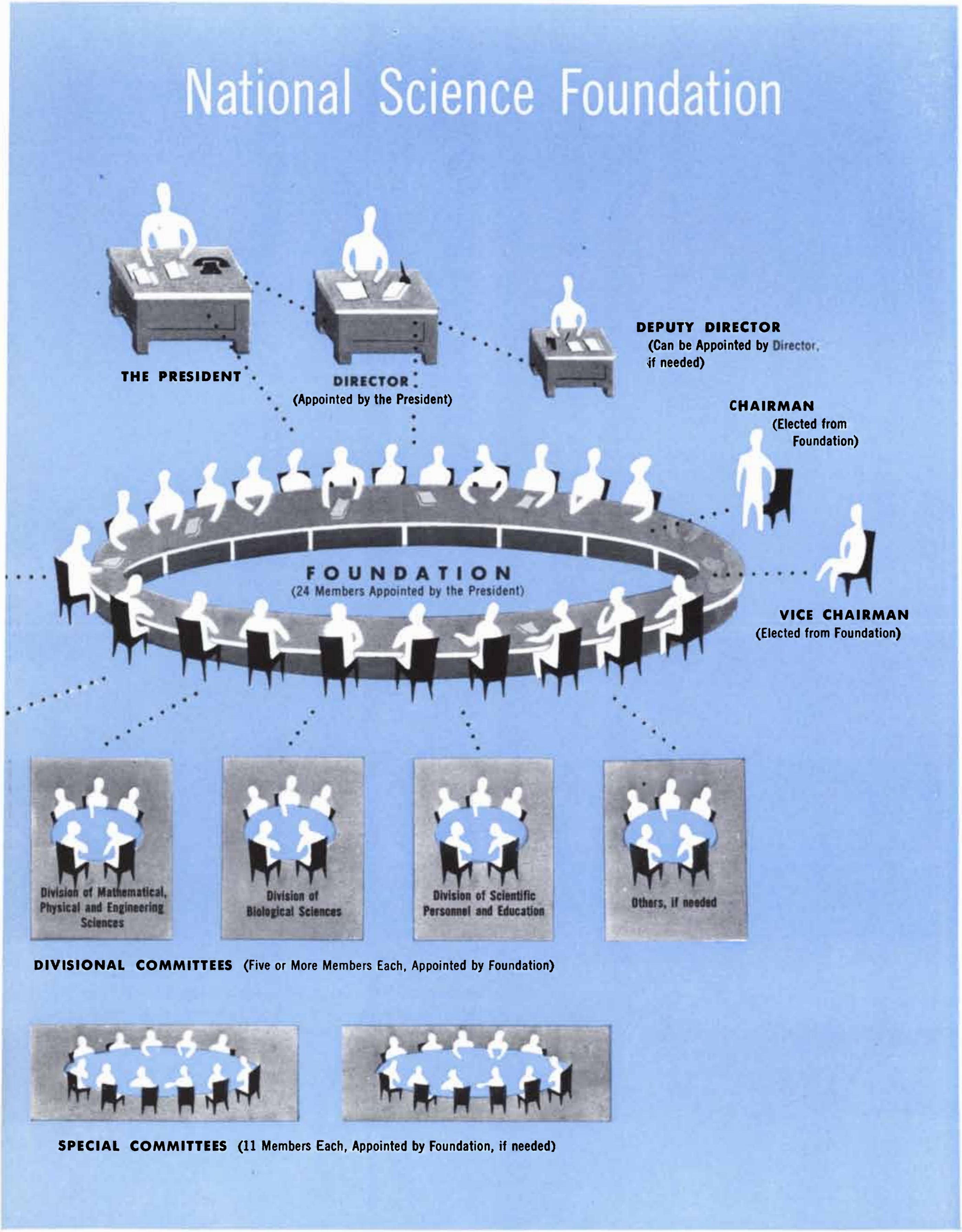
Yet none of this is to deny the scientific and human potential of social science, nor its great and urgent need. True, the direction of effort in the social sciences must differ sharply from that taken in the natural sciences. In the latter, the emphasis will rightly be on pure or basic work, since the spontaneous drift is away from it. In the social sciences, more attention will have to be given to practical problem-solving.

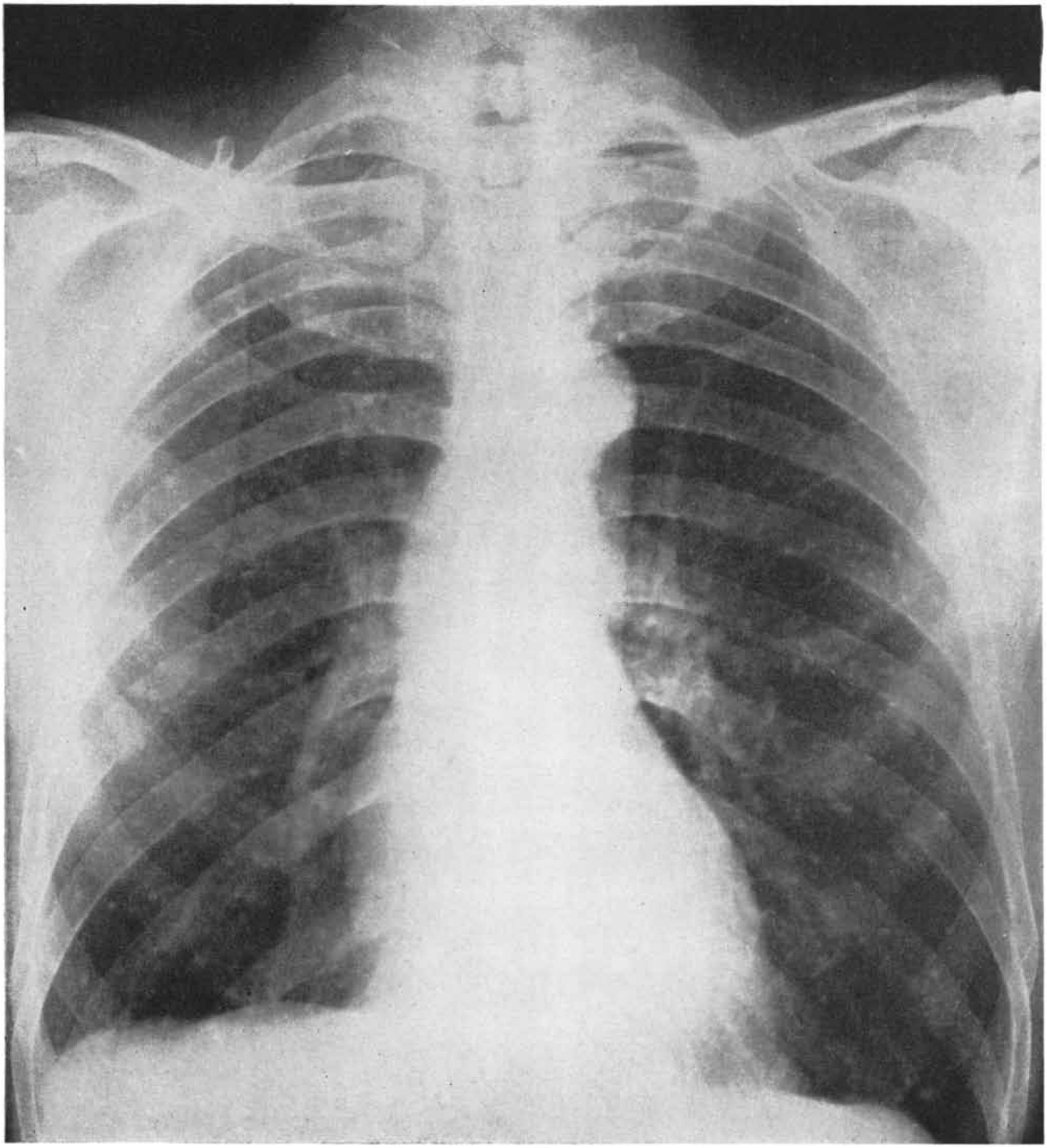
Some things the Foundation can do easily. It can help develop the tools of social science, such as statistics and semantics. It can go into certain fields that seem relatively factual and remote from the battle, such as anthropology and demography. It could look at such problems as labor mobility, which would have to be gone into simultaneously in all parts of the country and would cost some $800,000. It could study the adjustment of individuals to handicaps and illness. It could look at the procedures of that big and influential industry, public opinion polling—its sampling methods, panel studies, interviewer bias, and the like.

Since none of this promises to solve basic social and economic problems, the Foundation could, once its formula is worked out and once it has the necessary experience, go after the things that really matter.

Science is increasingly becoming a part of our culture, and general Federal aid is hardly more than a recognition of that fact. Science has given us much of what we have of material wealth, and is certain to give us more. But it is now generally recognized that material progress brings the exaggeration of social and economic problems, while at the same time it makes their solution possible. Will the coming National Science Foundation try to realize that potential, or will it be satisfied to act merely as one more vitally needed agency for still more material progress? Here the President, who appoints the board of the Foundation, and the board itself will face a major decision.

Alfred Winslow Jones is a writer on social science.


National Science Foundation
THE PRESIDENT
DIRECTOR
(Appointed by the President)
DEPUTY DIRECTOR
(Can be Appointed by Director, if needed)
CHAIRMAN
(Elected from Foundation)
VICE CHAIRMAN
(Elected from Foundation)
FOUNDATION
(24 Members Appointed by the President)
Division of Mathematical, Physical and Engineering Sciences
Division of Biological Sciences
Division of Scientific Personnel and Education
Others, if needed
DIVISIONAL COMMITTEES (Five or More Members Each, Appointed by Foundation)
SPECIAL COMMITTEES (11 Members Each, Appointed by Foundation, if needed)



LUNG LESIONS revealed in this X-ray photograph may have been produced either by tuberculosis or by histoplasmosis. Tuberculin test and histoplasmin skin test, however, may also be called into play. Symptoms of "acute", or non-fatal, form of histoplasmosis are rather similar to those of grippe, but sometimes the disease passes without manifestation worthy of notice.

HISTOPLASMOSIS: THE UNKNOWN INFECTION

The mild form of a fatal fungus disease appears to be spreading in the U. S. Its lesions are much like those of tuberculosis, complicating diagnosis

by Martin Gumpert

IN 1944 a five-month-old infant was admitted to the pediatric hospital of Vanderbilt University in Nashville, Tenn., with a puzzling illness. Its symptoms, which included fever, loss of appetite, and anemia, were those of many common childhood ailments; yet it was evident that this child was uncommonly sick. Dr. Amos Christie of the University staff suspected that its ailment was an obscure fungus disease called histoplasmosis. A skin test, and later the discovery of the fungus in the infant's blood, proved his diagnosis correct. No treatment is known for this disease, and the child died.

Up to that time, the medical literature had recorded only 80 cases of histoplasmosis, all of them fatal. The disease was thought to be extremely rare; even its name was unknown to most physicians. Dr. Christie, a pediatrician interested in the study of fungus infections, availed himself of the opportunity to investigate this little-known disorder. The skin test for histoplasmosis, which had only recently been developed, offered a handy method. He gave the test to the parents of the afflicted child. Although apparently healthy, both parents exhibited positive reactions to the test, indicating that they were infected with the fungus or had been at some time in the past. The scientist went on to apply the same test to several groups of children and found that a surprisingly large percentage of them were similarly infected, although many showed no symptoms of illness. Dr. Christie concluded that there must be a benign form of the disease of which doctors had been unaware, and that histoplasmosis was probably more widespread than anyone had suspected.

His suspicion was soon confirmed. Early in 1945 he received a visit from Dr. Carroll E. Palmer of the U. S. Public Health Service. Dr. Palmer examined closely some X-ray pictures that Dr. Christie had made of his suspected histoplasmosis patients. They showed calcifications of the lungs like those in tuberculosis. But the patients did not have tuberculosis; they had reacted negatively to tuberculin tests. Startled by the resemblance of these lesions to those of tuberculosis, Dr. Palmer decided to make a large-scale national survey. He gave the histoplasmin skin test to thousands of student nurses in 65 nursing schools distributed in various sections of the U. S. The results were astonishing: almost one fourth of all the students reacted positively to the test. The incidence of the disease varied by geographic areas. It appeared to be highest in the East Central states. In Kansas City, Mo., for example, 62 per cent of the persons examined had positive reactions.

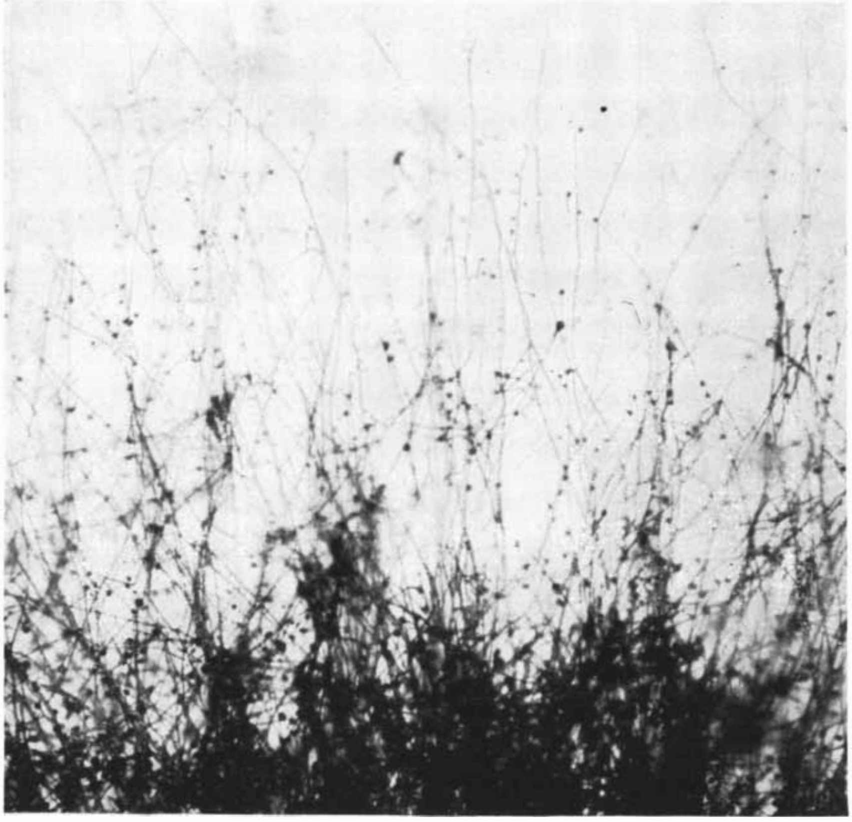
Since it seemed reasonable to assume that a positive reaction to the test was good evidence of previous infection with the histoplasmosis fungus or a closely related organism, Dr. Palmer decided that this disease, formerly thought so rare, must be fairly common. Later studies have supported his view. As is often the case when a disease becomes more widely recognized, there has been a sudden increase in the number of reported cases of histoplasmosis. It is now thought that millions of Americans are afflicted with this infection. And there is good reason to believe that a very high proportion of patients who have been diagnosed as tubercular because of lung calcifications may have histoplasmosis instead.

The high rate of mortality in diagnosed cases of histoplasmosis indicates the dangerous potentialities of this disease. It appears to exist in two forms: a so-called "acute" type, which is the mild form discovered by Dr. Christie, and a "chronic" type, which is highly fatal. The "acute" infection passes quickly and in most cases is unrecognized, since it either shows generalized symptoms like those of acute grippe or goes through a subclinical course that is not noticed at all, as in many of Dr. Christie's cases. The "chronic" type —the classical form of the disease—has been recognized only since the beginning of this century. It is sometimes known as Darling's Disease, after the American physician Dr. Samuel T. Darling, who discovered it. It is still difficult to diagnose, as mentioned earlier, because its symptoms do not distinguish it sufficiently from other diseases. The most common symptoms are fever, anemia, enlargement of the liver and spleen, swelling of lymph glands, loss of appetite and weight, ulcerations of the mucous membrane of the mouth, especially of the tongue, and a diminution in the number of white blood cells.

THE history of this baffling infection demonstrates the flexibility of mind demanded by scientific investigation and the necessarily tentative nature of all conclusions in science. Histoplasmosis confused medical scientists from the beginning because it was so much like other diseases. In 1906 Dr. Darling, then head of the Ancon Hospital in the Panama Canal Zone, observed among his patients a few cases of what seemed to be kala-azar, the "black disease" or "dumdum fever," which was then ravaging India. This Asiatic disease, which is caused by a parasitic protozoon of the Leishmania group, had not previously been seen in the Western hemisphere. But Dr. Darling's patients had two characteristic symptoms of kala-azar—enlargement of the spleen and a decrease of the white blood cells. The patients died, and in autopsies Dr. Darling found in their organs an organism resembling the Leishmania of kala-azar. He called this parasite, which he believed to be a protozoon, *Histoplasma capsulatum.*

By 1912 further study had led to the conclusion that the histoplasma organism was not a protozoon but a fungus. It was not until 1934, however, that a pure culture of Histoplasma capsulatum was obtained, by Dr. W. A. De Monbreun of Vanderbilt University. Now able to produce the disease experimentally in animals, he established that its agent was a

ORGANISM which causes histoplasmosis is the fungus *Histoplasma capsulatum.* When it invades the body it grows in the reticulo-endothelial system, which includes organs such as the spleen and liver. There its colonies become encapsulated much as those of the tuberculosis bacillus.



GROWING IN AIR on a culture dish, H. capsulatum sends out tendrils bearing spores. The route by which the disease spreads is not known but investigators think it may be borne through the air in droplets. This theory is enhanced by the fact that the disease often attacks the lungs.

fungus which is classified as belonging to the genus Histoplasma of the family Coccidioides.

This was a discovery of far-reaching significance. It gave proof of what was essentially an unknown type of disease. Fungus infections of the skin, such as ringworm and athlete's foot, were well known, but little attention had been given previously to systemic fungus infections, which are generally dangerous and often fatal. Studies which followed left no doubt that general fungus infections are much more frequent than had been supposed.

A DISEASE closely related to histoplasmosis has been known for some years. It is coccidioidomycosis, also known as San Joaquin Valley Fever or Desert Fever. It is endemic in certain districts of California and Arizona. Its agent is a fungus of the same family as Histoplasma. Like histoplasmosis, this disease has a relatively harmless "acute" form and a fatal "chronic" one. Also like histoplasmosis, it sometimes produces lung lesions resembling those of tuberculosis.

The discovery by Drs. Christie and Palmer, and by others who made the same finding independently, that fungus infections may cause lung calcifications has brought to light and helped to clear up a number of studies that had puzzled medical investigators. The tuberculin skin test for tuberculosis is believed to be almost infallible. Yet for a number of years physicians making mass X-ray examinations of children have reported that many children with apparently tuberculous lung lesions reacted negatively to the tuberculin test. In one mass examination in the South in 1938, an investigator found that there were almost as many chest lesions among patients who reacted negatively to the tuberculin test as among those who reacted positively. More than 48 per cent of the negative reactors had these lesions. In a considerable number of cases, even tuberculosis specialists pronounced these patients tuberculous beyond any doubt. For lack of any other explanation, all lung calcifications had long been classified almost automatically as evidence of tuberculosis.

But in 1938 Dr. Palmer, after examining 7,000 school children in Hagerstown, Md., decided that a large proportion had lung calcifications which could not be explained as tuberculous. Soon afterward, a group of investigators who examined Indian children in the Southwest established by means of a skin test that many of their lung lesions were caused by coccidioidomycosis. In Xenia, Ohio, however, an examination of 500 orphanage children showed that lung lesions found among them could not be attributed either to tuberculosis or to coccidioidomycosis. The examiners suspected that the cause must be some other fungus. Dr. Christie's 1944 histoplasmin skin test in Nashville finally identified what seems to be the major culprit: the fungus Histoplasma capsulatum.

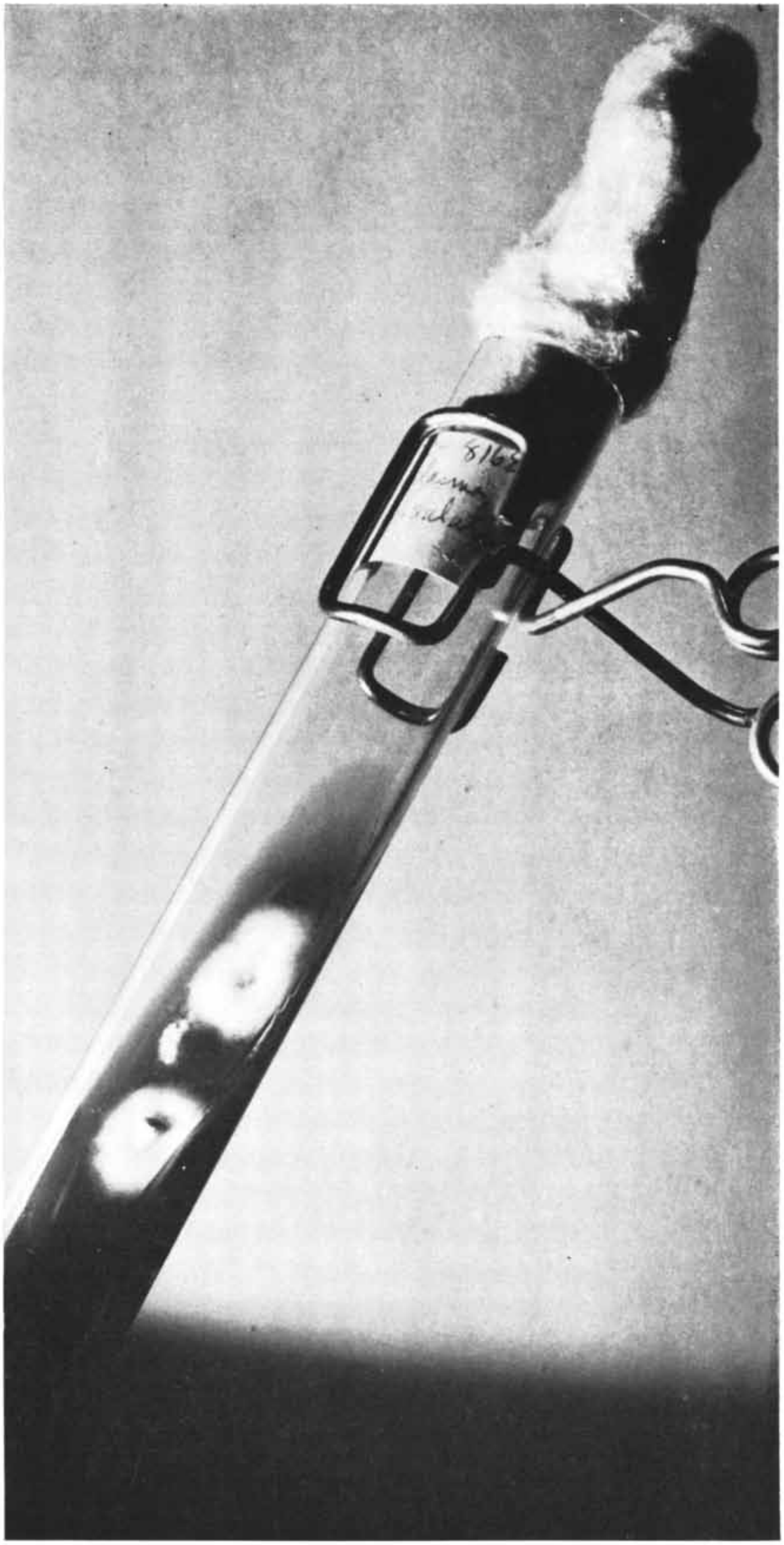
Little is known about this ominous fungus. It appears in nature in two varieties, one harmless, the other parasitic and responsible for causing histoplasmosis in man. The parasitic type is believed to be insect-borne. But the method by which the disease is spread is unknown; present medical opinion is that it is probably a droplet infection that attacks man through the respiratory system. The first significant symptoms of the acute infection are usually found in the respiratory organs. The fungus shows an affinity for cells of the reticulo-endothelial system (*i.e.*, chiefly the spleen and liver). The histoplasmin skin test to detect the fungus employs an antigen made from a culture of Histoplasma capsulatum. Dr. Chester Emmons of the National Institute of Health has questioned whether the test is specific for histoplasmosis alone; in animal tests he has found that coccidioidomycosis and another fungus disease give positive reactions to the same test. Presumably standardization of the test will eliminate these cross-reactions.

The disease seems to be more prevalent among adults than among children. A study in Kansas City, Mo., showed that the highest incidence of positive reactions to the test (88 per cent) occurred in the group of men aged 35 to 40; among women the highest incidence (67 per cent) was in the age group from 20 to 24. The principal histoplasmosis centers are Missouri, Kansas, Ohio, Indiana, Illinois, Tennessee, Arkansas and Louisiana.

THE role of fungi in human pathology has been too long overlooked. Our interest in the mysterious biological relationship between fungus and man has been greatly stimulated in the last few years by the discovery and use of penicillin, a fungus which is employed in therapy. But even penicillin may invade tissues and produce severe complications, as we are now coming to realize.

The new and dramatic history of histoplasmosis may have something to contribute to the basic medical problem of the threshold between health and disease. We have supposed that, thanks to new synthetic and antibiotic drugs, we are becoming more and more independent of our bacterial invaders and symbiotic parasites. Now suddenly a new threat springs out of the biological underworld, perhaps even stimulated in this case by our recent use of fungus species such as penicillin and streptomycin for curing man's ancient diseases. Nevertheless, one may venture to look on the bright side of the matter and hope that the study of histoplasmosis will open an entirely new field of attack and defense in the battle for health.

Martin Gumpert is a practicing physician and a writer on medical subjects.



CULTURE of the histoplasmosis organism is a white, fluffy growth rather similar to that of many other fungi, making identification difficult. Sometimes diagnosis is assisted by culturing specimens of blood and other infected material from a patient suspected of having contracted disease.

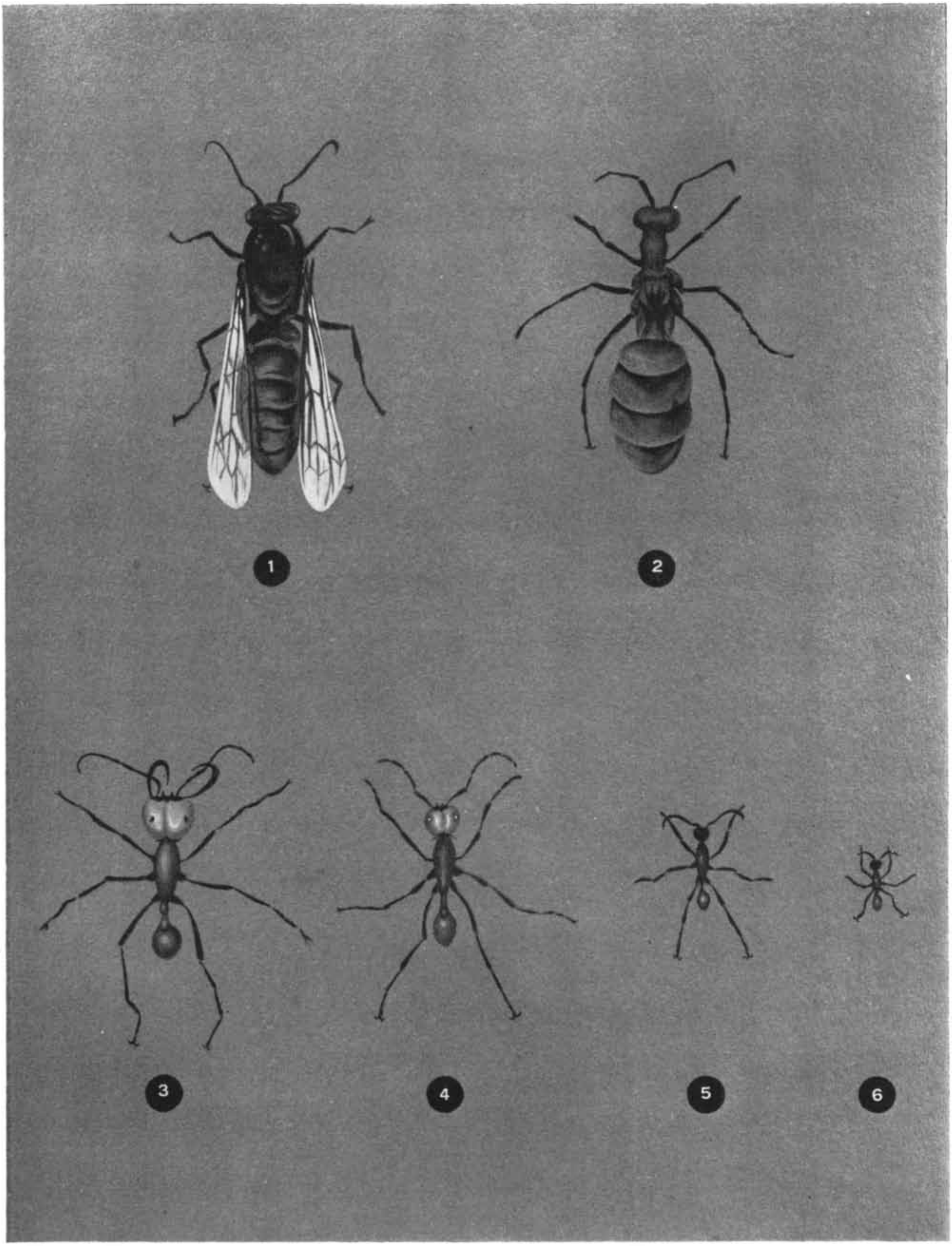


TABLE OF ORGANIZATION of an army ant colony is fixed by specialization in structure and function of its individual members, here shown 2.5 times life-size. Winged male (its appearance suggests the evolutionary link of ants to wasps) lives only long enough to mate a queen. Organization and behavior of the colony are polarized around queen (2) and her reproductive function. Workers, graded in size from major (3) down to minim (6) tend to specialize according to their size in defense, food-gathering or in nursing of offspring.

THE ARMY ANT

This explanation of how the creature conducts its complicated social life clearly distinguishes ants from men

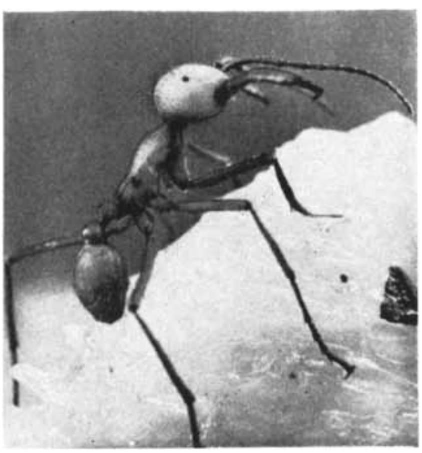
by T. C. Schneirla and Gerard Piel

Wherever they pass, all the rest of the animal world is thrown into a state of alarm. They stream along the ground and climb to the summit of all the lower trees searching every leaf to its apex. Where booty is plentiful, they concentrate all their forces upon it, the dense phalanx of shining and quickly moving bodies, as it spreads over the surface, looking like a flood of dark-red liquid. All soft-bodied and inactive insects fall an easy prey to them, and they tear their victims in pieces for facility in carriage. Then, gathering together again in marching order, onward they move, the margins of the phalanx spread out at times like a cloud of skirmishers from the flanks of an army.

THAT is how Henry Walter Bates, a Victorian naturalist, described the characteristic field maneuvers of a tribe of army ants. His language is charged with martial metaphor, but it presents with restraint a spectacle which other eyewitnesses have compared to the predatory expeditions of Genghis Khan and Attila the Hun.

Army ants abound in the tropical rain forests of Hispanic America, Africa and Asia. They are classified taxonomically into more than 200 species and distinguished as a group chiefly by their peculiar mode of operation. Organized in colonies 100,000 to 150,000 strong, they live off their environment by systematic plunder and pillage. They are true nomads, having no fixed abode. Their nest is a seething cylindrical cluster of themselves, ant hooked to ant, with queen and brood sequestered in a labyrinth of corridors and chambers within the ant mass. From these bivouacs they stream forth at dawn in tightly organized columns and swarms to raid the surrounding terrain. Their columns often advance as much as 35 meters an hour and may finally reach out 300 meters or more in an unbroken stream. For days at a time, they may keep their bivouacs fixed in a hollow tree or some other equally protected shelter. Then, for a restless period, they move on with every dusk. They swarm forth in a solemn, plodding procession, each ant holding to its place in line, its forward-directed antennae beating a hypnotic rhythm. At the rear come throngs of larvae-carriers and, at the very last, the big, wingless queen, buried under a melee of frenzied workers. Late at night they hang their new bivouac under a low-hanging branch or vine.

The army ant, observers are agreed, presents the most complex instance of organized mass behavior occurring regularly outside the homesite in any insect or, for that matter, in any subhuman animal. As such, it offers the student of animal psychology a subject rich in interest for itself. But it also provides an opportunity for original attack on some basic problems of psychology in general. The study here reported, covering the behavior of two of the Eciton species of army ants, was conducted by Schneirla over a 16-year period with extended field trips to the Biological Reservation on Barro Colorado Island in the Panama Canal Zone and to other ant haunts in Central America. In undertaking it, he had certain questions in mind. The central question, of course, was how such an essentially primitive creature as the ant manages such a highly organized and complex social existence. This bears on the more general consideration of organized group behavior as an adaptive device in natural selection. There was, finally, the neglected question of the nature of social organization. This is primarily a psychological problem because it concerns the contribution of individual behavior and relationships between individuals to the pattern of the group as a whole. It was expected that reliable data on these questions in the instance of the army ant might throw light on similar questions about human societies.



WORKER MAJOR is equipped with a wasplike sting in its tail as well as with big mandibles. Its aggressive response to extra-colony stimuli makes it the "soldier" of army ants.

The ant commends itself to study by man. Measured by the dispassionate standard of survival, it stands as one of the most successful of nature's inventions. It is the most numerous of all land animals both in number of individuals and number of species (more than 3,500 at present count). It has occupied the whole surface of the globe between the margins of eternal frost. Its teeming cities are to be found even on isolated atolls in mid-Pacific. The oldest of living orders, the ant dates back 60 million years to the early Jurassic period. More significant, the societies of ants probably evolved to their present state of perfection no less than 50 million years ago. Man, by contrast, is a dubious experiment in evolution that has barely got under way.

IN the esteem of political philosophers, from Solomon to Winston Churchill, ants have shared honors with the two other classes of social insects, the bee and the termite. Of the three, the ant is by far the most various and interesting. Bees live in hives; termites burrow almost exclusively in wood. Ants are not so easily pigeonholed. Lord Avebury, a British formicologist, marveled at "the habits of ants, their large communities and elaborate habitations, their roadways, possession of domestic animals and, even, in some cases, of slaves!" He might have added that ants also cultivate agricultural crops and carry parasols. It is the social institutions of ants, however, that engender the greatest enthusiasm. The late Henry Christopher McCook, in his *Ant Communities and How They are Governed, A Study in Natural Civics*, credited the ant with achieving the ultimate in democratic social order. The sight of an army ant bivouac put the British naturalist Thomas Belt in mind of Sir Thomas More's *Utopia*. The Swiss naturalist Auguste Forel urged the League of Nations to adopt the ant polity as the model for the world community.

The marvels of ant life have led some thinkers into giddy speculation on the nature of ant intelligence. Few have put themselves so quaintly on record as Lord Avebury, who declared: "The mental powers of ants differ from those of men not so much in kind as in degree." He ranked them ahead of the anthropoid apes. Maurice Maeterlinck, author of *The Life of the Ant*, hedged: "After all, we have not been present at the deliberations of the workers and we know hardly anything of what happens in the depths of the formicary." Others have categorically explained ant behavior as if the creatures could reason, exchange information, take purposeful action and feel tender emotion. Describing a tribe of army ants on the march in his book *Insect Behavior*, the American naturalist Paul Griswold Howes has "lieutenants keeping order or searching out the ground to be hunted or traveled next" and the privates in the line "obeying commands" and evincing "a wonderful sense of duty." Belt noted, as a matter of course, that "light-colored officers" keep the "common dark-colored workers" in line. R. C. Wroughton concluded from the precision of ant armies' maneuvers that "they are either the result of preconceived arrangement or are carried out by word of command."

Obviously anthropomorphism can explain little about ants, and it has largely disappeared from the current serious literature about ant behavior. Its place has been taken, however, by errors of a more sophisticated sort. One such is the concept of the "superorganism." This derives from a notion entertained by Plato and Aquinas that a social organization exhibits the attributes of a superior type of individual. Extended by certain modern biologists, the concept assumes that the biological organism, a society of cells, is the model for social organizations, whether ant or human. Plausible analogies are drawn between organisms and societies: division of function, internal communication, rhythmic periodicity of life processes and the common cycle of birth, growth, senescence and death. Pursuit of these analogies, according to the protagonists of the superorganism, will disclose that the same forces of natural selection have shaped the evolution of both organism and superorganism, and that the same fundamental laws govern their present existence.

This is of course a thoroughly attractive idea. It is representative, in the field of psychology, of current efforts in other fields of science to unify all observed facts by a single theory. But it possesses a weakness common to all Platonistic thinking. It erects a vague concept, "organism" or "organization," as an ultimate reality which defies explanation. The danger inherent in this arbitrary procedure is the bias which it imposes upon the investigator's approach to his problem. It reduces the gathering of evidence to the selection of appropriate illustrations and examples. This is a pitfall of which the investigator must be especially wary in the study of social behavior. Too often in this field theories and conclusions are composed of nine parts of rationalization to one part of evidence. The investigator in social science must be ruthless in discarding his preconceived notions, taking care to retain only the bare conceptual framework that is inductively supported by the already established evidence on his subject. In the gathering of new evidence he must impose on his work the same rules of repetition and control which prevail in the experimental sciences. Wherever possible he should subject his observations to experimental tests in the field and laboratory. In the area we are discussing this kind of work may at times seem more like a study of ants than an investigation of problems. But it yields more dependable data.

ONE of the most helpful sources of evidence concerning the ant is the study of the ant in its "more than royal tomb" of amber. This is the paleontologist's ant, trapped eons ago in the sticky gum of a conifer and thereby preserved intact for examination by scientists today. They find that the fossil ant is in all major respects identical with its twentieth-century descendants. From this evidence biologists reason that since the social behavior of the ant is primarily a function of its biological make-up, ant societies must be as ancient as the ant. This conclusion is supported by studies of ant behavior. The contemporary ant, as will be shown, exhibits a comparatively limited capacity for learning. On the other hand, there is little that it needs to learn when it crawls out of the cocoon. By far the greater part of its behavior pattern is already written in its genes and represents the "learning" of its race, acquired many generations ago in the hard school of natural selection.

The individual ant, as a matter of fact, is ill-equipped for advanced learning. By comparison with the sensitive perceptions of a human being, it is deaf and blind. Its hearing consists primarily in the perception of vibrations physically transmitted to it through the ground. In most species, its vision is limited to the discrimination of light and shadow. These deficiencies are partially compensated by the chemotactual perceptions of the ant, centered in its flitting antennae. Chiefly by means of its antennae, the ant tells friend from foe, locates its booty, and, thanks to its habit of signing its trail with droplets from its anal gland, finds its way home to the nest.

In an investigation of ant learning, Schneirla found that individual ants are capable of significant feats of progress in a given situation, but that on the whole ant learning is by rote. His subject in this study was the common garden Formica ant, which is known to forage freely within a radius up to 75 meters around its nest. The learning situation was presented by a maze, interposed between the laboratory nest and feeding box, with maze passages open on the return route to the nest. Each individual ant was identified and followed by means of a number pasted on its gaster (abdomen). The ants betrayed no evidence of purposive behavior. Compared to the rat, which in the same maze pattern may acquire a pronounced "goal set" and make straight for the other end of the maze after relatively few runs, the ants were at first quite haphazard in their behavior. It required almost a dozen runs before they ceased crawling aimlessly on the floors and walls of the first alley in the maze. Their learning curves then ascended steeply to a flat plateau; thereafter, they made as many wrong turns at the last choice points in the maze as they did at the first.

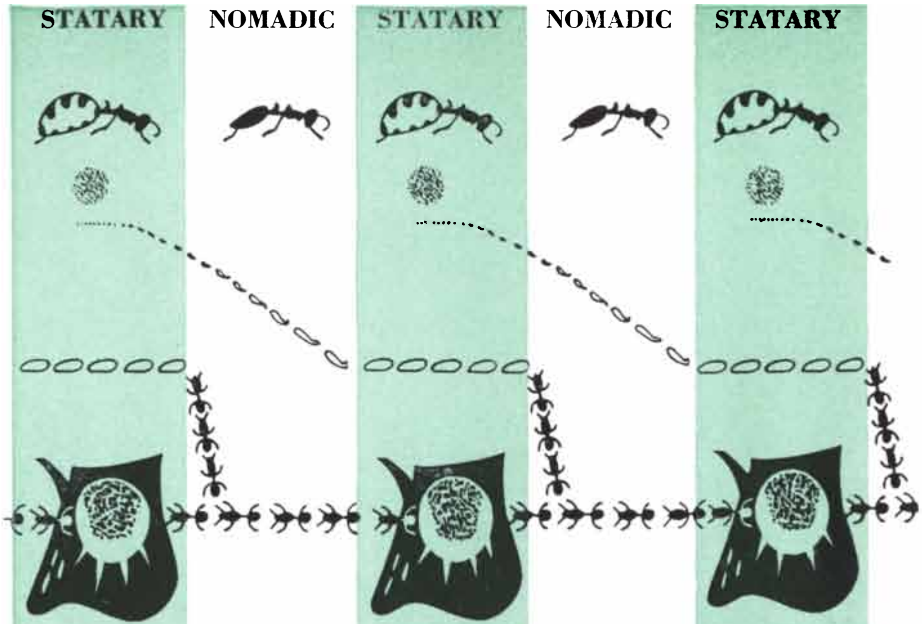
Control of clues provided in the maze by ant chemicals and variations in lighting revealed that the Formica ant possesses considerable learning capacity in its kinesthetic or "muscle" sense. Nevertheless, this study shows that the ant acquires merely a generalized maze habit, not an understanding of mazes. This conclusion is reinforced by another comparison with the rat. Confronted with abrupt changes in the maze layout, the rat will often exhibit plain evidence of emotional conflict, represented by an over-all deterioration of its learning progress. Ants, in the same situation, merely blunder ahead.

How the essentially uncomplicated repertory of the individual ant contrives, when ants act in concert, to yield the exceedingly complex behavior of the tribe is one of the most intricate paradoxes in nature. This riddle has been fruitfully explored during the past generation under the guidance of the concept of "trophallaxis," originated by the late William Morton Wheeler of Harvard University, who ranks as the greatest of U.S. formicologists. Trophallaxis (from the Greek *trophe*, meaning food, and *allaxis*, exchange) is based upon the familiar observation that ants live in biological thrall to their nestmates. Their powerful mutual attraction can be seen in the constant turning of one ant toward another, the endless antennal caresses, the licking and nuzzling. In these exchanges they can be seen trading intimate substances—regurgitated food and glandular secretions. Most ants are dependent for their lives upon this biosocial intercourse with their fellows. There is strong evidence that, as between larvae, workers and queen in a given tribe, there is an interchange of co-enzymes necessary to the existence of all. Army ant queens unfailingly sicken and die after a few days when isolated in captivity.

Trophallaxis, or "the spirit of the formicary," as Maeterlinck was pleased to call it, is therefore essentially chemical in nature. As can be seen by the mutual attractions and repulsions of ants for one another, their social chemicals are not only specific to species but also specific to colonies. Schneirla's most acute memory of his 16-year association with army ants is the characteristic Eciton odor which emanates from their columns, an odor reminiscent of potato blossoms. It is obscured near their bivouacs by the fetid smells which emanate from the decaying fragments of booty clinging to individual ants. The army ant queen, less exposed to offal, is distinguished by a delicate, indefinable odor. All this suggests that biochemists may here find a field for studies which should yield more effective ant repellents and poisons, as well as shed new light on animal behavior.

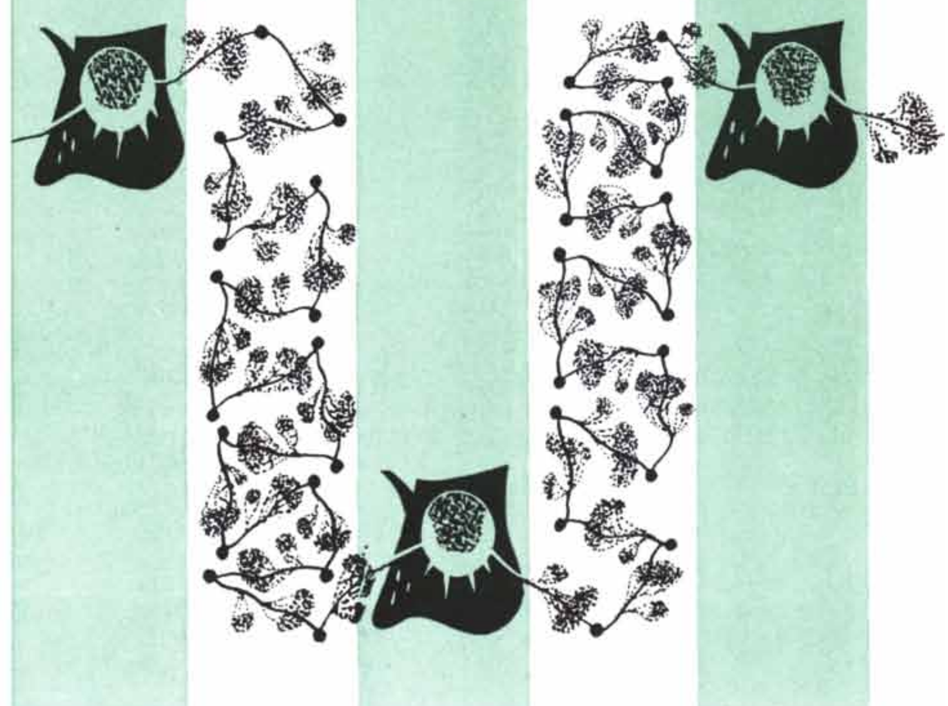
THE well-established concept of trophallaxis naturally suggests that clues to the complex behavior of the ant armies should be sought in the relationships among individuals within the tribe. Most investigators have looked elsewhere, with invariably mistaken results. In attempting to explain, for example, why an ant army alternates between periods of fixed bivouac and nomadic wandering, a half-dozen reputable scientists have jumped to the simplest and most disarmingly logical conclusion: food supply. The ants, they declared, stay in one place until they exhaust the local larder and then move on to new hunting grounds. Schneirla has shown, however, that the true explanation is quite different.

The migratory habits of the ant armies follow a rhythmically punctual cycle. The *Eciton Hamatum* species, for example, wanders nomadically for a period of 17 days, then spends 19 or 20 days in fixed bivouac. This cycle coincides precisely with the reproductive cycle of the tribe. The army goes into bivouac when the larvae, hatched from the last clutch of eggs, have gone into the pupal state in their cocoons. At the end of the first week, the queen, with her gaster swollen to more than five times its normal volume, goes into a stupendous five- to seven-day labor in which she delivers 20,000 to 30,000 eggs. The daily foraging raids, which



REPRODUCTIVE CYCLE motivates behavior (*see below*) of army ant colony. Events are synchronized by visceral punctuality of the queen. Precisely spaced broods develop from eggs, go through the larval and pupal stages and emerge from cocoons in orderly succession. The coincident behavior cycle provides statary bivouac at egg-laying crisis.

BEHAVIOR CYCLE consists of alternate periods of stay in fixed bivouac and of daily bivouac shift. Emergence of the callow workers from cocoons energizes the colony to resume nomadic wandering. Nomadism is further sustained by maturing of the larvae. When larvae spin cocoons, colony goes back into fixed bivouac, in hollow tree or similarly secluded recess.



BIVOUAC is a more or less cylindrical hollow cluster of the members of a colony. It builds from above downward as strings and filaments of ants, hooked together leg to leg, descend from log or vine. This is a typical nomadic period bivouac, hanging exposed in the open.

CLOSE-UP of bivouac suggests "fur of some terrible animal." Outer "tissue" of structure, as shown here, is made of workers major and intermediates. Minims concentrate around queen within. When pouchlike bivouac is poked with stick, larvae and cocoons pour out.

meanwhile have dwindled to a minimum, pick up again as the eggs hatch into a great mass of larvae. Then, on about the 20th day, the cocoons yield a new generation of callow workers, and the army sets off once more on its evening marches.

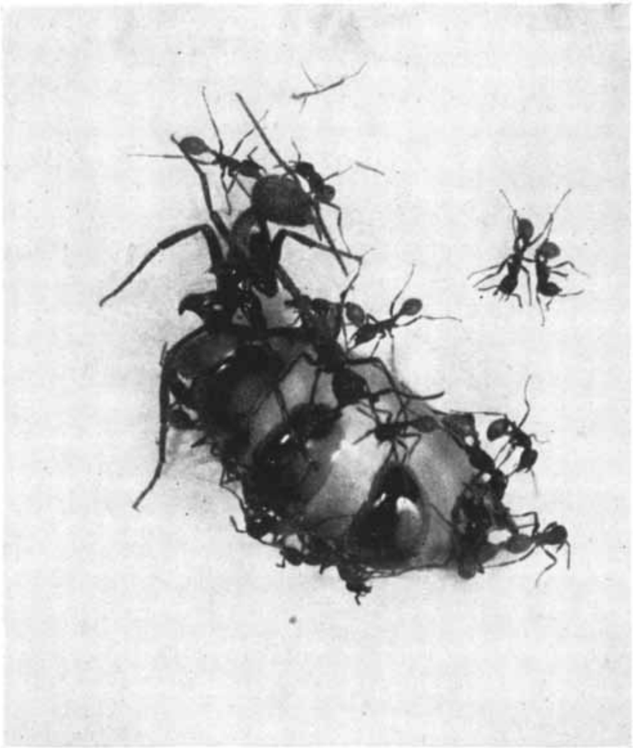
In determining this pattern of external social events Schneirla logged a dozen ant armies through one or more complete cycles, and upwards of 100 through partial cycles. Observations were set down in shorthand in the field. The coinciding pattern of internal biological events was documented by brood samples taken from many different colonies at various stages in the reproductive cycle. In the course of the last field trip, from November 1947 to March 1948, broods of more than 80 colonies were sampled, most of them repeatedly at intervals of a few days. In addition, detailed examinations were made of 62 queens in various phases of their physiological history and many of these were preserved for further study.

A SENTIMENTALIST considering this new picture of the army ant's domestic habits may find an explanation for its behavior more affecting than the food theory: the ants stay in fixed bivouac to protect the queen and her helpless young through the time when they are most vulnerable. Doubtless this is the adaptive significance of the process. But the motivation which carries 100,000 to 150,000 individual ants through this precisely timed cycle of group behavior is not familial love and duty but the trophallactic relationship among the members of the tribe. A cocooned and slumberous pupa, for example, exerts a quieting influence upon the worker that clutches it in its mandible—somewhat as a thumb in the mouth pacifies an infant. But as it approaches maturity and quickens within its cocoon, the pupa produces precisely the reverse effect. Its stirring and twitching excite the workers to pick up the cocoon and snatch it from one another. As an incidental result, this manhandling effects the delivery of the cocoon's occupant. (Cocoons in which the pupae were killed by needle excited no such interest among the workers and remained unopened.)

The stimulus of the emerging brood is evident in a rising crescendo of excitement that seizes the whole community. Raiding operations increase in tempo as the hyperactive, newly delivered workers swarm out into the marching columns. After a day or two, the colony stages an exceptionally vigorous raid which ends in a night march. The bivouac site is left littered with empty cocoons. Later in the nomadic period, as the stimulus of the callow workers wanes, the larvae of the next generation become the source of colony "drive." Fat and squirming, as big as an average worker, they establish an active trophallactic relationship with the rest of the tribe. Workers constantly stroke them with their antennae, lick them with their mouth parts and carry them bodily from place to place. Since the larvae at this stage are usually well distributed throughout the corridors and the chambers of the overnight bivouac, their stimulus reaches directly a large number of the workers. This is reflected in the sustained vigor of the daily raids, which continue until the larvae spin their cocoons.

THESE observations are supported by a variety of experimental findings in the field and laboratory. The role of the callow workers in initiating the movement to break bivouac was confirmed by depriving a number of colonies of their callow broods. Invariably, the raiding operations of the colony failed to recover from the lethargic state characteristic of the statary periods. Some tribes even extended their stay in fixed bivouac until the larvae grew large and active enough to excite the necessary pitch of activity. To test the role of the larval brood, captured tribes were divided into part-colonies of comparable size. The group with larvae showed much greater activity than those that had no larvae or that had cocoons in the early pupal state.

The interrelationships among members of the colony thus provide a complete explanation for the behavior cycle of the



QUEEN in labor has already delivered several thousand eggs, still has upwards of 20,000 to go. Exoskeletal plates of her enormously swollen gaster are widely separated, exposing the distended membrane. Workers attend labor excitedly, snatch up eggs when they emerge.

COLUMN of army ants on a bivouac-shift march is an inch wide, may stretch upwards of 300 meters in length. In this picture, the queen appears just above center, buried under excited workers. Attraction of queen is indicated also by a reversal in travel of workers ahead.

army ant. It should be observed, in conclusion, that the whole complex process is carried out by individuals which do not themselves originate the basic motivations of their behavior.

Long before the intricacies of its domestic existence were suspected, the army ant's reputation as a social animal was firmly established by its martial conduct in external affairs. It does not require an overactive imagination to perceive the classic doctrines of offensive warfare spelled out by the action of an ant army in the field. It carries through the maneuvers of wheeling, flanking and envelopment with a ruthless precision. But to find its motivations and explain its mechanics, one must consult the ant, not von Clausewitz.

Army ant raids fall into one of two major patterns. They are organized either in dense swarms which form at the head of the column or in a delicate tracery of capillary columns branching out at the forward end of the main raiding column. Both types of raiding are found in subgenera of each of the common species of Central American army ant. The *Eciton eciton* species was selected for this study because it leads its life entirely on the surface of the jungle floor and is thus accessible to continuous observation. Whether the army ants raid in swarm or column, however, the essential mechanics of their behavior are substantially the same.

The bivouac awakes in the early dawn. The stir of activity begins when the light (as measured by photometer) reaches .05 foot candles, and it mounts steadily as the light increases. In strands and clusters, the workers tumble out of the bivouac into a churning throng on the ground. A crowding pressure builds up within this throng until, channeled by the path of least resistance, a raiding column suddenly bursts forth. The ants in the column are oriented rigidly along the line of travel blazed by the chemical trail of the leaders. The minims and medium-sized workers move in tight files in the center. The "workers major," displaced by the unstable footing afforded by the backs of their smaller fellows, travel along each side. This arrangement no doubt lends suggestive support to the major's legendary role of command. It has an adaptive significance in that it places the biggest and most formidable of the workers on the flanks. Unless disturbed, however, the majors hug the column as slavishly as the rest. The critical role of the tribal chemical in creating this drill sergeant's picture of order may be demonstrated by a simple field experiment. Removal of the chemically saturated litter from the trail brings the column to an abrupt halt. A traffic jam of ants piles up on the bivouac side of the break and is not relieved until enough ants have been pushed forward to re-establish the chemical trail.

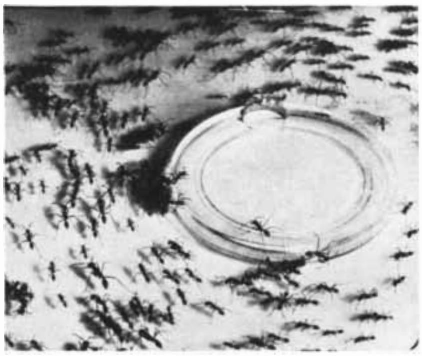
Appearances are less ordered at the front of the column, where the "scouts" and "skirmishers" are most frequently observed. The timid individual behavior of the forward ants scarcely justifies such titles. Compared with the Formica, the Eciton is a far less enterprising forager. It never ventures more than a few inches into the chemically-free area ahead. Even this modest venturing is stimulated principally by physical impact from the rear. At the end of its brief pioneering sally, the Eciton rebounds quickly into the column. It is here that the critical difference between column and swarm raiding arises. The column-raiding ants are somewhat freer in their pioneering behavior and so open new pathways more readily. In the swarm raiders the comparatively reluctant progress of the forward elements creates a counterpressure against the progress of the column. This forces the head of the column into a broad elliptical swarm which arrays itself at right angles to the line of march. With ants pouring in from behind, the swarm grows steadily in size as it moves forward, often achieving a width of more than 15 meters.

THE PATH of an ant army, whether in swarms or columns, shows no evidence of leadership. On the contrary, each individual makes substantially the same contribution to the group behavior pattern. The army's course is directed by such wholly chance factors as the stimulus of booty and the character of the terrain. On close inspection, therefore, it appears that the field operations of ant armies approximate the principles of hydraulics even more closely than those of military tactics. This impression is confirmed by analysis of the flanking maneuver as executed by the swarm raiders. A shimmering pattern of whirls, eddies and momentarily milling vortices of ants. the swarm advances with a peculiar rocking motion. First one and then the other end of the elliptical swarm surges forward. This action results in the outflanking of quarry. which is swiftly engulfed in the overriding horde of ants. It arises primarily. however, from an interplay of forces within the swarm. One of these forces is generated by the inrush of ants from the rear. Opposed by the hesitant progress of the swarm. the new arrivals are deflected laterally to the wing which offers least resistance. This wing moves forward in a wheeling motion until pressure from the slow advance of its frontal margins counterbalances the pressure from the rear. Pressure on the opposite wing has meanwhile been relieved by drainage of the ants into the flanking action. The cycle is therewith reversed. and a new flanking action gets under way from the other end. External factors. too, play a role in this cycle. The stimulus of booty will accelerate the advance of a flank. The capture of booty will halt it and bring ants stampeding in for a large-scale mopping-up party. But raiding activity as such is only incidental to the process. Its essential character is determined by the stereotyped behavior of the individual ant with its limited repertory of responses to external stimuli.

THE profoundly simple nature of the beast is betrayed by an ironic catastrophe which occasionally overtakes a troop of army ants. It can happen only under certain very special conditions. But. when these are present, army ants are literally fated to organize themselves in a circular column and march themselves to death. Post-mortem evidence of this phenomenon has been found in nature; it may be arranged at will in the laboratory. Schneirla has had the good fortune to observe one such spectacle in nature almost from its inception to the bitter end.

The ants, numbering about 1,000. were discovered at 7:30 a.m. on a broad concrete sidewalk on the grounds of the Barro Colorado laboratories. They had apparently been caught by a cloudburst which washed away all traces of their colony trail. When first observed. most of the ants were gathered in a central cluster. with only a company or two plodding, counterclockwise. in a circle around the periphery. By noon all of the ants had joined the mill. which had now attained the diameter of a phonograph record and was rotating somewhat eccentrically at fair speed. At 10:00 p.m. the mill was found divided into two smaller counterclockwise spinning discs. At dawn the next day the scene of action was strewn with dead and dying Ecitons. A scant three dozen survivors were still trekking in a ragged circle. By 7:30. 24 hours after the mill was first observed. the various small myremicine and dolichoderine ants of the neighborhood were busy carting away the corpses.

This peculiarly Eciton calamity may be described as tragic in the classic meaning of the Greek drama. It arises. like Nemesis. out of the very aspects of the ant's nature which most plainly characterize its otherwise successful behavior. The general mechanics of the mill are fairly obvious. The circular track represents the vector of the individual ant's centrifugal



IN LABORATORY, circular-column milling by army ants is spontaneous and common event. Mill may be started by a few ants circling a dish or short-cutting square corners of nest.

impulse to resume the march and the centripetal force of trophallaxis which binds it to its group. Where no obstructions disturb the geometry of these forces, as in the artificial environment of the laboratory nest or of a sidewalk. the organization of a suicide mill is almost inevitable. Fortunately for the army ant. it is rare in the heterogeneous environment of nature. In the diversity of its natural habitat. the stereotyped army ant is presented with innumerable possibilities for variation in its activity. The jungle terrain, with its random layout of roots and vines. leaves and stones. liberates the ant from its propensity to destroy itself and diverts it into highly adaptive patterns of behavior.

The army ant suicide mill provides an excellent occasion for considering the comparative nature of social behavior and organization at the various levels from ants to men. Other animals occasionally give themselves over to analogous types of mass action. Circular mills are common among schools of herring. Stampeding cattle. sheep jumping fences blindly in column and other instances of pell-mell surging by a horde of animals are familiar phenomena. Experience tells us that men. too, can act as a mob. These analogies are the stock-in-trade of the "herd instinct" schools of sociology and politics. They are cited by those who hold that emotionalized, individually degraded. regimented patterns are the rule in group behavior of mankind.

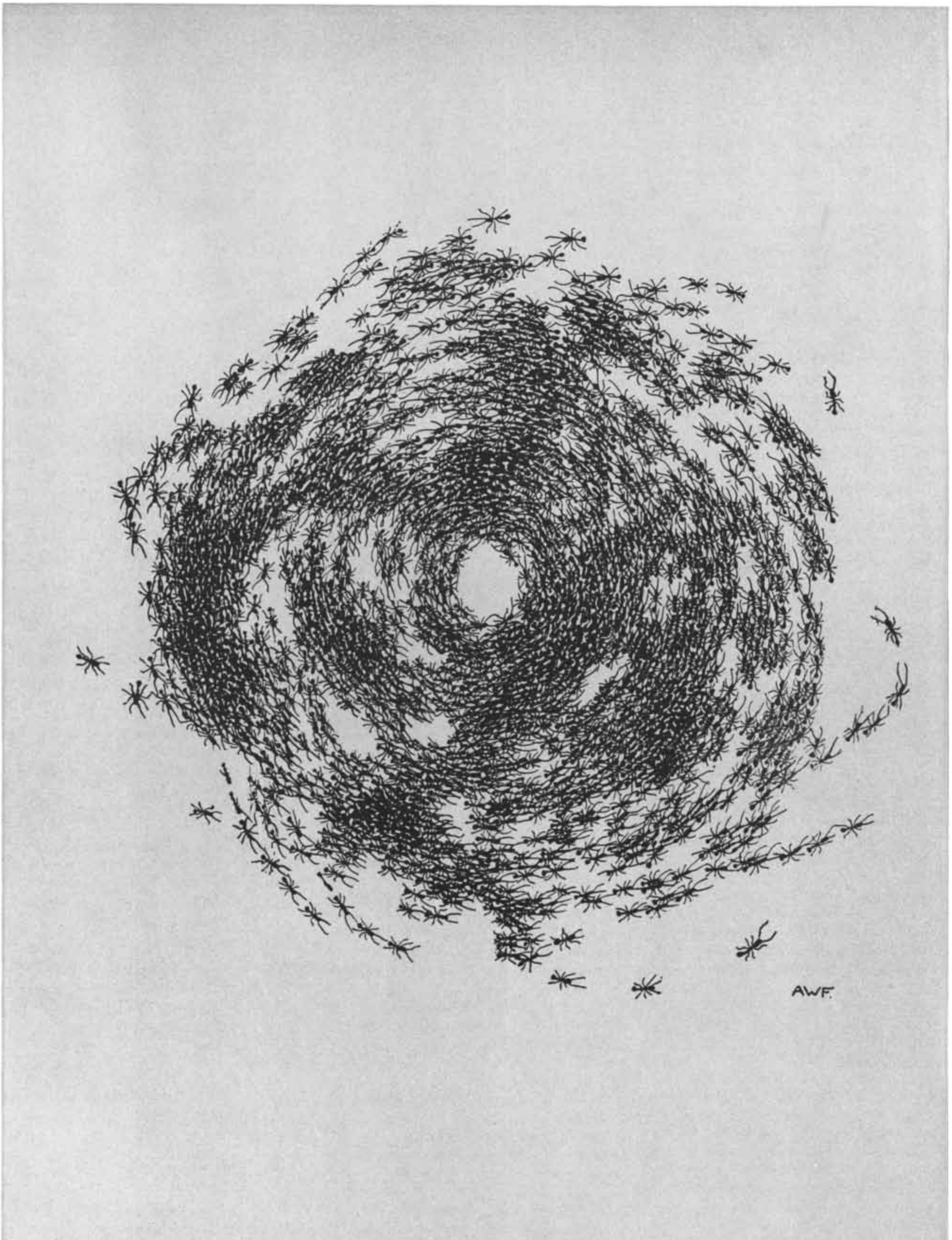
We are required, however. to look beyond the analogy and study the relationship of the pattern to other factors of individual and group behavior in the same species. In the case of the army ant, of course. the circular column really typifies the animal. Among mammals, such simplified mass behavior occupies a clearly subordinate role. Their group activity patterns are chiefly characterized by great plasticity and capacity to adjust to new situations. This observation applies with special force to the social potentialities of man. When human societies begin to march in circular columns. the cause is to be found in the strait-jacket influence of the man-made social institutions which foster such behavior. The phenomenon of milling, it turns out, has entirely different causes and functions at different levels of social organization. The differences. furthermore, so far outweigh the similarities that they strip the "herd instinct" of meaning.

The same reservations apply to the analogies cited to support the superorganism theory. Consider. for example, the analogy of "communication." Among ants it is limited to the stimulus of physical contact. One excited ant can stir a swarm into equal excitement. But this behavior resembles the action of a row of dominoes more than it does the communication of information from man to man. The difference in the two kinds of "communication" requires two entirely different conceptual schemes and preferably two different words.

As for "specialization of functions," that is determined in insect societies by specialization in the biological make-up of individuals. Mankind, in contrast, is biologically uniform and homogeneous. Class and caste distinctions among men are drawn on a psychological basis. They break down constantly before the energies and talents of particular individuals.

Finally, the concept of "organization" itself, as it is used by the superorganism theorists, obscures a critical distinction between the societies of ants and men. The social organizations of insects are fixed and transmitted by heredity. But members of each generation of men may, by exercise of the cerebral cortex, increase, change and even displace given aspects of their social heritage. This is a distinction which has high ethical value for men when they are moved to examine the conditions of their existence.

T. C. Schneirla is curator, department of animal behavior, American Museum of Natural History. Gerard Piel is chairman of the board of editors of SCIENTIFIC AMERICAN.



CIRCULAR COLUMN described in text on opposite page is shown here in drawing traced from photograph. Tendency to form such columns betrays essential mechanics of army ant behavior. This mill developed from cluster of ants that had been isolated accidentally on a sidewalk. Stereotyped ants slavishly followed chemical trail laid by first few individuals that ventured out of cluster. As heat of day speeded travel of ants, the resulting centrifugal force increased the size of the mill to an outside diameter of about seven inches.

SCIENCE AND THE

Atomic Energy Abroad

A FEW weeks ago Dr. L. Kowarski, the distinguished nuclear physicist who is scientific director of the French Atomic Energy Commission, paid a flying visit to the U.S. At Brookhaven National Laboratory he gave a talk on the progress of atomic energy research in western Europe. The gist of his report:

Both in terms of manpower and funds, Britain's atomic energy effort is about one tenth the American, and the French is one tenth the British. Next in magnitude is the Swedish program.

As is well known, an experimental low-energy pile is already in operation at Harwell, the main British atomic energy research station. This establishment is about the size of Brookhaven or the Argonne National Laboratory in Chicago. In France, a low-energy pile will be completed late this year or early in 1949. The Swedish pile project is not scheduled to be finished until some time later.

In Kowarski's opinion, no other country in western Europe has the resources to develop a pile of its own. In fact, he thinks that Sweden may find it impossible to carry her project through to completion. Norway also has a pile project, based on her large heavy water plants, but Kowarski is pessimistic concerning its outcome. Nor can Switzerland, despite her high-quality technical resources, develop a pile. In the Netherlands, several major nuclear research projects are under way, but construction of a pile is not contemplated.

Social Research

DURING the late war British scientists became enthusiastic champions of "operational research"—a system of applied team study by men in different sciences which was brilliantly successful in solving many specific military problems, especially in aerial and submarine warfare. Now a group of outstanding British men of science from various fields have joined in proposing a plan to apply operational research to Britain's pressing economic problems.

The proposal is to establish a Social Sciences Research Council, to operate in the social sciences in Great Britain in somewhat the same fashion as the National Science Foundation is intended to operate in the natural sciences in the U.S. The report which outlines the plan, drafted by a committee of the British Association of Scientific Workers, has become a best seller in England. Its chief thesis is that Britain's recovery must be guided by greater use of the social sciences.

It points out that Great Britain, recognizing that her economic future depends on better and more efficient production, has already raised her expenditures for technological research. In a very few fields, these have been matched by increased expenditures for related social research; in the field of housing, for example, scientific teams are studying not only how to build better houses, but what kind of houses ought to be built. This approach, it is argued, should be done on a larger scale and in many more fields. So far, the report declares, Britain has made little use—less than the U.S.—even of such comparatively simple social science techniques as vocational aptitude testing.

The report proposes that the Social Sciences Research Council should sponsor and conduct research, survey the work being done in various fields, and organize operational research teams to tackle outstanding public problems. It also urges establishment of social research units in government departments and the expansion of university social science faculties.

Code for Scientists

A UNIQUE "Charter for Scientists" has been drawn up by the World Federation of Scientific Workers, an organization initiated two years ago by the powerful British Association of Scientific Workers. The Charter is eventually to be adopted by the Federation's 19 affiliates in 15 countries as a part of their bylaws. It provides a kind of Hippocratic oath for scientists. Its preamble points out that the profession of science, being of comparatively recent origin, lacks a code such as governs older professions like medicine and the law. The Charter seeks to fill this gap.

The Charter states explicitly that the scientist is obligated to "maintain the international character of science, to aid agencies seeking to prevent war and to resist the diversion of scientific effort to war aims." It lays down conditions of work for scientists, from adequate salaries and facilities to the free right of publication and the abolition of secrecy. It further demands that scientists be permitted to participate in the management of agencies, whether government or private, that conduct research. It criticizes sharply, as destructive of scientific progress, the widespread tendency to subordinate scientists to non-scientists in research organizations.

The Charter also urges a manifold extension of science education in all countries. Two things are asked: free education for student scientists, and the inclusion of science in all school curricula so as to make science, like music and art, an accepted part of every individual's cultural background.

BCG

WITH $2 million from the International Children's Emergency Fund, the largest BCG vaccination program ever undertaken is under way in 11 European countries. Its object is to save European children from tuberculosis.

As a result of semistarvation, two thirds of the children in the 11 countries (Albania, Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Poland, Rumania and Yugoslavia) already have or have had tuberculosis. The other third can be saved only by an immediate increase in food rations or immunization measures. Since the former is out of the question, the latter is being taken up. About 15 million children altogether—all those susceptible to tuberculosis as determined by mass tuberculin testing—will be treated with BCG, a vaccine prepared from a weakened strain of tuberculosis bacteria. The campaign, which is under the direction of Dr. Johannes Holm, technical director of the Danish Red Cross, is a cooperative undertaking of the World Health Organization, the several Scandinavian Red Cross organizations and the 11 governments.

AEC Progress

THE Atomic Energy Commission has just reported several new developments in its program of medical and economic applications of atomic energy. One of them is the use of radioactive cobalt as a supplement to radium in the treatment of cancer. Radiocobalt tubes and needles are prepared by treatment in the atomic pile after fabrication from ordinary cobalt. They are inserted into tumors in much the same way as the usual gold "seeds" filled with the radioactive gas radon, and will accomplish no more and no less than the latter. They will not eliminate radon, for radiocobalt has a much longer radioactive half-life than radon and, though less expensive, involves greater hazards. Clinical trials of the new tubes and needles will soon be made.

About 200 agricultural studies are under way in which AEC-supplied radio-

CITIZEN

isotopes are employed as tracers. In a new project, for which the Commission is providing funds as well as material, isotopes are to be utilized not as tracers, but to determine the effects of radioactivity on plant growth. Almost since the discovery of radioactivity in 1896, a considerable body of European scientific opinion has contended that small doses of radiation stimulate the growth of crops. Actual experimental work both here and abroad has been inconclusive; results have sometimes been good and sometimes bad, and where good, may have been due to rare minerals present in the radioactive materials. Now the matter is to be put to the test, with the help of the AEC, by the Department of Agriculture and a number of cooperating state agricultural experiment stations.

In the area of basic research, the Commission announced the finding of evidence for the "exchange current" theory of nuclear binding forces (*see article beginning on next page*) by Drs. Herbert L. Anderson and Aaron Novick at the Argonne National Laboratory. Anderson and Novick measured the magnetic forces in hydrogen 3 and helium 3. Their data, they report, demonstrate that nuclei are held together by a flow of current within the nucleus as electric charges shift from one nuclear particle to another.

UNAEC Suspends

TWO YEARS of effort to frame an agreement on control of atomic energy through the United Nations have ended in failure, at least for the time being. On May 7, the American, British and French delegates to the UN Atomic Energy Commission proposed that the Commission suspend further discussion and report its inability to agree to the Security Council and General Assembly. The resolution's acceptance by the Commission seemed a foregone conclusion; the only members opposed were Russia and the Ukraine.

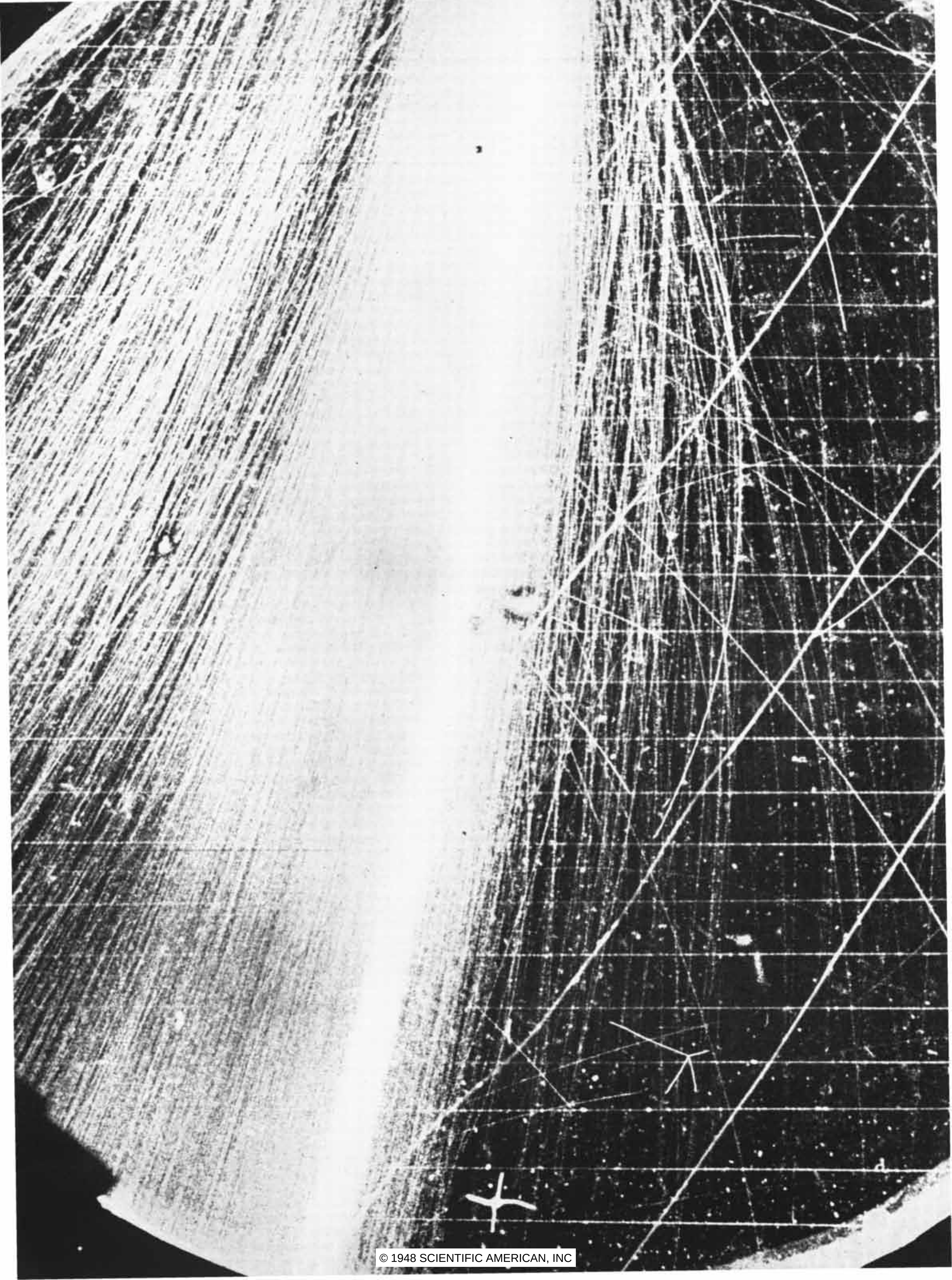
In support of their proposal, the American, British and French delegates prepared a report in which Russian intransigence and the general deterioration of relations between Russia and the West were blamed for the failure.

Meetings for July

FIRST International Poliomyelitis Conference. New York, July 12-17.

American Society of Civil Engineers. General meeting. Seattle, Wash., July 21-23.

International Union of Crystallography. Cambridge, Mass., July 28-August 3.



The Ultimate Particles

Presenting a comprehensive review of what is known thus far about the fundamental units of matter and the forces that play among them in the atom's core

by George W. Gray

And yet so poor is nature with all her craft, that, from the beginning to the end of the universe, she has but one stuff . . . to serve up all her dream-like variety. Compound it how she will—star, sand, fire, water, tree, man—it is still one stuff and betrays the same properties.

—Ralph Waldo Emerson.
Essay on Nature

SCIENCE today is concerned with a multitude of problems. many of them of a fundamental character. but none is more basic than the search for the ultimate units of matter and energy. Thales of Miletus posed the question 25 centuries ago when he asked: "Of what and how is the world made?" It is still the supreme enigma. The world includes man. and the elucidation of its nature cannot but reveal something of the hidden nature of life and of man.

Our question. therefore. is not alien to our humanity. The ultimate particles which enter into combination to make hydrogen and iron also enter into the construction of bone and muscle, blood and nerve and brain. In studying the constitution of atoms we are studying the fundamental stuff of the universe—of suns and mountains and seas. the black carbon of coal, the green chlorophyll of grass, the red hemoglobin of blood.

The forces which energize the elementary particles to cause nuclear cohesion. or under other conditions to cause nuclear fission. are not to be set apart as members of a remote, inhuman realm known as physics. These mighty forces are within us: they are ourselves. the very foundations of that matter and energy whose interplay constitutes all that we experience of the physical universe. Indeed. nature knows no such specializations as physics. chemistry, biology and the other categories into which we fit our fragments of knowledge. She knows only the particles and their incessant interactions as expressed in phenomena such as magnetism, radiation. life. death.

CLOUD CHAMBER reveals powerful beam of alpha particles fired by the 184-inch cyclotron at the University of California. Beam is curved by a magnetic field about the chamber.

I. Particles

A biologist probing the minute architecture of protoplasm must wield his dissecting needle with extreme delicacy. else he may destroy the thing he is trying to explore. But the physicist. wishing to unveil the still more minute architecture of the atom. resorts to artillery. His method is that of banging one particle against another. and the harder the blow, the more revealing is the debris resulting from the violence.

ACKNOWLEDGEMENT

The author wishes to thank the following physicists for their invaluable help in the preparation of this article: Kenneth T. Bainbridge and J. C. Street of Harvard; Gregory Breit of Yale; Serge A. Korff of New York University; Ernest O. Lawrence. Donald Cooksey, Wilson Powell and Robert Serber of the University of California; Philip M. Morse, M. S. Livingston and H. S. Snyder of Brookhaven National Laboratory; J. Robert Oppenheimer of the Institute for Advanced Study. and John A. Wheeler of Princeton University. "Meson Song" is used with the kind permission of its authors: Dr. and Mrs. H. C. Childs, Dr. and Mrs. R. E. Marshak, Dr. and Mrs. R. L. McCreary, Dr. and Mrs. J. B. Platt. Dr. and Mrs. S. N. Voorhis, all of the University of Rochester. and George E. Valley of the Massachusetts Institute of Technology.

The value of the bombardment technique was shown a half century ago when Wilhelm Konrad Röntgen, experimenting at the University of Würzburg with cathode rays, discovered a mysterious radiation coming from that part of the glass tube against which the stream of cathode rays (electrons) impinged. The discovery of these X-rays in 1895, of radioactivity in 1896. of the electron in 1897 and of radium in 1898—those four golden years which ushered in the heroic age of physics!—brought not only revolutionary knowledge. but also new and powerful research tools.

A few weeks after Röntgen's discovery, J. J. Thomson used X-rays to bombard air and other gases and found that the rays knocked out negatively-charged fragments which eventually were identified as *electrons.* The discovery of radioactivity later led to the finding of alpha particles. It was by using the alpha particles which spontaneously shoot out of radium and other radioactive elements that Ernest Rutherford in 1911 bombarded gold into betrayal of its nucleus. Subsequent batterings showed that all atoms have this central, massive, positively-charged core around which the electrons revolve as negatively-charged satellites. Alpha particles themselves were found to be helium nuclei. In 1919 the alpha-particle barrage turned up another fundamental of structure when Rutherford bombarded nitrogen and found positively-charged *protons* bouncing out of the nitrogen nucleus. Thirteen years later the same artillery helped James Chadwick to blast out a still more elusive nuclear constituent, the *neutron.*

Britain was the scene of the Thomson. Rutherford, and Chadwick discoveries,

THE FUNDAMENTAL PARTICLES

(AS OF MAY 1948)

This chart lists the particles which are currently accepted by the majority of physicists. It lists only elementary particles; it does not include compound particles such as the deuteron and the alpha particle. Nor does it include the "nucleon." This is covered by neutron and proton, for which nucleon is the more general term.

MASS PARTICLES

PARTICLE	CHARGE	MASS	DISCOVERED	TRACK
ELECTRON	—	1	BY THOMSON, 1897	
PROTON	+	1836	BY RUTHERFORD, 1919	
NEUTRON	0	1836	BY CHADWICK, 1932	
POSITRON	+	1	BY ANDERSON AND NEDDERMEYER, 1932	
MESON MU	—	200	BY ANDERSON AND, INDEPENDENTLY, STREET AND STEVENSON, 1936	
MESON MU	+	200		
MESON PI	—	320	BY POWELL, OCCHIALINI AND LATTES, 1947	
MESON PI	+	320		
NEUTRAL MESON	0	88	SUGGESTED	

ENERGY PARTICLES

PARTICLE	CHARGE	MASS	DISCOVERED	TRACK
PHOTON	0	0	SUGGESTED BY EINSTEIN, ELABORATING ON PLANCK, 1905	
NEUTRINO	0	0 ?	SUGGESTED BY PAULI AND FERMI, 1931	

but it was America's turn next. Carl D. Anderson and Seth H. Neddermeyer at the California Institute of Technology were photographing the tracks which cosmic rays make darting through a Wilson cloud chamber, of which more later, when suddenly they espied a strange new track. It was similar in density and angle of curvature to paths previously made by electrons smashed out of atoms, but under the pull of magnetism it curved to the left whereas the paths of electrons curved to the right. This showed that the new particle had a positive charge. Thus, by the chance hit of a cosmic ray, the positively-charged electron was discovered. Anderson named it *positron*.

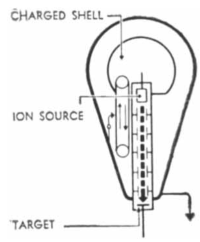
Nor was this all that the cosmic rays had in store. Four years later the same mysterious bombardment from outside the earth's atmosphere, accidentally smashing an atom in this same California laboratory, gave the track of another kind of particle. The density of its path, its angle and direction of curvature, indicated a negatively-charged mass which Anderson described as "larger than that of a normal free electron and much smaller than that of a proton." The same discovery was being made simultaneously by J. C. Street and E. C. Stevenson at Harvard. They determined the mass of the particle as about 130 times the weight of the electron. Later determinations have fixed the weight more closely as 200. Because of its "in-between" mass, Anderson named the particle *mesotron*, from the Greek meaning "intermediate." In usage the word has been shortened to *meson*, and both names are used interchangeably at present.

IN 1947 other particles of mass intermediate between those of electron and proton were discovered by C. F. Powell, G. P. S. Occhialini, and C. M. G. Lattes at the University of Bristol, in England. Studying a group of photographic plates which had been exposed to cosmic rays in the Bolivian Andes (cosmic rays are more abundant at high altitudes), they found the tracks of objects whose masses appeared to be about 320 times the electron mass. Some had positive charges, some negative. For convenience, heavyweights are called *pi* mesons. The previously discovered lightweights of 200 mass are called *mu* mesons. There is also evidence for a neutral meson of about 88 mass. Thus there are now known to be at least five kinds of mesons—positive and negative *pi*, positive and negative *mu*, and one neutral. Mesons of other masses, both lighter and heavier, have been inferred from a few cosmic-ray photographs, but the evidence is sketchy and they remain question marks.

In addition to the particles of matter just described, a bombarded atom may yield up radiant energy. And since these radiations behave as chunks when they strike our detectors, the energy units also must be listed among the particles. They are called *photons*, and they come out of the atom in an almost infinite variety of sizes—as visible light, X-rays, gamma rays and other forms of electromagnetic radiation.

Besides photons. another kind of energy particle is believed to exist. The first hint of it came from beta particles, which are electrons that certain radioactive nuclei discharge spontaneously. In the case of radium E, for example. the nucleus ejects an electron and becomes polonium, and later the polonium nucleus discharges an alpha particle and becomes lead. A curious fact about the radium E emission is that the electrons emerge with various velocities. One atom will shoot out its electron with an energy of half a million electron volts, another with that of a million volts, others with still higher velocities. As a result of these subtractions of varying amounts of energy from radium E nuclei, we should expect the resulting polonium atoms to have different energies and therefore discharge their alpha particles at different velocities. But no, the alpha particles all come off with a uniform energy corresponding to 5.5 million volts. It is as though several guns were loaded with different amounts of gunpowder, some having one pound, some two, others three pounds, and despite these differences in charge each gun fired projectiles of the same weight at the same velocity. Such a situation is unthinkable. It violates the law of conservation of energy. There is also in the radium E transformation a discrepancy in the property of the nucleus known as angular momentum. This angular momentum is called "spin," and it is measured in terms of a special unit of physics. An electron has a spin one-half this unit, whereas the change from radium E to polonium requires a subtraction of one full unit or some other whole number.

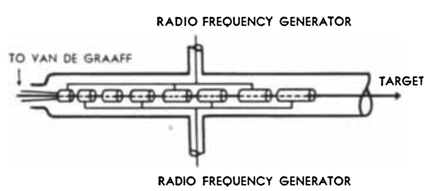
It was to resolve this scandalous situation that Wolfgang Pauli postulated the existence of the *neutrino*. He assumed that the neutrino is of extremely small mass, probably zero; that it has a spin of one-half; that it can carry energy of different degrees of magnitude, and that it moves at the speed of light. As radium E atoms break down to form polonium they discharge the excess energy in two fractions: one as the electron, the other as the neutrino, and the sum of the two is always the same. Thus a proper balance is preserved, and the residual nuclei are each left with the same endowment of energy. With its spin of one-half added to the electron's one-half, the neutrino hypothesis also conserves angular momentum. Attempts have been made to detect the presence of neutrinos by trapping their energy, but with no success. Nevertheless, many other atomic phenomena argue for the neutrino's existence. Several years ago K. T. Bainbridge and E. B. Jordan, working with the powerful mass-spectrograph at Harvard. discovered certain atoms of indium which had the same weight as certain atoms of cadmium. These atoms, which have the same weight but different chemical properties, are called isobars. Since they differ in total charge and hence in potential energy, one isobar would be expected to be unstable and to decay into the other by radioactive loss of energy. But both the indium and cadmium isobars are completely stable. The presence of neutrinos is believed to account for this stability.



ELECTROSTATIC generator operates by building up charge and hurling its particles in one great bolt.

Thus, in 1948, theory and experiment are offering, as the elementary units whose interactions account for the behavior of the physical world, at least nine particles of matter (protons, neutrons, electrons, positrons, five or more kinds of mesons) and two particles of energy (photons and neutrinos).

Can nature really be so complicated? May it not be that some, at least, of these particles are compounds of even more elementary building blocks? And, if so, what are the elementary ones? Do we already have them among the 11, or are there still finer and more elusive structural members beyond the reach of our instruments?



LINEAR accelerator impels particles by giving them several "kicks" as they pass down a series of tubes.

These are questions one overhears in the laboratories. They are questions for whose answers the cosmic rays are being intercepted and searched. Because of them more powerful accelerators are being built. more sensitive detectors. more accurate recorders.

II. Atomic Artillery

The alpha particles and other discharges from radioactive atoms, and the cosmic rays which continually bombard the earth from interstellar space, have been highly useful as research tools, but both are beyond the control of man. It was the desire to command the conditions of his experiments that led the physicist to devise his own artillery. He wanted to be able to choose the kind of projectile, to put more projectiles into a given barrage, and to regulate the velocity with which the projectiles struck their target.

Twenty years of inventive effort have been devoted to the problem, and several types of apparatus are now available. Each has its distinctive feature, but most of them may be grouped in two broad classes: the direct-voltage accelerators and the resonance accelerators.

In the direct-voltage machines, the projectiles move in straight paths through a long vacuum tube, impelled by the maximum voltage of the discharge. Examples are the *voltage multiplier* used by J. D. Cockcroft and E. T. S. Walton at the Cavendish Laboratory, and the *electrostatic generator* developed by Robert J. Van de Graaff at the Massachusetts Institute of Technology. Machines of this type are literally artillery pieces: barrels through which invisible bullets are fired at high velocity.

The resonance accelerators operate on a different principle. In them, projectiles are started at relatively low speeds and by the repeated push of periodic pulses of voltage are brought up to the energy required for the bombardment. Most of the resonance machines accelerate their projectiles in a whirling stream, swinging them around and around in circular or constantly enlarging spiral paths. Examples of these electrical slingshots are the *cyclotron*, the invention of E. O. Lawrence of the University of California; the *betatron*, developed by D. W. Kerst of the University of Illinois; and the *synchrotron*, first suggested in this country by E. M. McMillan of California and independently by V. Veksler of Russia.

There is also a resonance machine, the *linear accelerator*, which makes no use of the whirling principle, but sends its projectiles in straight lines through a tube, starting them slowly and building up to high speed by pulses of voltage added to the stream at equal intervals of time as it moves through the long barrel. E. O. Lawrence and D. H. Sloan developed the first linear accelerator about 14 years ago.

The energy of bombardment is rated in electron volts, a unit adopted to express the energy of the particles ejected by the radioactive atoms. The highest-energy projectiles obtained from spontaneous radioactivity are the alpha particles of 10.54 million electron volts (which hereafter shall be noted, in the physicist's shorthand, as "mev") discharged by thorium C′. This is a respectable energy, more than any accelerator was able to deliver until about the mid-1930's; but the bombardiers early realized that the search for the ultimate particles would require many times this power. By the famous equation of Albert Einstein, $E = mc^2$, the binding forces which hold nuclei together could easily be calculated. These computations showed that to break the oxygen nucleus, for example, into its elementary parts 127 million electron volts would be required. It would take 487 mev to smash the iron nucleus, and 1,580 mev to disrupt lead.

THE first to project a machine in the class of more than 100 mev was E. O. Lawrence. After building several cyclotrons of progressively larger size and higher power, the inventor and his group designed one with a magnet having a pole diameter of 184 inches, and work on this 4,000-ton apparatus began at the University of California in 1940. The war interrupted its construction, and when building operations were resumed in 1945 the design was modified to apply a newly-recognized principle of frequency modulation. This change was introduced to make a correction for the relativity effect which makes particles increase rapidly in mass as their velocity approaches that of light. By varying the frequency of the pulsations of added voltage to correspond with the lagging rate of the more massive particles, the cyclotron was changed into a *synchro-cyclotron*. Since its completion in the fall of 1946, the synchro-cyclotron has abundantly proved its superiority to the unmodified cyclotron. Designed originally to operate at about 100 mev, the modified machine has accelerated deuterons to 200 and alpha particles to 400 mev. Bombardments with these projectiles have demonstrated the strange transformation of neutrons into protons, and have even manufactured mesons, as will appear later in this article.

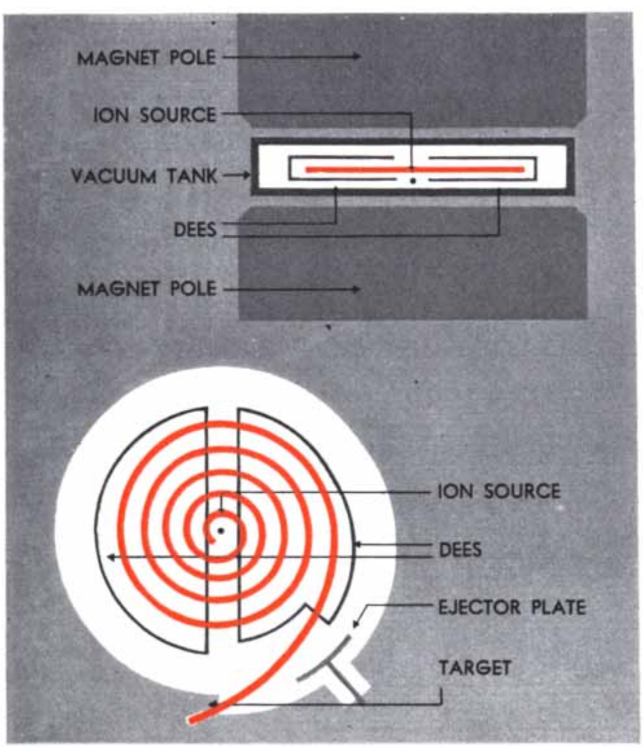
This 184-inch synchro-cyclotron at California is the most powerful accelerator now in use, but larger giants are coming. Most of them are proton-synchrotrons, an apparatus which accelerates protons through hundreds of thousands of small impulses. Whereas synchro-cyclotrons appear to have an upper limit somewhere around 750 mev, the synchrotron is able to build up voltages in the billions without disturbing the stability of the paths traveled by the particles or impairing the intensity of the beam. A 1,300-mev proton-synchrotron is under construction at the University of Birmingham, England; in the U. S. one of 3,000 mev is projected by the Brookhaven National Laboratory on Long Island, and one of 6,000 mev by the University of California. These accelerators will provide projectiles comparable to those produced by cosmic rays. It is believed they may enable experimenters to create protons and neutrons.

III. Detectors

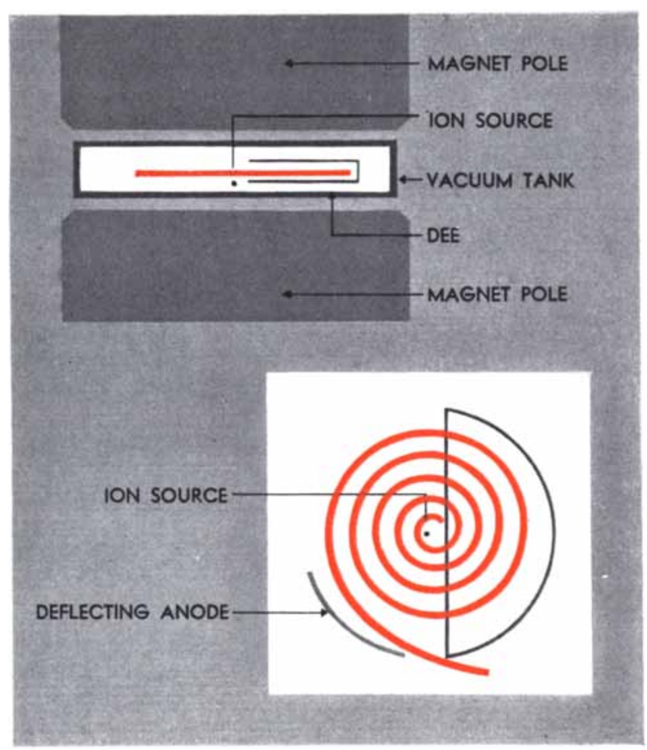
The targets of the gigantic artillery pieces of modern physics are unimaginably small. There are several methods of determining the sizes of nuclei, and they are in reasonable agreement in indicating that the atomic core is a globular or oblate structure whose volume varies approximately with its mass. The diameter of the hydrogen nucleus, the lightest, is $\frac{15}{100,000,000,000,000}$ of a centimeter, while at the other extreme, the uranium nucleus has a diameter $\frac{200}{100,000,000,000,000}$ of a centimeter. Thus the largest nucleus found in nature, although 238 times as massive, has a diameter only 13 to 14 times that of the smallest.

These dimensions are most difficult to visualize. If it were possible to enlarge the uranium atom until its nucleus became just visible, the nearest of its satellite electrons would be revolving in an orbit about six feet from that center; and beyond this orbit would be another, and then another—a total of 92 encircling electrons distributed among seven orbits. Imagine a solar system with 92 planets traveling around its sun, and yet one so small that it would take many billions to form a spot as large as the period at the end of this sentence.

Light has no wavelength small enough to form an image of these infinitesimals, and all that the physicist knows of their structure he gathers by inference from circumstantial evidence—the fingerprints,



CYCLOTRON accelerates particles by whirling them in the field of a powerful magnet. Each particle is pulled from one side of its orbit to the other by rapidly alternating the charge on the "dees." This machine is used to accelerate positively-charged particles.



SYNCHRO-CYCLOTRON extends the principle of the simple cyclotron to produce particles of higher energy. Its design, which embodies one dee instead of two, compensates for the fact that particles increase in mass as they are pushed closer to the speed of light.

footprints and other clues which the invisible particles leave behind. Many years ago he found that when the projectiles shot out of radium happen to collide with matter under certain conditions, the effects become visible. Since then the physicist has shown great ingenuity in inventing ways to trap matter under the conditions that show up these collision effects. Two arrangements are the Geiger-Müller counter and the Wilson cloud chamber.

The cloud chamber operates by a simple scheme in which the moisture-laden air within it is suddenly cooled by the withdrawal of a piston that expands the volume of the chamber. If a charged particle darts through the chamber at the moment of this expansion, droplets of the supersaturated vapor attach themselves to the air molecules which have been mutilated by collision with the particle, and thus the course of the speeding particle is revealed as a track of cloud. It is as though some invisible demon should plunge through a crowd and the police were to observe its path and estimate its force by the position and number of people knocked to the ground. The physicist is able to get additional information by placing the cloud chamber between the poles of a magnet. Negatively-charged particles then swerve in one direction, positively-charged in the opposite, and the radius of the curvature tells something of the mass of the particle. By installing plates of lead or other dense metals across the chamber, as barriers to slow the particles passing through them, it is possible to measure the particles' energies. The cloud chamber thus is an instrument of unusual versatility.

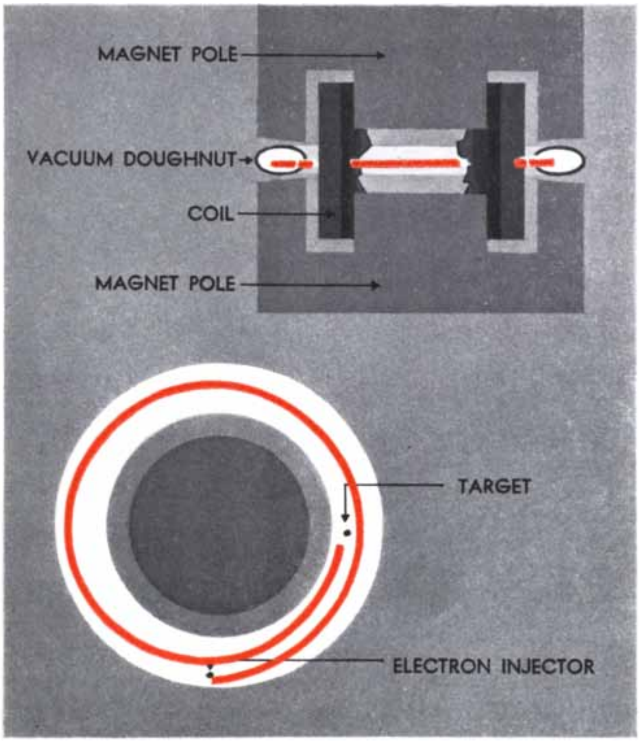
THE Geiger-Müller counter—an invention of two German physicists—reveals the invisible presence by another procedure, although its action also is based on the fact that a charged particle mutilates or ionizes the air molecules with which it collides. If these ionized molecules are positively charged, they will move to a negatively-charged electrode; if negatively charged, to the opposite. The counter is a trap to catch such occurrences. The minute electric current generated by the mutilations is amplified, and can be made to cause a click in a loudspeaker. Or the tiny current may operate a mechanical recorder, or cause a visible pulse on the screen of a cathode-ray tube. There are also other particle-detecting devices—fluoroscopes, electroscopes, specially prepared photographic plates with thick coatings of emulsion. It is by various means that physics has arrived at its present view of the nucleus.

IV. The Surrounding Vacuum

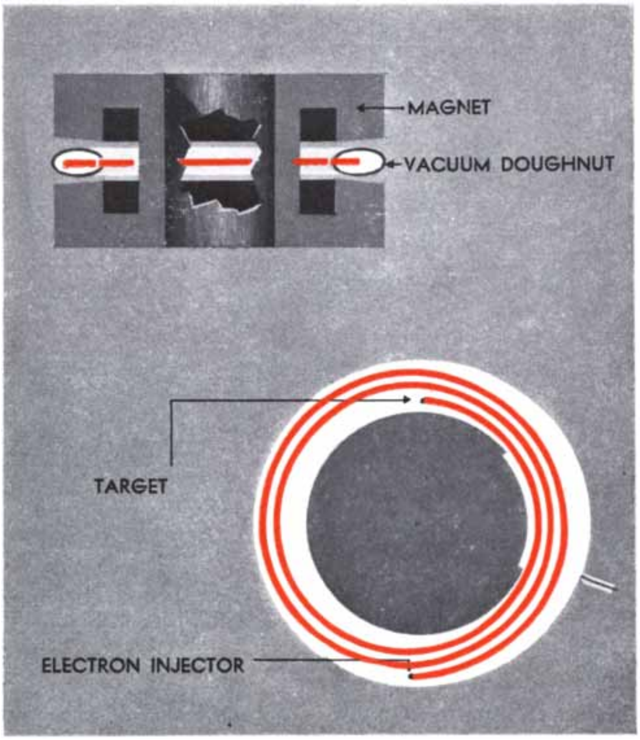
The microcosm of the atom presents a strange spectacle for the imagination. Between the nucleus and the orbit of the nearest encircling electron is a gap vaster in proportion to the sizes of these bodies than the space separating the sun from the orbit of the earth. This abyss within the atom is a perfect vacuum.

Occasionally, if the atom is of uranium, plutonium or some other radioactive species, a readjustment occurs within the nucleus and there is ejected an alpha particle, beta particle or the photon of a gamma ray. When that happens, the vacuum is of course momentarily crossed by the speeding particle, but these transits are rare and are so instantaneous as to be measured in billionths of a second.

Even a stable atom may occasionally suffer the accidental impact of a cosmic ray. If the hit is only a glancing one, it may provoke the nucleus to eject a particle; but if the blow is head on, the energy transfer may be so great as to smash the structure into fragments. Numerous photographs of such explosions have been taken in the course of cosmic-ray research, and more recently in cyclotron research at the University of California. These pictures show a burst of several tracks originating at a common center and radiating in many directions like the points of a star. "Stars" of 20 tracks and more have been photographed, and each marks the path of a speeding nuclear fragment of some atom in the photographic emulsion that was blasted by the impact of a cosmic ray. Each fragment, as it moves away from the place of



BETATRON was developed to accelerate electrons rather than positively-charged particles. Whirled in a doughnut-shaped tube, the electrons are impelled by a changing magnetic field. They may then be used as primary bombarding particles or to generate high-energy X-rays.



SYNCHROTRON is also designed to accelerate electrons, although in the future it will also be used to accelerate protons. Like the betatron, it whirls its particles in a tube. Its fundamental design also enables higher particle energies than does the simple betatron design.

the explosion, is believed to function as a new nucleus, attracting to itself wandering electrons which become its satellites. Thus an exploded silver atom may become several nuclei of smaller mass and lower charge, each with its surrounding vacuum and attendant electrons.

The vacuum is a theater for the exchange and transformation of energy. Because of its proximity to the central powerhouse of the nucleus, tremendous electromagnetic forces play across this space, and amazing events can transpire there. If a high-energy photon, that of a gamma ray, chances to dart into the vacuum, the interaction of the photon with the electromagnetic field may create two particles, an electron and a positron. Cloud-chamber photographs have been taken of the tracks made by these pairs, both originating at a common point, with the path of the positron curving in one direction, and that of the electron in the opposite. This positron-electron pair is an example of the creation of matter out of energy. The nucleus gives up none of its mass; it serves only as a catalyst to provide a field of electromagnetism for the gamma ray to work on; the ray then surrenders its energy, which instantly reappears in the form of the two material particles.

There is, however, an even deeper underlying reality. Our account of the creation of positron-electron pairs is a rough-hewn portrayal of what is elegantly expressed in the laconic mathematics of P. A. M. Dirac's theory. This theory is concerned with the various states of energy which may be occupied by an electron. The number of such states is infinite. Plotted on a chart they stretch from zero upward, but the chart also points to an equal number of energy states below the zero line. It may strain common sense to speak of the energy of motion as less than nothing, but negative quantities have proved useful in mathematics and the concept must be admitted. The levels of less-than-zero are negative-energy states, but for simplicity (to avoid confusion with the negative electrical charge on the electron) let us call them minus-energy states, and those above zero, plus-energy states. The point is that a negatively-charged electron, any electron, can occupy either a state of minus-energy or one of plus-energy.

But electrons are lazy. Their tendency is to drop into conditions of lower energy, and this would seem to mean a general movement to levels below the zero line. However, there is a law, the Pauli "exclusion principle," which forbids more than one electron to occupy a given energy state; and consequently, after all the minus-energy states were taken, perhaps in some mad cosmic scramble at the beginning of time, there was nothing left for the losers but to accept the lowest available plus-energy states.

It is these electrons in plus-energy states that whirl in the orbits around nuclei, that flow through wires and other conductors to form electric current, that dance in the candle flame to generate light. Indeed, all the electrons that make up the perceptible universe are those which were forced by the exclusion principle into plus-energy states. The others, which presumably are more numerous, are comfortably at rest in their berths of minus energy—withdrawn from the dynamic world, buried in the vacuum.

But not completely unobservable, declared Professor Dirac. Theory told him that the chance blow of a gamma ray might knock an electron out of its minus-energy state. In that case, the hole left in the substratum should appear as a particle, a particle having the same mass as the electron but of opposite charge—in other words, a positively-charged electron. This speculation was published in England almost a year before the discovery of the positron. Since then hundreds of tracks of positron-electron pairs have been photographed. The tracks soon end, betraying the early disappearance of both positron and electron as free bodies. This is to be expected. For the electron is usually captured by some nucleus looking for another satellite; and as for the "hole," almost as soon as it appears the nearest electron leaps into it. Then both hole and electron disappear into the vacuum, and their energy darts off as radiation.

Such a picture is difficult to reconcile with ordinary logic. The region surrounding the nucleus was described earlier as a void. Now the same region is portrayed as the repository of innumerable electrons at rest in states of negative energy. Which is right? Can space be both empty and occupied? Apparently the two pictures represent different aspects of the same thing. Nature requires a perfect vacuum to serve as the sea of negative-energy states—and where all the negative-energy states are occupied, there is a perfect vacuum.

V. The Forces Within

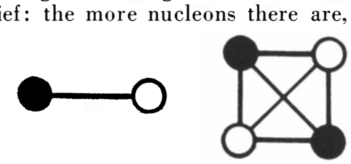
Some of the nucleus itself may be vacuum. If the particles which join to form it maintain their individuality as separate units, as seems probable, it is necessary to assume that there is space between them. Whatever its structure, the nuclear material is the quintessence of mass. Most of the world's weight is concentrated in these tiny cores. A cubic centimeter of platinum with its electrons weighs about three quarters of an ounce; but when the encircling electrons are peeled off and each atom is stripped down to its naked nucleus, we arrive at something that when packed together averages 130 million tons per cubic centimeter. And the same is true of all atoms, for nuclear material whatever its origin is "one stuff and betrays the same properties." The whole of Mount Everest might thus be packed into a cigarette case. W. D. Harkins has calculated that if all the matter making up the earth were collapsed down to its nuclear material, the diameter of our planet would shrink from its present 8,000 miles to about 1,080 feet—with no shrinkage in its weight.

Every particle known to the cloud chamber has been detected coming out of nuclei. Photons come out as gamma rays, electrons in the form of beta particles come out, and so do alpha particles, positrons, neutrons, protons, and mesons. In addition there is the hypothetical neutrino which the physicists assume must come out. Does this mean that the nucleus is a mixture of all these various particles?

The physicists don't think so. In the case of photons, for example, no one has ever seriously suggested that they are constituent particles. Gamma rays are created by the internal forces; when the forces reach such a state of imbalance that the nucleus must change to a lower energy, the shift is made and the surplus energy is ejected as a photon of gamma radiation. In the same way, it is now believed, electrons, positrons and mesons do not exist as components, but under certain stresses are created by the conversion of energy into mass. In this view, which is the prevalent one today, nuclei are composed of protons and neutrons—and nothing else. Protons and neutrons therefore are in a different class from the other particles: they are the nuclear building blocks, and because of this are called *nucleons.* All the other particles are by-products created by the interactions of nucleons.

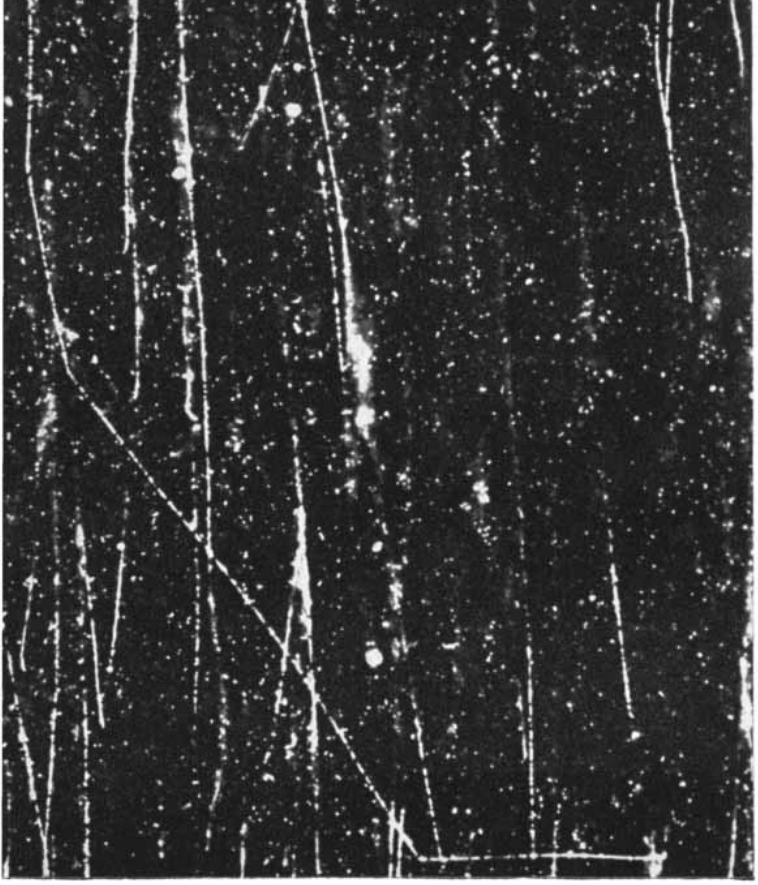
INTERACTIONS are not likely to occur in the case of simple hydrogen, for its nucleus is a solitary proton. The first step toward complexity is the double-weight hydrogen atom whose nucleus, known as the deuteron, consists of one proton joined to one neutron. Helium is the next. Its nucleus is made up of two protons and two neutrons, and therefore represents the union of two deuterons. But the helium core is something radically different from the sum of two deuterons. Measurements show that the binding force which holds this heavier nucleus together exerts the power of 28.20 million electron volts, whereas the binding force of the deuteron is only 2.19 mev.

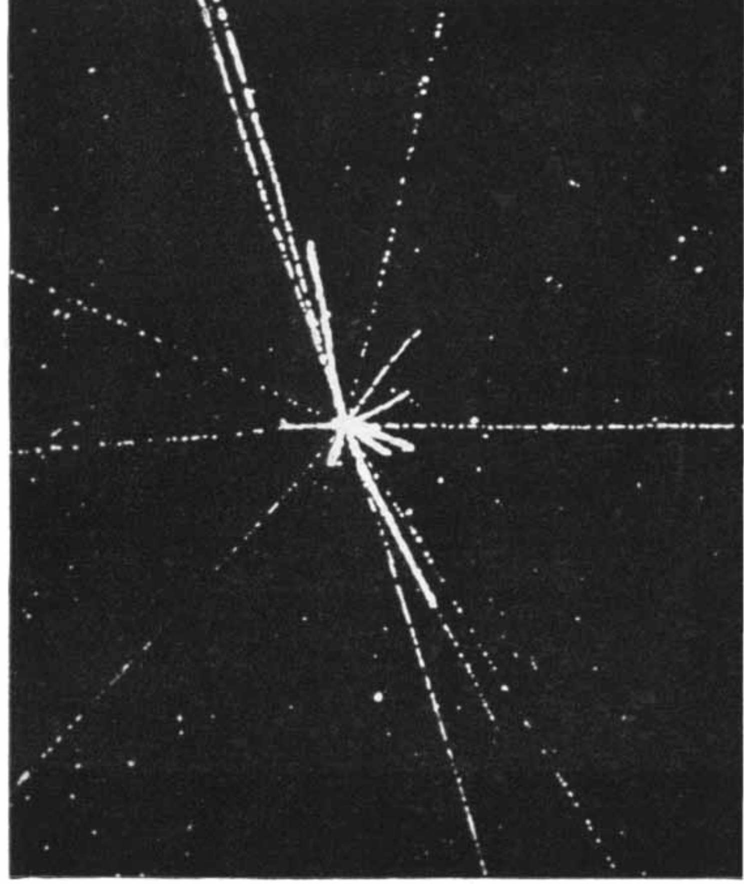
A reason for the higher binding force of the heavier nucleus has been suggested by Eugene P. Wigner of Princeton. In brief: the more nucleons there are, the



greater is the number of bonds holding them together. The accompanying diagrams, depicting the deuteron and the helium nucleus according to the number of particles, illustrate how this works.

The nucleons of the deuteron, since there is only one bond between them,



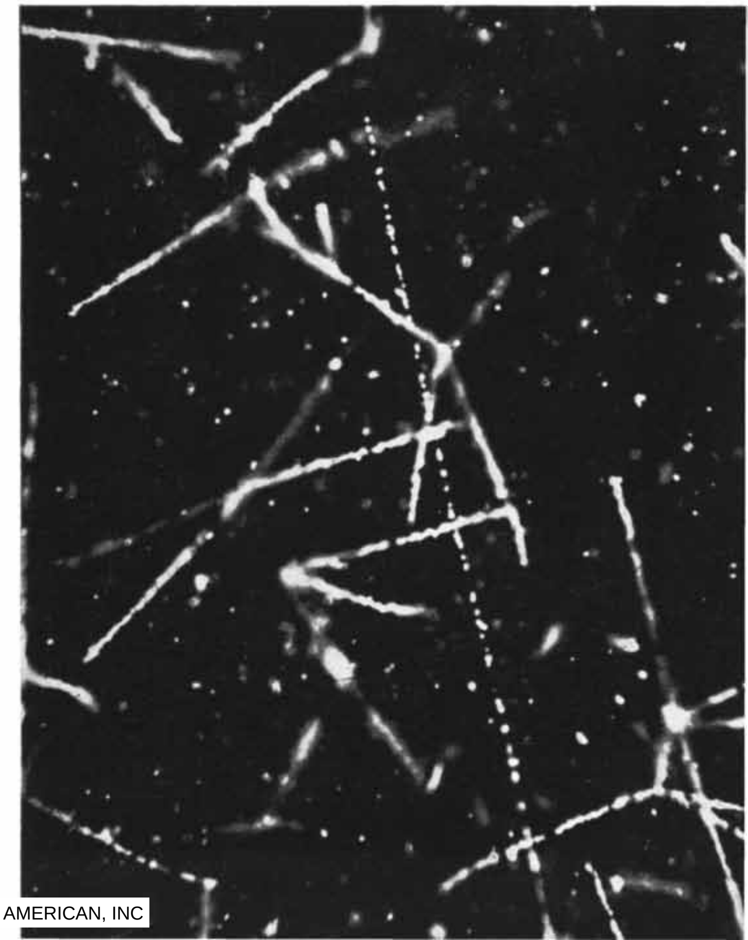


PROTON, starting at upper left and ending at lower right, is deflected from three nuclei in special photographic emulsion employed in the study of particles.

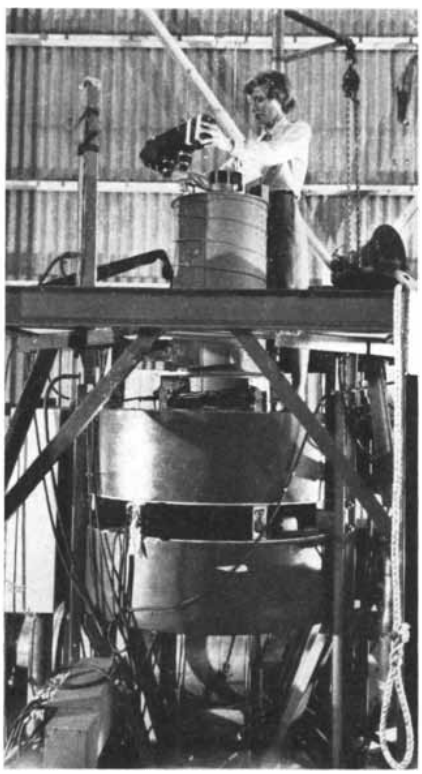
HEAVY NUCLEUS in the photographic emulsion explodes in a shower of heavy and light fragments when it is struck by a cosmic-ray particle of huge energy.

COLLISION of one proton with another is indicated by forked track at bottom. Bombarding proton is deflected at an angle; the other leaves a track in recoiling.

"STARS" of emitted particles are produced in emulsion when it is impregnated with radioactive thorium. Long track beginning at bottom is a recoiling proton.



CLOUD CHAMBER used with Berkeley cyclotron is lighted in quick flashes to permit track photographs.



CAMERA is put in place to make photographs of tracks in cloud chamber between poles of a magnet below.

CONTROL PANEL from which the Berkeley cyclotron is operated is observed by Physicist Luis W. Alvarez.

average one-half bond per particle; whereas, with six bonds joining its four nucleons, helium averages one and one-half per particle. The effect is to make helium a more tightly knit structure. Its nucleons draw closer to one another, and its mass becomes slightly less than the sum of the masses of two deuterons. This "mass defect," which one finds in all nuclei made of two or more particles, is highly significant. for it represents the amount of matter that has been converted into energy to provide the binding force.

The nature and mechanism of this binding force is one of the great mysteries. Indeed, the quest for the ultimate particles depends. in large measure, on understanding the binding force.

Gravitational attraction operates between particles just as it does between stars and planets. It is possible to calculate the magnitude of this force between two protons by applying Newton's law that gravity varies inversely as the square of the distance. In the close quarters of the nucleus this gravitational attraction of nearby particles for one another is considerable. But it is not nearly great enough to account for the tremendous binding forces of nuclei, ranging from 28.20 mev for helium to 1,780 mev for uranium.

Moreover, there is present in all these nuclei. from helium to uranium and beyond. a disruptive agency more powerful than gravitation. It is the force of repulsion which exists between bodies carrying the same kind of electrical charge. The mutual repulsion of proton for proton is so great that, according to Frederick Soddy's calculation, if a gram of protons could be concentrated at one point on the earth's surface and another gram at the opposite point on the other side of the globe. the repulsion of these two tiny positive charges for one another would be equivalent to a pressure of 28 tons. This is at a distance of 8,000 miles! And yet within the confines of the nucleus protons dwell in such close communion that millions of volts are required to blast them apart.

It was this paradox that led physicists to assume the existence of a force of attraction which is able to overrule the electrical force of repulsion. They call it the *nuclear force*, since it is able to operate only over distances of very small magnitude, such as those within the atomic nucleus. Exact measurements of this force were made by, among others, Merle A. Tuve and a group at the Carnegie Institution of Washington. using the 1.2 million-volt electrostatic generator of the Department of Terrestrial Magnetism. They fired protons at hydrogen nuclei, and gradually increased the voltage until a speed was reached at which the momentum drove the projectile so close to the nucleus that it was attracted rather than repelled. This marked a boundary—the distance at which the nuclear force of attraction began to operate. By applying the principles of wave mechanics. a mathematical analysis of the experimental results was made by Gregory Breit. assisted by E. U. Condon and R. D. Present. and their calculation gave these findings:

1. The electrical force of repulsion ceased to control when the projectile proton got within about 1/12.000,000,000.000 of an inch of the target proton.

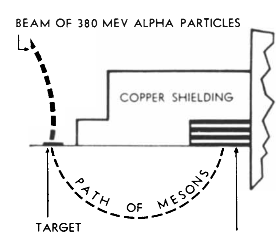
2. The nuclear force of attraction which suddenly took control at that distance was approximately 10^{36} times greater than the gravitational force between the two protons.

Experiment has shown that the nuclear force of attraction operates also between neutrons. and between protons and neutrons.

The nucleus, according to this testimony. is a powerhouse of opposing forces —-an electromagnetic field and a nuclear-force field. One evidence that electromagnetic force operates within the nucleus is the emission of photons of gamma radiation. These photons are quanta of the electromagnetic field. But if the electromagnetic field is thus quantized in the form of a particle, may it not be that the nuclear-force field also has its particle? It was this question that led the Japanese physicist Hideki Yukawa to speculate on the existence of the meson some months before it was discovered in a cloud chamber.

VI. Mesons

Mesons are the most baffling and unpredictable objects thus far glimpsed among the debris of bombardments. Not only were they discovered by means of cosmic rays. but they appear to constitute about three fourths of all the cosmic rays reaching sea level. the other fourth being electrons. They are not the primary cosmic rays that reach our atmosphere from outer space. but are secondaries knocked out of air atoms by the incoming primaries. Instruments sent to high altitudes in balloons indicate that most of the primary rays are protons. They travel with such prodigious energy that they are able to penetrate many miles into the atmosphere. mutilating atom after atom in a series of collisions. Meanwhile. the mesons and electrons knocked out of atoms by these



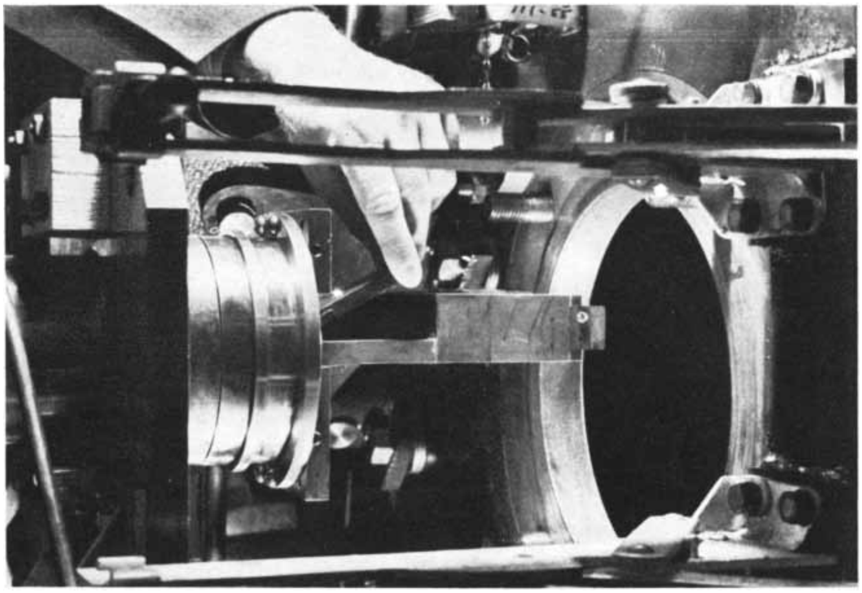
MESONS were produced and recorded in Berkeley cyclotron by bombarding carbon with alpha particles.

runaway protons may receive energies almost as great as those of the primaries themselves. There is evidence that some mesons reaching sea level plow into the earth with 100 million mev, for they have been detected in mines at depths of one mile. As they move at speeds close to the velocity of light, these high-speed mesons smash other particles out of atoms. One of them passing near an atomic nucleus and deviated by its electromagnetic field is thereby accelerated and caused to give off high-energy radiation in the form of a gamma-ray photon. This photon, by its interaction with atoms, may initiate a shower of electrons and photons, thus launching hundreds of particles as additional cosmic rays. Mesons appear singly, in pairs and in showers; and, as it has been stated earlier, some are negatively charged, some positively and some are neutral.

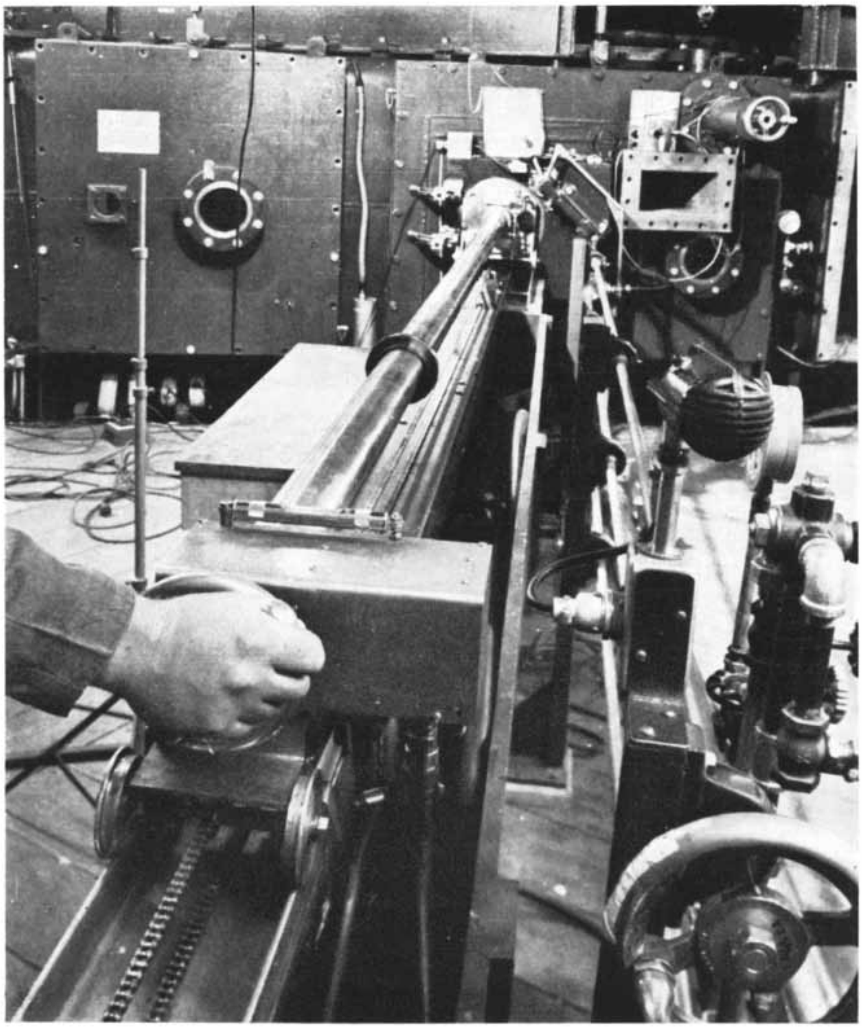
Until 1948 no one had been able to obtain mesons experimentally. But with the completion of California's 184-inch cyclotron an apparatus was at hand by which atoms might be battered into giving off these nuclear oddities. Early in 1948, Eugene Gardner and C. M. G. Lattes set up an experiment to see if this could be done. Lattes, formerly of the University of Bristol group, only a few weeks before this had joined the California staff, coming on a Rockefeller Foundation fellowship.

For the bombardment they used alpha particles. As the alpha particles emerged from the cyclotron at energies of 380 million electron volts, they encountered a thin sheet of carbon in the form of graphite. This was the target from which Gardner and Lattes hoped to hammer mesons. If any came out, the magnetic field of the cyclotron would bend their courses into curving paths that were calculated from their masses. This made it possible to put a stack of photographic plates across the expected paths. Mesons knocked out of the carbon should penetrate the emulsion of the plates and, by ionizing granules with which they collided, the mesons might photograph their own tracks. This was the logic of the experiment.

The photographic plates were exposed. Then, because of their thick emulsions, they were given 30 minutes in the developing fluid. And behold, the meson tracks became visible! There were hundreds of them. Indeed, 30 seconds' bombardment with the cyclotron gave 100 times as many mesons as Dr. Lattes had been able to photograph in 47 days of cosmic-ray observations in the Bolivian Andes last year. To be sure, the laboratory mesons were not as energetic as those produced by cosmic rays; their speed was that of a mere four mev. But under the controlled conditions of the laboratory it was possible to measure their masses quite exactly. The fact that the particles can be produced at will, and in such large numbers,



TARGET HEAD of the Berkeley cyclotron was especially rigged for the production of artificial mesons (*see drawing on opposite page*). Here packet of photographic plates is placed in slot. Carbon target is at tip of rig.



LONG PROBE is designed to facilitate the removal of radioactive targets after they have been bombarded in cyclotron. Targets are removed from the end of the probe and placed in lead-shielded carts by remote control.

INSIDE THE CYCLOTRON at Berkeley are the essentially simple parts that manipulate its various bombarding particles. Above and below are the 184-inch poles of its great magnet. Just below the upper pole,

makes this recent achievement in California the beginning of a new chapter in meson research. As larger and more powerful accelerators are built, we can look forward to mesons of hundreds and even thousands of mev energy.

PRACTICALLY all the mesons knocked out of carbon (and later out of beryllium, copper and uranium) by the cyclotron bombardment weighed about 313 times the electron mass. This corresponds rather closely to the mass of 320 reported by the University of Bristol group for the heavyweight mesons discovered last year in its cosmic-ray photographs; and perhaps the 313 mass measured in the laboratory is a more exact determination than that estimated from the photographs taken on the mountain top. It is assumed, therefore, that these particles of 313 mass which were knocked out of carbon by the cyclotron bombardment are the *pi* mesons discovered by the Bristol group in 1947.

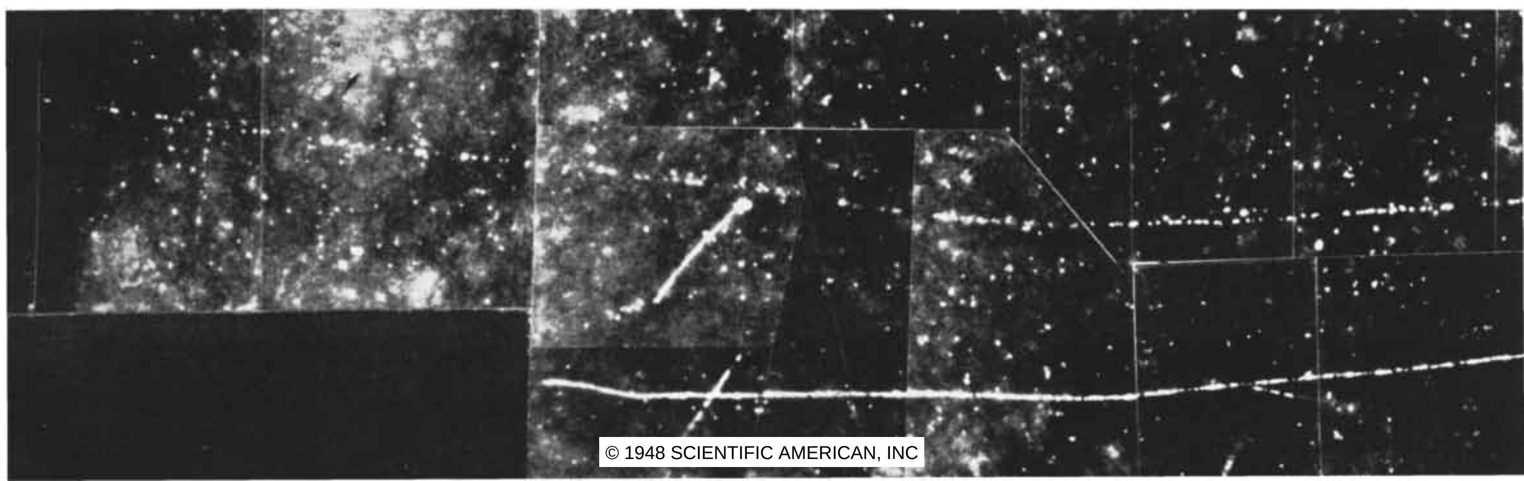
The photographs show that the heavyweight particle, the *pi* meson, has a remarkably short life—less than two millionths of a second—and what happens at the end of its existence depends on the electric charge of the particle. If the *pi* meson is positively charged, it travels a distance determined by its speed and then disintegrates into a positive *mu* meson, with the emission of a neutral meson of a mass of about 88.

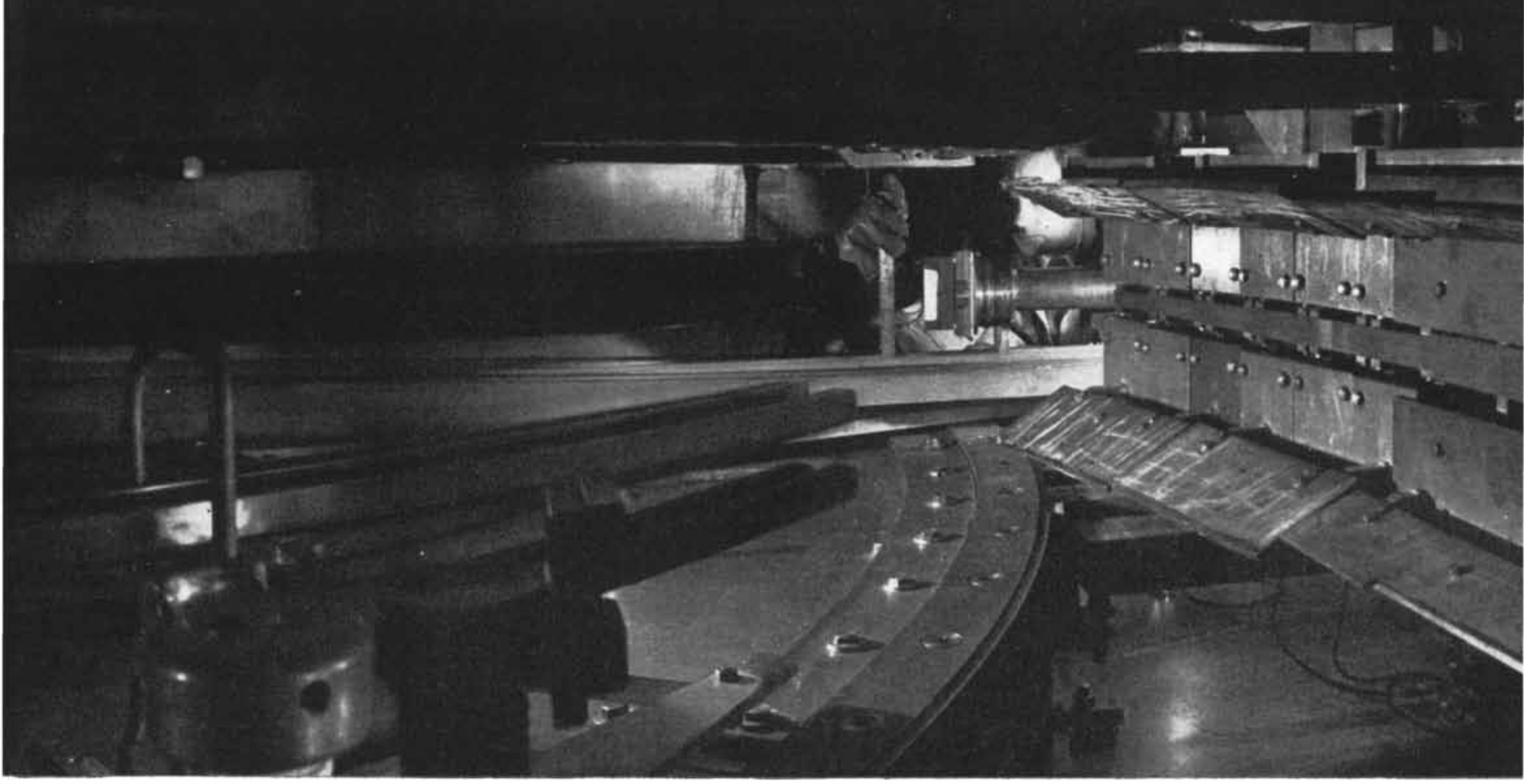
If on the other hand, the *pi* meson is negatively charged, the positive charge of some atomic nucleus eventually attracts it, and the meson disappears into the nucleus which subsequently explodes in the familiar "star" effect.

What happens to the lightweight, the *mu* meson of 200 mass? Again, the end result depends on the electrical character of the particle. If it is positively charged, the *mu* meson decays into a positron, and the photographs provide data which suggest that a neutral meson and a neutrino are also released in the disintegration. If the *mu* meson is negatively charged, it is of course subject to the attraction of the positive charge of nuclei, and consequently the particle is captured by the first atom it encounters. The meson then begins to revolve around the atom's nucleus. According to studies by John A. Wheeler of Princeton University, the new satellite draws progressively closer and closer to the nucleus, cutting deeper and deeper into its interior, until suddenly the meson disappears. In the case of atoms lighter than aluminum this disappearance is heralded by the emission of an electron, with the release at the same time of a neutral meson and, presumably, a neutrino. In the heavier atoms, the meson simply vanishes with no perceptible emission or disintegration fragments—but it is assumed that a neutral meson is discharged, or a neutrino, or possibly both.

Of the state of mesons within the nucleus physicists know almost nothing, but

ARTIFICIAL MESON produced in the Berkeley cyclotron wrote its track in a pile of photographic plates which were then assembled in a mosaic. The meson enters the picture at upper left, darts through the emul-





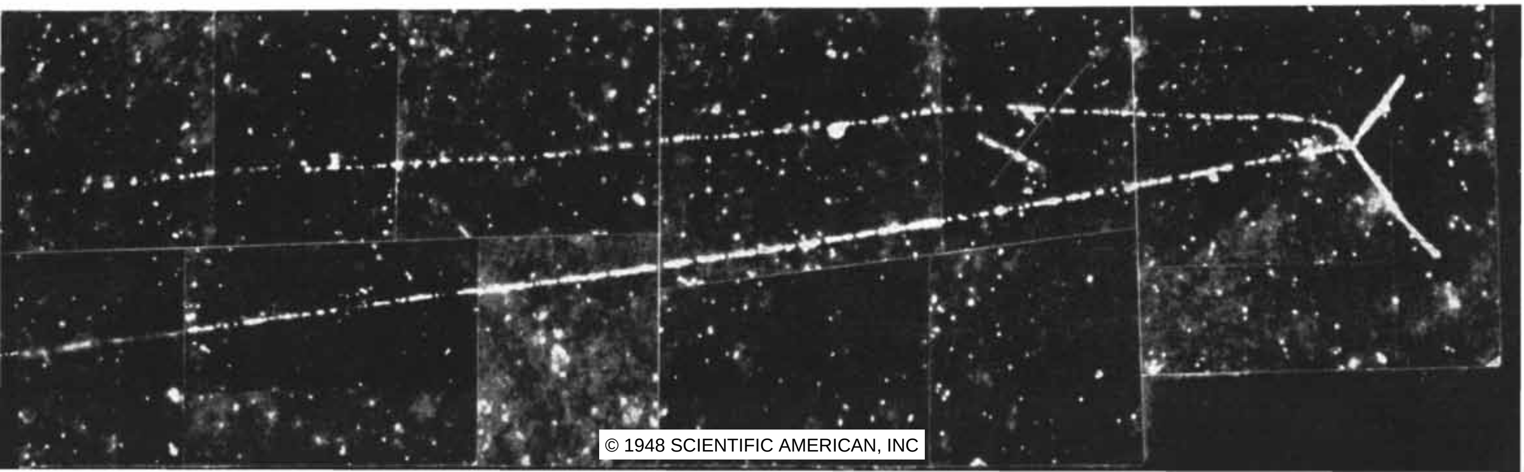
obscured by copper facings, is the cyclotron's single dee. At right one of Berkeley experimenters examines the end of the target probe. When the cyclotron is in operation, all this apparatus is sealed in vacuum tank.

an idea widely discussed portrays the particles as existing in the force fields of the constituent nucleons. According to this theory, the field of a neutron is continually interacting with the corresponding field of an adjacent proton and in these fields the electric charge is perpetually being exchanged, shuttling back and forth between proton and neutron in an eternal game of tennis in which the electric charge is the ball. The proton biffs its charge to the neutron, and thus detached from its charge becomes itself a neutron, while the neutron which receives the charge becomes a proton. But the recipient hardly gets the charge before it volleys it back to its former owner. Thus we have a picture of the atomic nucleus as a place where protons are continually becoming neutrons, and neutrons protons, with the charges in transit most of the time.

Several studies with the 184-inch cyclotron have demonstrated that an exchange of charge does take place. The experiment most directly proving this was conducted by Wilson Powell and Walter Hartsough at the University of California laboratory in 1947. They used 100-mev neutrons as projectiles. and fired them into a cloud chamber filled with hydrogen gas. Since the nuclei of the gas were all protons, whatever interactions occurred could be interpreted only as neutron-proton interactions. The momentum with which these 100-mev neutrons struck was gigantic. When a neutron makes a head-on collision with a proton in the cloud chamber. the force of the blow can be as high as 3.4 tons. This force, if it were exerted as an even pressure over one square inch of area, would equal the weight of 39,000 earths. While the neutron is being pushed by this force, its acceleration is 5×10^{27} times that of gravity. Thus propelled, the neutron approached so close to the proton that the distance separating the two particles was of the same order as that which prevails within nuclei. The results of the collision were interpreted from the subsequent behavior of the particles, and this indicated that in a large number of instances the charge was exchanged. At the moment when projectile and target were in close contact, the positive charge of the proton passed over to the neutron. and the latter darted off as a proton, while the former moved in a new path as a neutron.

While the cyclotron experiments show that the exchange does indeed take place, they reveal nothing of the mechanism by which the transfer is made. Whether or not the meson takes part in these interchanges, and carries the charge back and forth between the particles as Yukawa suggested, remains in the realm of speculation. The only objective evidence we have of mesons is their appearance as free particles shot out of nuclei as a result of high-energy collisions. These discharges are accompanied by changes in the status of the bombarded nucleus. Pre-

sion for about an inch and a half and is captured by a nucleus. This then explodes, sending one fragment back along the path of the meson. Capture of the meson by a positive nucleus indicates that it has negative charge.



MESON SONG

We have mesons *pi* and mesons *mu*,
And mesons that serve as nuclear glue.
We have mesons large and mesons small,
Plus charge or minus, or no charge at all.

Chorus: What! No charge at all?
No! No charge at all.
A very small rest mass,
And no charge at all.

Vector or scalar or halfway between,
Sometimes the convergence can scarcely be seen.
Two hundred, four hundred, nine hundred mass,
All sorts of charges in every weight class.

Chorus:

The forces exchange when at distances small;
There's the depth of the well and the height of the wall;
The quadripole moment a tensor demands
What very strange forces we have on our hands!

Chorus:

Oh Bose! Oh Fermi! Perhaps Einstein, too,
Send a unified theory for both *pi* and *mu;*
With spin and statistics, adjustable range,
Nuclear structure is yours to arrange.

Chorus: What! No sense at all?
No! No sense at all.
A very small rest mass,
And no sense at all.

sumably the emergence of a positive meson means that a proton has lost its charge, that the nucleus now has one more neutron than it had before; while the emergence of a negative meson signals the transformation of a neutron into a proton.

Current attempts to explain meson behavior can only be described as groping approximations. There is a song going the rounds of the laboratories which expresses some of the bewilderment that confronts those who experiment with and meditate on the new-found particles. It was composed by a group of physicists and wives at a social gathering following a seminar on mesons led by George E. Valley at the University of Rochester last January. The "Meson Song" (*see box*) ends with the refrain:

What! No sense at all?
No! No sense at all.
A very small rest mass,
And no sense at all.

Perhaps many readers would agree that mesons make no sense at all. And yet these particles cannot be dismissed. Their evidence is all about us; they write their wriggly paths in our cloud chambers and photographs; they bombard us from all directions. While you have been reading this article, several thousand mesons driven by cosmic rays have plunged through your body.

VII. Theories

Many physicists are frankly dissatisfied with the complexity of nuclear theory. Some are testing daring new ideas in the search for a simpler and more unified pattern to describe the microcosmic architecture. At Princeton, for example, Dr. Wheeler and his group are considering the possibility that mesons, protons and neutrons may all be built up from electrons, positrons and neutrinos. It is a highly speculative suggestion which physicists view with cautious skepticism, as they do all new attempts at simplification. Dr. Wheeler himself points out that the idea must remain a question until there is fuller examination of electromagnetic and electron-positron pair theories. But he and his associates are definitely exploring the implications of a world built of electrons and positrons as the material units, with neutrinos as the energy units.

The electron-positron pair is the key to the concept. We know that when electron meets positron both are annihilated, with a release of gamma radiation. It has also been proved that the action of a gamma ray on the electromagnetic field can call a pair into existence. Imagine, then, a condition in which pairs of plus and minus electrons are continually being created and destroyed. Imagine these newborn and dying positives and negatives perpetually weaving back and forth within the nucleus, describing a network of paths, and by these movements generating the binding forces.

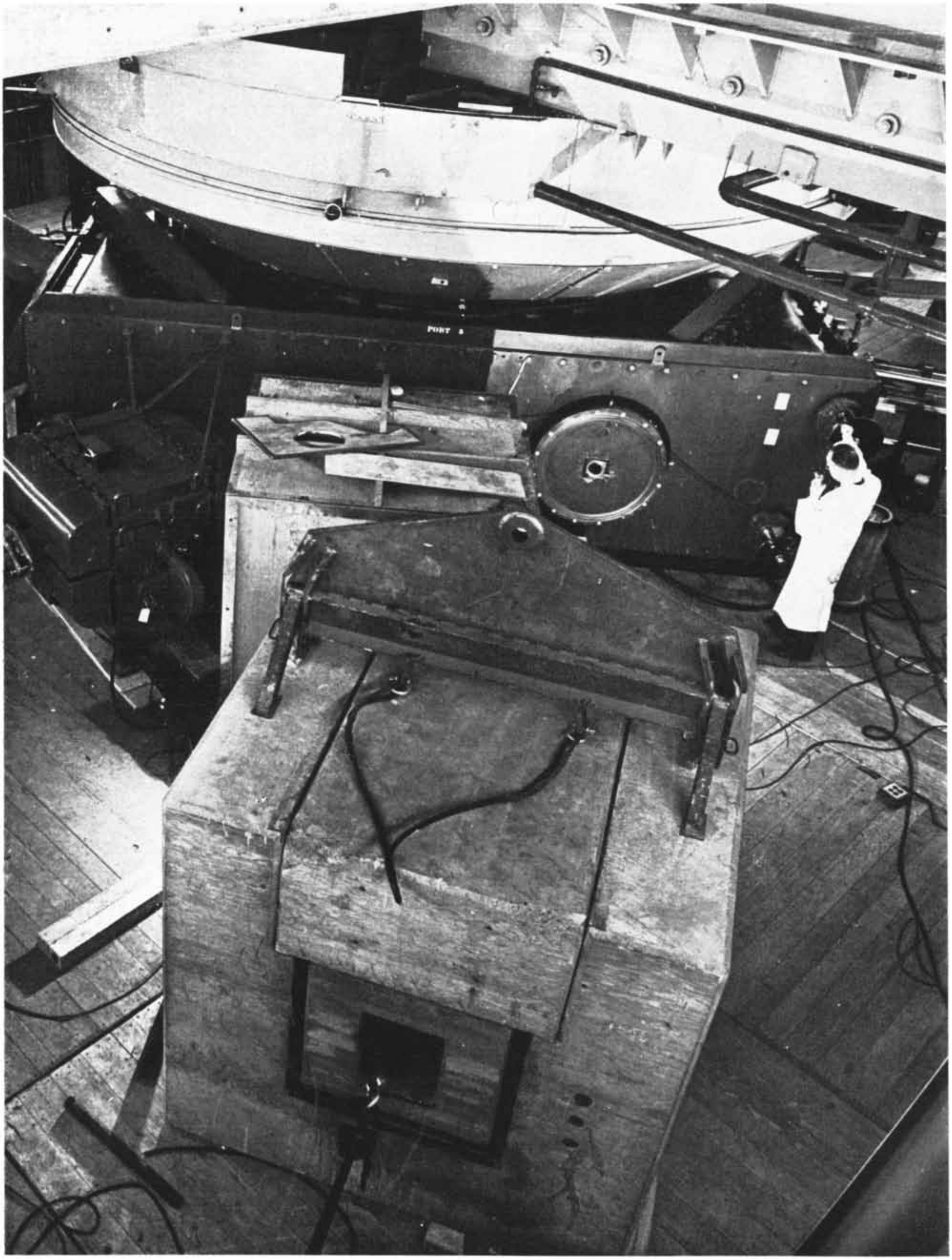
"It would be a gain if we could get away from the postulate of a special nuclear force," said Dr. Wheeler, "and account for the binding energy in terms of something we already know. Chemists used to imagine a 'chemical force' to account for the affinity of certain atoms and molecules for one another but as knowledge of the electrical structure of atoms advanced, the chemists came to see that affinity was simply a manifestation of electromagnetism. So we think it may turn out to be in the case of the nuclear force."

COSMIC-RAY research provides statistics that may have a bearing on this question. Counting devices indicate that among secondary cosmic rays the positive mesons outnumber the negatives about five to four. There are indirect indications that the primary rays which produce mesons in the upper atmosphere release about nine in a single collision. If we assume that a proton breaks up into nine mesons, the most likely order of fragmentation would be five positive mesons and four negative ones, the extra positive being the proton's charge.

The neutrino also may enter into some of the material particles. For example, a neutron, of mass 1,836 times that of the electron or positron, may embody 918 electron-positron pairs, but since each electron's spin of one-half unit would cancel out each positron's opposite spin of one-half, this would leave the neutron with no spin. By assuming that a neutrino enters into the structure, the neutron's actual spin of one-half is explained.

It would seem a great simplification to reduce the world to three elementary particles—two of matter and one of energy—with their interactions accounting for all the forces. But for the present the idea is only a conjecture, and whether or not it can fertilize definitive experiments remains to be seen. Of course, there is always the possibility that what Leibnitz called "the pre-established harmony" is beyond the reach of instruments, even beyond the reach of our imaginations. J. B. S. Haldane has given it as his opinion that "the universe is not only queerer than we suppose, but queerer than we *can* suppose." It isn't likely that many nuclear physicists will accept this doctrine of defeatism. They will continue their bombardments, their trapping of cosmic rays, their examination of the debris. The theorists will continue to follow up these experiments with their fascinating analyses, their rationalization of the results, sometimes with predictions of results to come. And eventually the strange assortment of protons, neutrons, mesons, electrons and positrons, with their accompanying photons and neutrinos, will take their places in a completely consistent picture. Such is the hope and the faith of science.

George W. Gray is a writer on scientific subjects.



VACUUM TANK of the Berkeley cyclotron surrounds the apparatus shown on pages 36 and 37. Sometimes a beam of particles is brought through the side of the tank. Neutrons are brought out through the hole in the plate at right center. They are then formed into a collimated beam by a hole in the concrete block in the foreground. Usually the cyclotron is surrounded by concrete shielding. Here part of the roof has been lifted.

THE

SELF-PORTRAIT OF LEONARDO, who lived before medical knowledge had appreciably succeeded in the postponement of death, powerfully expresses man's sad acceptance of its inevitability. Leonardo died at 67.

NOTHING in life seems more inevitable than old age and death. But this anthropomorphic fatalism springs from ignorance of the durability of living substances. Death is by no means a universal law of nature. The biologist observes that, while "all men are mortal," the same principle does not apply to all living things. Enough exceptions exist to encourage the hope that science may learn how to lengthen human life.

Consider fishes, for example. Fishes are not immortal. Their life span is limited by primitive dangers that are no less prevalent in the deep than in the jungle. Some fish die of mysterious poisons, such as the "red tide" that plagued the Florida coast last year. Some succumb to parasites that invade their internal organs, and some to the rasp-mouthed hagfish that bores into a flank and gradually devours the living host. Most fishes no doubt end their days in the jaws of their larger and swifter relatives. But there is one malady that fishes do not die of—old age.

Fishes do not die of old age because they do not grow old. Indeed, no animal "grows" old in a physiological sense. A growing organism is young. Only when the body reaches its adult size, and growth ceases, do the changes that we think of as signs of age begin to make their appearance.

But most fishes have no adult size. The tiny larval fish newly hatched from its egg capsule does not enter upon a fixed period of rapid growth up to mature size and strength. Its parents could not, if they had the minds to do so, anticipate a day of maturity when their offspring would be a fish among fish, ready to face the terrors of its watery world. Rather, the young fish continues to grow bigger and stronger as long as it manages to survive. The fact that fishermen always catch the "big ones" in the remotest lakes and streams, with no one around to see, is not necessarily a reflection on the veracity of the human race. Where fish are least disturbed by predators, including the human variety, they have time to grow big.

Although the age of many fishes can be read from annual rings formed in the scales, locating the oldest members of the fish population for study is obviously not

BIOLOGY OF OLD AGE

Senescence and death, which to man seem unavoidable, are not the rule among all species of living things

by Florence Moog

an easy job. So it is not surprising that we cannot say with certainty how long fishes live. Our best evidence indicates a life span of nearly a century for a few relatively well-known fresh-water species —pike, carp, catfish. Of the ages attained by deep-sea fishes, almost nothing is known.

For the purpose of determining how close living things can approach to immortality, plants, thanks to their habit of remaining in one place, make better material than animals. Some plants, of course, lose their young growing tissue after a period

BALD CYPRESS of Tula, in Mexico, is 52 feet through and probably the oldest living thing in the world.

of development and soon die. But others continue to grow by annually producing fresh buds and shoots, and such plants apparently live until disease or want of food or cold or drought or storm put an end to them. Many trees survive for centuries and some for thousands of years. Perhaps the oldest living thing is a great bald cypress which is still growing near the town of Tula in central Mexico. With a trunk 52 feet in diameter, this tree may have been 1,000 years old on the date when Jehovah is reported to have created heaven and earth.

The only true immortals, however, are the microscopic, one-celled organisms—algae, fungi, protozoa. These tiny organisms grow to a maximum size, then divide to produce two identical individuals which share the parent's protoplasm between them. The daughter units, if conditions are favorable, grow and divide and grow and divide, again and again. With no limits set on their growth, many of these creatures do not experience "natural" death. An isolated amoeba was observed to undergo 200 successive divisions and was still multiplying merrily when the experiment was terminated after 13 months. A culture of green algae was reported to be in good condition after having produced 1,300 generations in five years. In 1943 a protozoan culture raised by L. L. Woodruff of Yale completed its 37th year of continued growth. In that time it had passed through 20,000 generations. Of course not all the individuals produced were allowed to survive; if they had been, the entire surface of the earth would have been much too small to accommodate them!

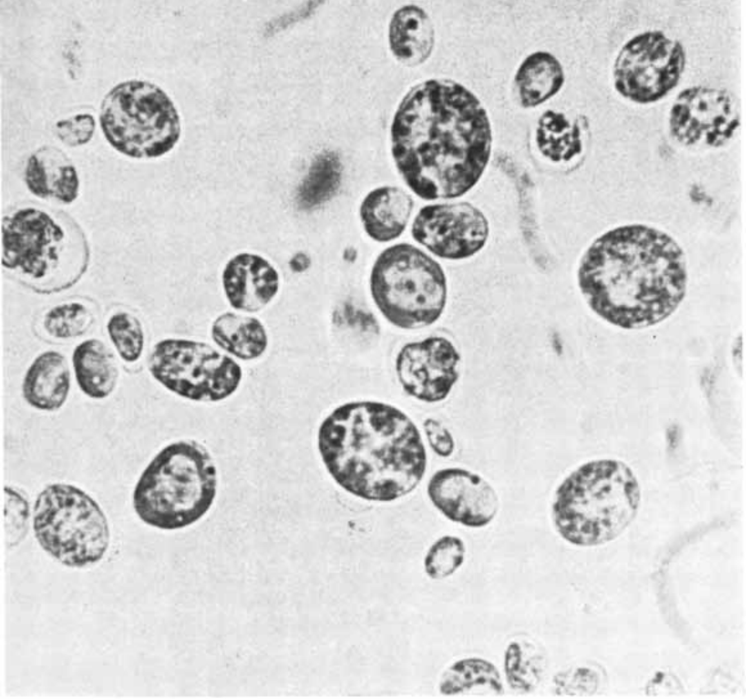
Given conditions under which growth can go on, even living material that ordinarily ages and dies will remain young far beyond its normal term. At the Rockefeller Institute in 1912 Alexis Carrel removed a bit of heart tissue from a chick embryo and immersed it in a nutrient solution of foodstuffs extracted from embryos. Trimmed at intervals and provided regularly with fresh nutriment, this tissue lived and grew until the experiment was deliberately ended in 1946. A chicken hatched in 1912 would have died 20 years ago, yet there is no reason to suppose that this snippet of heart need ever have died.

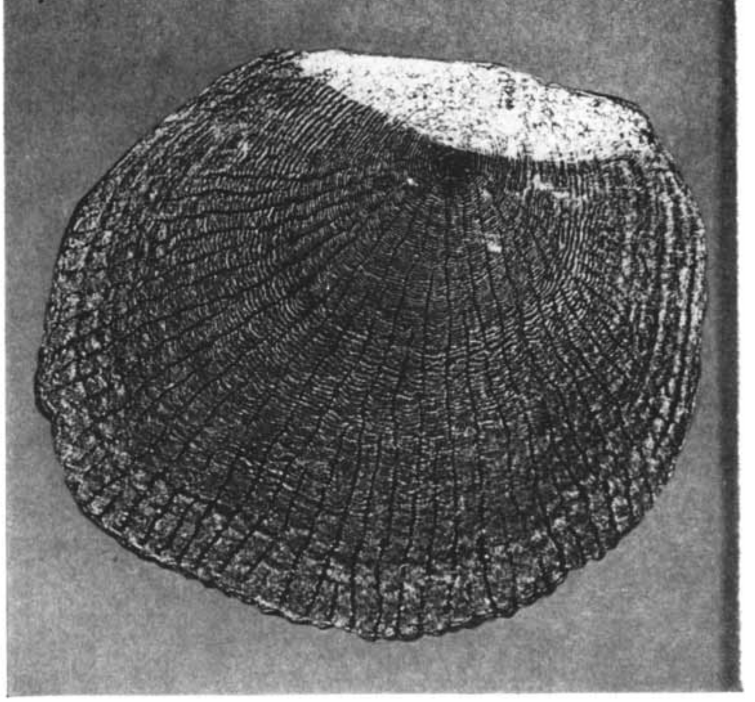
The young-old rats that C. M. McCay raised at Cornell a few years ago provide a no less striking, if not so durable, example of the age-resisting power of growth. Ordinarily a rat reaches full growth and maturity in four months. At two years he is elderly, and, unless he is a very exceptional rat, he dies before the age of three. McCay found that by feeding a diet sufficient in vitamins and minerals, but deficient in calories, he could stretch the growth period from four months to as long as 1,000 days. In one experiment the last withered survivor of a normally-grown group died at 965 days; at that age the retarded animals were bright young adolescents. When the slow-growing rats at last came close to the normal adult size, however, growth ceased. Age then proceeded to overtake the group, the last retarded animals dying at about four years. So the degenerative changes of age, it seems, can be staved off only so long as the achievement of maximum size can be held in abeyance.

Having a determined maximum size seems to be the condition of mortality among living things. Land animals cannot escape this condition, since on dry land the strength which living material can attain puts an outside limit on size. A whale may reach a weight of 140 tons; beside such a mass a five-ton African elephant is a pigmy. Yet the bulk of the elephant probably comes close to making the greatest demands that living bone and connective tissue can satisfy, for our rich fossil record discloses but one true land animal that was bigger than the modern elephant. An animal that grows to a "whale of a size" has to reside in a denser medium than air. In air, the bones of a whale-sized behemoth could not support its weight.

THE inexorable mathematics of dimensional change also contributes to making unlimited size a luxury beyond the means of land-living forms. An increase in size, particularly among mammals, entails a change in shape. A leggy foal does not become a full-grown horse merely by enlarging, nor does a baby simply elongate into a man. Form needs to change during growth because as the linear dimensions increase, the weight goes up at a much faster rate. Doubling the length, width and thickness of a two-pound book, for example, would produce a book weighing not four pounds but 16. If an 18-inch, seven-pound infant became a six-foot man by uniform enlargement in all directions, he would weigh 448 pounds! So it is not surprising that nature has resorted to the device of continually altering form to keep a growing body within manageable proportions.

If shape is to vary as the organism increases in size, the skeleton, and particularly the joints, must remain alterable as long as growth continues. But plasticity and strength do not go hand in hand. A young, developing joint is not so strong as a mature one that no longer grows. This is apparently one reason why, among the more active and venturesome types, evolution has favored those which grow rapidly to a fixed adult size. If such forms





ONE-CELLED ORGANISMS, which reproduce by dividing, are the only true immortals. Because they constantly grow and divide, technically an individual never dies. The example is *Chlorella*, the common green alga.

FISHES appear not to age in the same sense as land animals. They die from violence or disease. Above is a scale from the sand flounder *Lophopsetta aquosa*. Its age, measured by intervals in scale rings, is four years.

can maintain their mature strength long enough to reproduce themselves adequately, from nature's point of view they are "made." In the struggle for existence it does not matter how soon after the reproductive period death occurs.

One-celled forms escape the penalty of maximum size by halving themselves whenever they reach it. Trees evade the penalty because, not needing to support and move masses of soft tissue, they can keep on growing. And fishes are similarly exempt. Since the support of weight is no problem in the sea, all that fishes need is a reasonably firm backbone to enable the body to cut through the resisting water. They can grow steadily by simple enlargement, and so they do not grow up and they do not grow old. But animals that have learned to lead an active life in a medium of thin air have all foregone the advantages of unending growth.

A limited size thus seems to be the price we pay for the privilege of living on land. But is aging an inevitable part of that price? Must senescence and senility always follow the attainment of mature size? Biologists and non-biologists alike have speculated on these questions since the time of Aristotle. Numbers of theories, of more or less pragmatic value, have been invented to account for senescence. The exhaustion of a "life ferment," the "starvation" or "wearing out" of tissues, have been suggested, though it is difficult to find an exact meaning for these terms. The disappearance of germ cells has also been offered as a cause of age, though there appears to be no necessary correlation between presence of germ cells and aging. The gradual "poisoning" of body tissues by putative toxins emanating from the colon is a perennial favorite among hypotheses. Its adherents have advocated as preventives of aging everything from the drinking of sour milk to the removal of the large intestine.

THE antithesis between growth and age has not proved easy to understand. When cells divide, as they do in growing tissues, the nuclei, in which the controlling agents or genes of the cells are located, break down, and nuclear materials flow into the general cellular substance. When divisions cease, this sort of interchange ceases too. Is this lack of nuclear-cytoplasmic mingling, then, the cause of aging? That it is a contributing factor is generally believed. But if it is a factor, it is not a hopeful one. The extent to which any tissue will divide and grow is determined by heredity and is not subject to alteration. And even if it were possible to make growth go on without limit, the effect would hardly be desirable.

Cessation of growth, however, does not now seem to be as calamitous as it seemed in the days when it was taken to mean that tissues become static. Ten years ago the body was still often described as an internal combustion engine that takes in fuel but not substance. But in the middle 1930's Rudolf Schoenheimer and a group of co-workers at Columbia University's College of Physicians and Surgeons launched a radioactive-tracer study of the traffic that goes on among body constituents. By determining the fate of "labeled" substances which were fed to experimental animals, Schoenheimer was soon able to demonstrate that long after growth has stopped the structural materials of the organism are in an endlessly unsettled state. If a labeled protein building stone is fed to a rat on Tuesday, it will by Thursday be found incorporated into proteins all over the body, even in such apparently inactive structures as tendons and ligaments. Fats are just as unstable; in tissue fats and in fat deposits alike there is a restless fitting in and throwing out of molecules. Not even bone appears to be satisfied with its structure. If radioactive phosphorus is fed, the largest part of it finds its way into the bone salts of the skeleton, and, within a month, finds its way out again.

So the body is just as much in process of construction when size increase has stopped as when it is proceeding. That fact takes care of the old fear that mature organs must inevitably "wear out" or exhaust their "vital reserves." Yet the body does become old. With the passage of time, tissues become drier and infiltrated with fat, blood vessels harden, muscles weaken, bones grow brittle, eyes and ears gradually fail. Apparently the processes of self-renewal fall ever shorter of maintaining the efficiency of youth.

The pressing—and promising—problem for the immediate future is to determine the factors underlying the gradual decline of self-renewal. Two possibilities, which are not mutually exclusive, exist: 1) the failure may be in the biochemical apparatus that is designed to synthesize the material out of which the body is constantly remade; 2) it may lie in the apparatus for burning materials and obtaining energy from them. In the former case, the body cells would in time become "worn"; in the latter they might become choked with abnormal waste products of incomplete metabolism. In either case the real failure would involve the indispensable biochemical agents called enzymes.

TREES, like fishes, do not die of old age because they are constantly growing. The bald cypress of Tula (*page 41*) may be several millennia old. Shown above are the rings of a commonplace specimen of the Douglas fir.

MAN, like other land animals, degenerates independently of violence and disease. His skin wrinkles, his arteries harden, his joints stiffen. These processes lead to the ultimate physiological failure that causes death.

Enzymes are complex chemical molecules which, though present in the minutest quantities, take our inert foodstuffs in hand and manufacture living tissue out of them. Without enzymes no vital process could continue. Their depletion could readily explain the phenomena of senescence. So far interest in biochemistry has centered on what enzymes are present in various parts of the body and how they operate, not on how they change with age. The few pieces of work which have been done, however, do indicate that in mammalian tissues the passage of time brings about a lowering of enzymatic efficiency. Thus the body decays in much the same way that a mansion falls into disrepair because of a want of servants.

From both a theoretical and practical point of view, evidence of a lowering of enzymatic efficiency after the close of the growth period is important. Theoretically it promises to help us toward complete understanding and ultimate control of age deterioration. Practically it suggests a means right at hand whereby the rate of aging may be held to a minimum. This means is nutrition. Since the days of Horace. writers have praised the value of a temperate diet for continued health. Not even starvation has wanted its advocates. The sixteenth-century Venetian nobleman Luigi Cornaro, in poor health when young, adopted a diet of less than 12 ounces of solid food per day, and at 91 wrote a book recommending his regimen.

NOW that we understand something of the biochemical machinery that runs the body, we can appreciate why it is wise to refrain from overburdening this machinery with more food than it is equipped to handle. Too many calories in the first half of life may be a major cause of premature impairment of sensitive areas—joints, kidneys, heart and blood vessels. Obviously we shall never apply to human beings the technique of greatly prolonging growth through underfeeding that McCay used in rats. But the day may come when mothers will be persuaded that making junior expand at the fastest possible rate is not quite the highest achievement of motherhood.

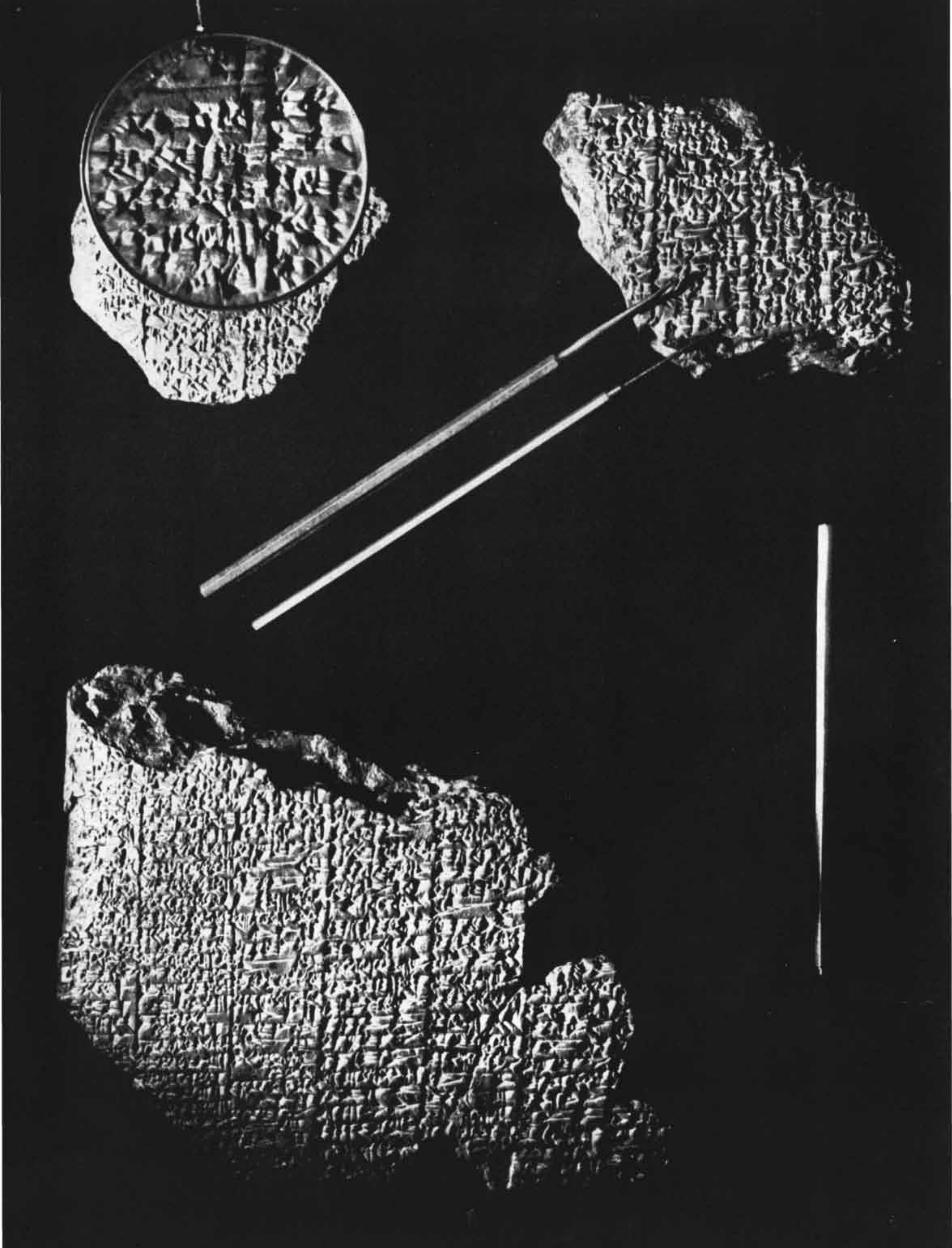
More important than calories in the diet are vitamins and minerals. Only a decade ago the importance of these accessory food factors was obscure, and not always taken seriously. Now we know that they are building stones of enzymes. Without an adequate supply of vitamins and minerals, enzymes cannot renew themselves, and they fall behind in their jobs. If deficiencies are severe, characteristic symptoms soon develop—nervous disorders, eye inflammations, bleeding joints, rickets. If deficiencies are slight but long-continued, do the effects accumulate into the disabilities of premature age? No research on this problem has yet been undertaken, unfortunately, but the possibility seems likely. Pending further information, a varied diet, well supplied with foods naturally rich in vitamins, remains the best kind of long-life insurance on the market.

Within the last 10 years scientific interest in the problems of aging has been gaining momentum rapidly. This interest comes barely in the nick of time, for the disorders of premature and pathological age—arthritis, nephritis, cardiovascular disease—have become a tremendous problem. Currently these disorders kill 800,000 Americans every year and reduce hundreds of thousands more to invalidism. If those who are now young are to be saved from swelling these ranks, some means of preventing abnormalities of the aging process must be found.

As medicine has learned to cope more effectively with the diseases of childhood and early maturity, the percentage of our population in the older age groups has been mounting steadily. Today close to 30 per cent of Americans are over 45; in 1980, according to estimates, the percentage will have risen to 40. So the second aim of age research must be to defer the age of senility. Already modern living conditions have brought about some progress in this direction. Surely few people nowadays would consider it necessary to "resolve," as did the lady in Dryden's play, to "look young till 40."

HOW far deterioration and natural death can be pushed back is still a matter of debate. Most conservative physiologists would grant that health and vigor can last to the age of 100. The enthusiastic Russians, who have recently been probing the secrets of age with great energy, would set the limit above 150. Verdi composing *Falstaff* at 80, Edison taking out his 1,033rd patent at 81, Oliver Wendell Holmes in service on the Supreme Court bench at 90, Titian painting *Christ Crowned with Thorns* at 95 are only a few of many authenticated examples that show that years alone need not dull the highest powers of the human organism. What nature can do for some, science can learn to do for all.

Florence Moog is assistant professor of zoology in Washington University at St. Louis.



"IF A SLAVE GIRL FLED . . ."

Being an account of how the law code of Lipit-Ishtar, a Sumerian king who ruled 19 centuries before Christ, was found to antedate the code of the great Hammurabi

by Francis R. Steele

AMERICANS are often described as megalomaniacs whose chief desire is to construct or own the fastest vehicle, the tallest building, the most expensive painting or the fattest bank account. Perhaps this description contains a particle of truth. If so, it is ironical that for almost half a century America has been the possessor of a superlative treasure of which it has not even been aware. This prize, only recently discovered in a dusty archaeological storeroom, consists of a handful of ancient Babylonian clay fragments that were originally unearthed nearly 50 years ago at the site of ancient Nippur. Now deciphered, these priceless tablets turn out to be one of the world's two oldest law codes. (The other, just reported from Iraq, is said to be a generation or two older.) The tablets show that history's first great law codifier was not Hammurabi, as long supposed. An earlier Babylonian king named Lipit-Ishtar wrote a law code which preceded Hammurabi's by a century and a half.

News of this possession, though hardly likely to evoke a general celebration, is nonetheless of considerable interest to others besides archaeologists. The average man understandably lacks a highly developed appreciation of such an exotic thing as a law code. His interest is awakened only on such occasions as he is accused of an infraction of the local Motor Vehicle Code and finds it necessary to pay for his experience, or when he is forced to grapple with the intricacies of a tax or price code. By and large he is content to leave the law to barristers. Yet the history of law is the history of society, and everyone interested in that history is familiar, at least by name, with the works of a few of the greatest lawgivers: the *Corpus Juris* of Justinian, compiled in 529 A.D.; the Hebrew laws of Moses, laid down in the second millennium B.C., and the celebrated code of King Hammurabi, inscribed in Babylonian cuneiform at the beginning of the seventeenth century B.C. Discovery of the law code of Lipit-Ishtar, to which Hammurabi was indebted for parts of his code, now sheds new light on the origins of human law.

THE LAW CODE of Lipit-Ishtar was written in cuneiform on a tablet 11 inches high and nine wide. Of it four small fragments remain, two of which are glued together. Here the fragments are arranged in the positions they occupied in the original.

Our knowledge of the history of early Near Eastern civilization depends in large measure upon the inscribed records unearthed by the modern excavator's spade. These records stretch back to the close of the fourth millennium B.C., when the Sumerians invented a simple pictographic system of writing. This simple script was soon modified and developed into the complex yet more flexible syllabic cuneiform script in which the writings of the great Babylonian and Assyrian Empires were cast. The earliest documents reveal to us a highly intricate society with detailed regulations for family relations, commerce and government. The picture is by no means complete, since only a small fraction of the original material has been recovered. Our knowledge grows as each new piece of information is added.

The reconstruction of the Lipit-Ishtar code rests chiefly on four small pieces of an ancient clay tablet. These four pieces were among more than 30,000 tablets and fragments dug up at the turn of the century in the famous Nippur excavations by a University of Pennsylvania group which made the first full-fledged archaeological expedition to the Near East from American shores. The curious fact is that the Lipit-Ishtar fragments were actually brought to this country at least two years before the Hammurabi code was unearthed, but their story remained undiscovered for many years after the Hammurabi stele (pillar) was accepted as containing the oldest law code.

The four fragments lay unnoticed among thousands of others from the Nippur expedition in the University of Pennsylvania Museum until the Museum decided several years ago to sort and catalog all the unclassified inscriptional material in its Babylonian collection. Similarity in script, composition and content suggested that the four pieces belonged together. They were evidently parts of a single original tablet. They appeared to deal with Sumerian law, but this in itself was not remarkable, since Sumerian laws had been found on previously discovered tablets. The significance of this particular tablet emerged only after a careful study and translation of the fragments.

One of the first hints that the tablet represented something more than a random collection of laws was the discovery that part of the text was in a style different from the rest. In the left-hand columns of two fragments, short literary phrases were recognized. Further examination revealed the names of the Sumerian gods Utu (the sun god) and Enlil (the chief god of Sumer and tutelary deity of Nippur). Then, in the next to last column of one fragment, an entire sentence was translated:

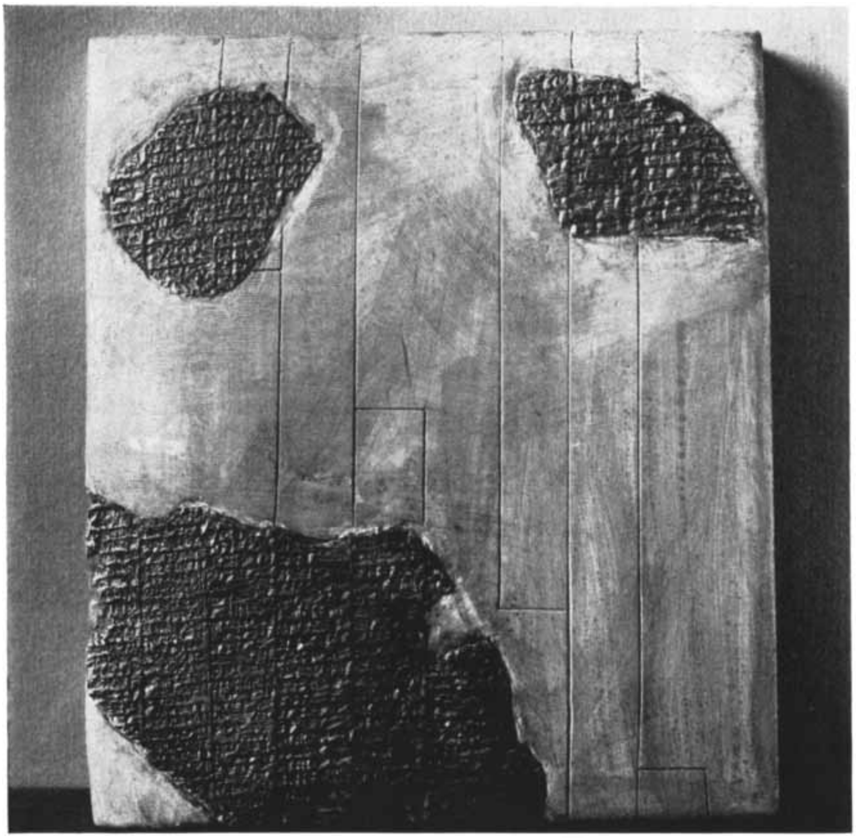
"Verily, in accordance with the true word of Utu, I caused Sumer and Akkad to hold to true justice. Verily, in accordance with the pronouncement of Enlil, I, Lipit-Ishtar, the son of Enlil, abolished enmity and rebellion."

The name of the king, Lipit-Ishtar, would not be expected in the text of a law. It was at once clear that this section must be the official epilogue of a complete law code. Later, part of Lipit-Ishtar's name was discovered in the first column of the reverse side of one of the fragments. It appeared to be part of a prologue. Confirmation of this hypothesis was soon forthcoming. Thorkild Jacobsen, director of the Oriental Institute of the University of Chicago, called my attention to a tablet in the Louvre Museum in Paris which had been published some years before by de Genouillac as *A Hymn to Lipit-Ishtar*. Jacobsen suggested that the Louvre tablet actually contained the prologue to our law code. This indeed proved to be the case; the text of the Louvre tablet fitted into our broken text. It had in all likelihood been copied from our complete tablet.

Thus it was established beyond question that we had a formal law code, which, like the later one of Hammurabi, began with a prologue and ended with an epilogue.

Its date in relation to Hammurabi's code can be fixed, with reasonable assurance, within a few years. Lipit-Ishtar's reign ended 129 years before Hammurabi became king of Babylon. Hammurabi erected his famous code stele no earlier than the 35th year of his reign. Hence Lipit-Ishtar's code is at least 164 years older than Hammurabi's and may be as much as 175 years older, since we do not know in which year of his 11-year reign Lipit-Ishtar compiled his code. Its absolute date can only be approximated, for we do not have exact dates for the kings of Babylon. Within the past few years new evidence has lopped several hundred years from the dates previously assigned to them; the accession year of Hammurabi, which in 1900 was reckoned as 2342 B.C., is now estimated as 1728 B.C. So from the current evidence we may roughly date Hammurabi's code in 1690 B.C. and Lipit-Ishtar's in 1865 B.C.

To prepare for the task of deciphering and translating the four Lipit-Ishtar fragments, it was necessary to study all the previously published examples of Sumerian law and become familiar with Sumerian style and legal terminology. I discovered that more than half of the previously known Sumerian laws came from three tablets, also in the possession of the University of Pennsylvania, which the Assyriologist Henry F. Lutz had published nearly 30 years ago. Since both the Lutz tablets and our code fragments had been dug from Nippur and appeared to date from approximately the same period, there was a presumption at least of some connection between them. Further study showed that a very intimate connection did indeed exist. When I began to copy and transliterate the texts of the new fragments, I soon discovered that they paralleled the Lutz texts verbatim at several points. Six points of contact where the two sets of texts overlapped each other were established. I found that by means of these clues all four of the code fragments could be placed almost exactly in the positions they had occupied in the original unbroken tablet. Thus the tablet was reconstructed, as the illustration shows, with gaps left for the missing text.



FRAGMENTS ARE ASSEMBLED in tablet reconstruction. About 400 lines of the original text have been recovered. Of this about half is written on these pieces, the rest on the copies made by students practicing cuneiform.

The size of the tablet was determined from the shapes of the fragments and comparison of the overlapping texts. It was found, for example, that there were 53 lines of text in the Lutz tablet between a given line in one column and the adjacent line in the next column of one of the code fragments, indicating that each column in the code tablet was 53 lines high. The curvature of the largest piece in the Lipit-Ishtar code (made up of two fragments that had been glued together) indicated that the midpoint of the complete tablet lay between the fifth and sixth columns from the left-hand side. It was therefore clear that the original tablet was 10 columns wide and had a total of 20 columns of text on both sides. Measurement of the average number of lines per inch and the average width of columns on the code tablet showed that the complete tablet was 11 inches high by nine inches wide.

THE Lutz tablets, while they paralleled sections of the code, were evidently not complete texts. How can they be accounted for? People do not ordinarily amuse themselves by copying sections of a law code. There is, however, an entirely plausible explanation. The city of Nippur, as we know from countless other records, was one of the chief cultural centers of Babylonia throughout its history. It had a large library of literary and historical records and a thriving scribal school in close association with this library. Hundreds of literary and historical texts have been excavated from Nippur. With these have been found hundreds of so-called school texts, in which we find sign lists and exercises written by pupils in the scribal school who were learning the cuneiform characters of the Sumerian and Babylonian languages by copying documents.

Since Nippur, as one of the chief cultural centers, must have possessed an official copy of the law code of Lipit-Ishtar, it is likely that students were assigned sections of the code to copy as exercises in cuneiform writing. If we may assume this much, we can surmise that the Louvre tablet represents a school exercise by a pupil who copied on the small tablet he was using only the code prologue, and that the Lutz tablets were written by students copying sections of the code as advanced lessons in writing Sumerian law. Fortunately for us, both the school copies and the code fragments were recovered, for otherwise we would have no idea of the size of the complete code tablet nor of the arrangement of the legal material within it. On the other hand, the scientific value of the school texts is materially enhanced by their association with the code fragments for, as a result, the laws they contain are shown to be part of a specific code from a definite period in history rather than an arbitrary selection of Sumerian laws at random.

The law code of Lipit-Ishtar probably consisted of some 100 laws, running to an estimated 1,200 lines of text. This is about a third the length of the Hammurabi code, which runs well over 3,600 lines and contains about 300 laws, of which 250 have been preserved. (The others were erased, presumably to make way for an inscription, by the Elamite conquerors of Babylon.)

We have recovered about 400 decipherable lines of the Lipit-Ishtar code, approximately a third of the complete document. This includes 80 lines of intelligible prologue, 60 lines of epilogue and the texts of 35 laws. About half of our available text is supplied by the four code fragments, the rest by the Lutz and Louvre tablets.

The translation of the Sumerian code has not been completed and the full meaning of many of its passages is still far from clear. But some preliminary comments can already be made on likenesses between the code of Hammurabi and that of Lipit-Ishtar. The structure and general character of the Babylonian paragraphs, as well as the fact that both codes have prologues and epilogues, give us good reason to suspect that the Hammurabi code was framed upon the Lipit-Ishtar pattern. Both royal codifiers cited the same gods, Enlil and An (the heaven god) as their sponsors in the giving of law. Both kings ascribed to the sun god (Utu in Sumerian, Shamash in Babylonian) the ultimate authorship of law and justice. The epilogues of both codes bear similar passages which promise blessing to the man who will respect the legislation, and invoke curses from the gods upon that man who ignores the law, alters the inscription or damages the monument. In sum, the law code of Lipit-Ishtar displays a precedent of form and structure that was more or less closely followed by later lawgivers, including Hammurabi.

The two codes were alike not only in form but in the substance of their laws. To be sure, few instances have been found in which they exactly duplicate each other, but most of the laws in the fragmentary Sumerian code have either close parallels or at least analogues in the Babylonian code. In some cases the two codes are almost identical:

LIPIT-ISHTAR	HAMMURABI
"If a man cut down a tree in [another] man's garden, he shall pay one half mina of silver."	"If a man cut down a tree in [another] man's garden without [the knowledge] of the owner of the garden, he shall pay one half mina of silver."
"If a man rented an ox and destroyed its eye, he shall pay one half the price."	"If a man rented an ox and destroyed its eye, money [equal to] half of its price he shall pay to the owner of the ox."

Where parallels between the two codes exist, there are differences in wording, some slight, some considerable, but the substance of the law usually remains the same. On the other hand, some of Lipit-Ishtar's laws have no counterpart in the Hammurabi code. Two examples are:

"If a man entered the garden of [another] man and was seized there for theft, he shall pay ten shekels of silver."

"If the slave-girl or slave of a man fled into the heart of the city and dwelt in the house of [another] man for one month and it is confirmed, slave for slave shall be given. If he has no slave, he shall pay fifteen shekels of silver."

As to why these laws disappeared in the interval between Lipit-Ishtar and Hammurabi, or why the latter failed to include them in his code, we do not know. The Lipit-Ishtar fragments are still in process of translation. When this is completed, we shall have additional data regarding the differences between Sumerian legal concepts and those of the Babylonians a century and a half later.

FOR nearly half a century the modern world has credited Hammurabi with the institution of codified law. Now, with the discovery of the Sumerian law code, we are able to push the history of codified law back nearly two centuries. No one doubted that laws existed before Hammurabi, for legal clauses had been found in business documents written several centuries before his time. In fact, it is quite likely that earlier codes were even compiled. The importance of the new discovery of the law code of Lipit-Ishtar, however, may well lie in the light it throws upon the social development of lower Mesopotamia in the first half of the second millennium B.C. It gives us further information about Sumerian culture and the role of this people in man's early history. It appears that we should now add the codification of law to the long list of known Sumerian achievements.

There is a passage in the Lipit-Ishtar prologue that further whets our interest. The king, describing a possible mutilator of the code text against whom he invokes the curses of the gods, says, "... he enters the storehouse, cuts down its pedestal, erases its inscription and writes his own name thereon..." This suggests that the Lipit-Ishtar code, like Hammurabi's, was inscribed upon a permanent monument. It is not at all unlikely, therefore, that buried somewhere in southern Mesopotamia, perhaps in the capital city of Isin, the original monument or stele containing the Sumerian code of Lipit-Ishtar lies awaiting the excavator's spade.

Francis R. Steele is Assistant Curator of the University of Pennsylvania Museum's Babylonian Section.

TRANSLATION of the text is matched against the corresponding passages in the original cuneiform.

"If a son-in-law has entered the house of his [prospective] father-in-law and has made his betrothal-gift and afterwards they made him go out [of the house] and gave his wife to his companion; they shall present to him the betrothal-gift which he brought and that wife may not marry his companion."

"If a man rented an ox and damaged its eye, he shall pay one half the price."

WHITE PINE

Once king of the primeval forests from Maine to Minnesota, the noble conifer has exerted a powerful influence in American history

by Donald Culross Peattie

FOR three hundred years, until well after the turn of the present century, White Pine was unrivaled as a timber-producing tree. I will also venture to say that no other tree in the world has had so momentous a career. Certainly no other has played so great a role in the life and history of the American people. Fleets were built to its great stands, and railroads bent to them. It created mushroom fortunes, mushroom cities. Earlier, it was a torch in the hands of American liberty. Though now it has fallen dramatically from its high estate to a modest place among the other conifers, its saga is worth recalling.

As a botanist, let me then formally introduce the hero of this saga. You may distinguish it at a glance, almost as far as it can be seen, by its pagoda-like outline and habit of growth. The whorled branches grow in well-separated tiers, like successive platforms of a tower. This structure is as clearly marked in very young specimens as in the oldest, though it is less obvious in dense groves where the older, lower branches have died and the congested crowns are deprived of full development. The persistent smoothness of the smoke-gray or dark slate-colored bark is also a unique trait. No other of our pines has such tardy formation of heavy bark; it finally appears in furrows at the bases of old trees, with rough ridges between the furrows, the ridges built up of purplish scales.

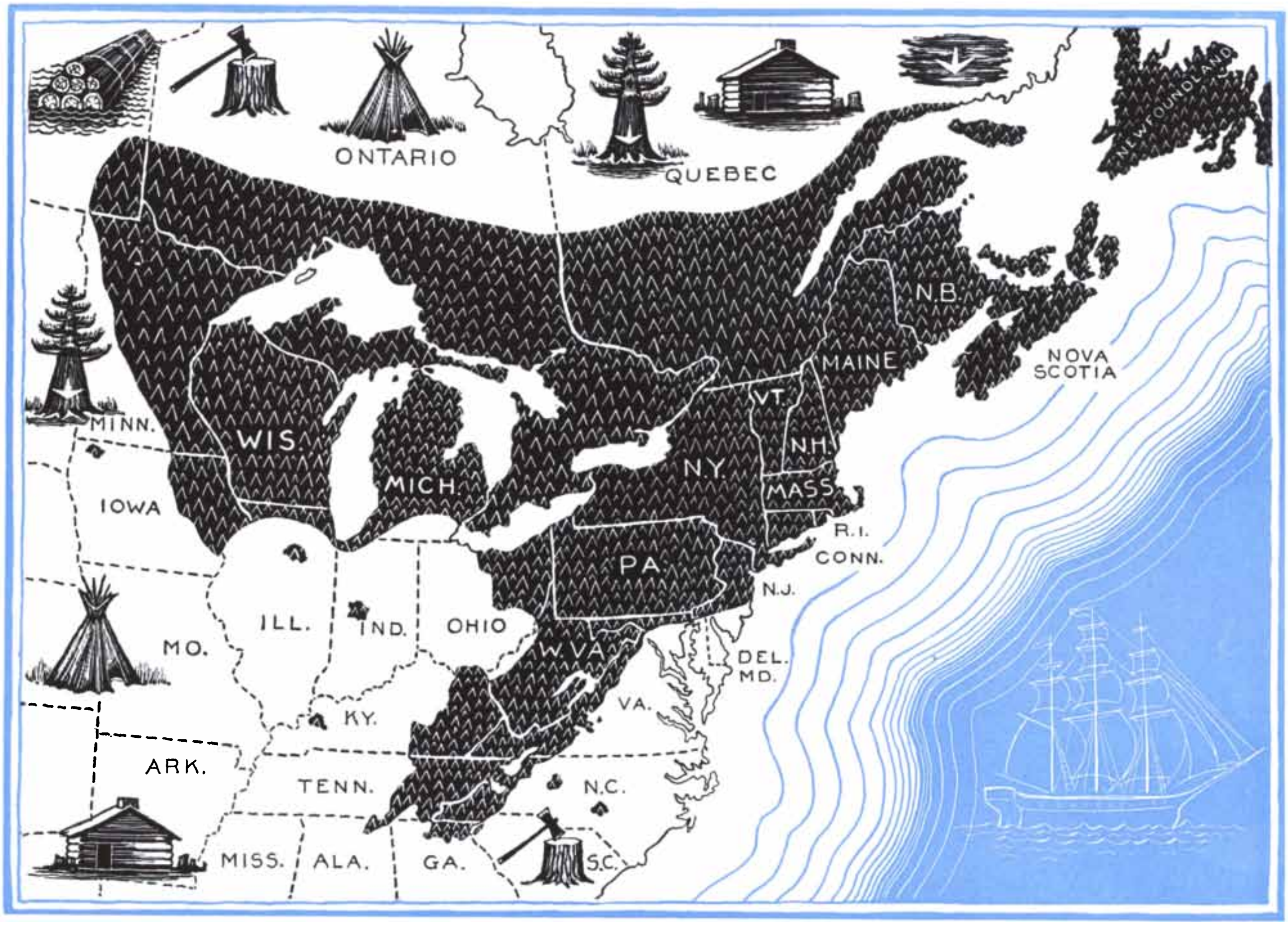
Unlike all our other pines, the White Pine has five needles in a bundle (or sometimes four, in the southern Appalachians). This enables one to recognize at a glance even a detached twig. The needles have a silky feel in the fingers—slim, smooth, soft. They are distinctive with their white bands of stomata which give a slightly glaucous cast to their deep blue-green color.

The cones, too, flexible and often sinuous, are unlike all others in our region. They are unique in being pendant on short stalks, in their length and slenderness, and in the leathery thinness of their unarmed rounded scales of a pale brown hue. The male catkins, of a bright pale yellow, are clustered at the ends of the twigs. The female conelet appears pinkish, with purplish scales. In one season the conelet ripens into the cone, which by October is mature and sheds its seeds on the winds. The foliage, however, persists two years, finally turning yellow and falling when pushed off by the new growth.

The White Pine is a northern species, ranging from Newfoundland to Manitoba and south to Iowa, northern Illinois, central Indiana, eastern Ohio and Pennsylvania. Thence it runs south on the Appalachians to Georgia. In North Carolina, where it is found chiefly on the Blue Ridge, it grows up to an altitude of 3.800 feet. It is at its best above 2,800 feet, in the high cool coves.

In the aboriginal American forest, White Pine was perhaps the most abundant species throughout its range in New England, New York, Pennsylvania, Michigan, Wisconsin, Minnesota, and many parts of New Brunswick and Quebec. Over vast areas it formed pure or nearly pure stands, or it had only red pine for an intimate associate, according to the testimony of early "land lookers" (or timber cruisers, as we would say now). The fact that today in those same localities it is intermixed with spruce, balsam, aspen, hemlock, canoe birch, gray pine, and many other North Woods species, only means that the kingdom which White Pine once held as its own has been invaded, since the days of the sawmills, by an influx of trees that once were its humble subjects. Much of Pennsylvania and almost all of New York outside the Adirondacks—so it has been asserted—was one vast White Pine forest. Pioneers used to say that a squirrel could travel a squirrel's lifetime without ever coming down out of the White Pines; and save for the intersection of rivers this may have been but slight hyperbole. When the male flowers bloomed in these illimitable pin-

VIRGIN FOREST of White Pine near Warren, Pa., is one of the very few stands that escaped devastation.



THE ORIGINAL FOREST of White Pine covered what is now the U.S. from Maine west to Minnesota and south to Georgia and Alabama. Colonial woodsmen worked principally in the forests of southern New England. The great mills of the nineteenth century moved north to Maine and west to Michigan and, finally, to the south.

eries, thousands of miles of forest aisle were swept with the golden smoke of their reckless fertility. Great storms of pollen were swept from the primeval shores far out to sea and to the superstitious sailor seemed to be "raining brimstone" on the deck.

Nor can one easily conceive, from the second growth that is almost all that is left to us, of the toppling height of the virgin White Pines. Trees 150 feet tall astounded the first settlers and explorers; 80 feet or more of the trunk of such a specimen might be free of branches and marvelously straight and thick. On the present site of Dartmouth College a specimen 240 feet in height was measured. This would surpass anything in the eastern United States and would do credit to the Douglas fir of the West, and even the redwood. Similar heights were recorded from Maine, Quebec, New Hampshire and both eastern and western New York in pioneering times. How many others were felled, unmeasured or unrecorded, we cannot know. It was possible for the old land lookers to climb some lofty spruce and from its top sight these mighty groves miles away on the horizon—"clumps," they called them, or "veins of pine" running like sighing rivers through the primeval forest. A branch was thrown down on the ground to point the direction of the groves, and the way was then found through the trackless wilderness by compass.

THE first account in English of this tree appeared in John Josselyn's *Account of Two Voyages to New England* (1674): "The Pine-Tree . . . is a large Tree, very tall, and sometimes two or three fadom about; of the body the English make large Canows of 20 foot long, and two foot and a half over, hollowing of them with an Adds and shaping of the outside like a boat." But White Pine had undoubtedly been carried to Europe by the earliest navigators in Canadian waters. Before the middle of the sixteenth century it was growing at Fontainebleau, and was mentioned then by the French naturalist Belon.

In 1605 Captain George Weymouth of the British Royal Navy sailed his vessels up one of the Maine rivers and, perhaps first of the Englishmen, he got more than a coasting sailor's look at the White Pine. He took away with him specimen logs of mastwood, and seeds or young trees. These were planted at Longleat, estate of Thomas, Viscount Weymouth, second Marquis of Bath, since when the English have called our tree the Weymouth Pine. But it has never proved adaptable to the English climate. Only in its own country was White Pine destined to a great role.

Certainly it was the first gold struck by the New England settlers. The exploitation began immediately and was so intensive that it was soon necessary to pass our first forest conservation laws. Not that anyone then could have envisaged the day when the virgin stands would all be gone, so vast and dense was White Pine's empire; but the wastefulness in the mills began with the first one (built about 1623, at York, Maine) and was never to cease while the virgin timber lasted.

It was not the wood requirements of the puny colonies that threatened this great resource, but the fact that, aside from fish and furs, timber was the only great export of early New England. Within 30 years she was selling her White Pine not only to England but to Portugal, Spain, Africa, the West Indies and ultimately even to densely forested Madagascar.

How one could sell trees to jungle countries can only be explained by recalling that most tropical timbers are heavy and hard; they lack the qualities of lightness and softness in which the

White Pine excels. Weighing only 25 pounds to the cubic foot, dry weight, it is the lightest of all the pines of eastern America, yet in proportion to its weight it is strong. It could be had in solid "sticks" of prodigious lengths for the masts of sailing ships.

Certainly no wood light enough and strong enough for masting was grown in Europe in such lengths. And England, mistress of the seas and forever at war with the other navies of the world, had no mastwood at all. She pieced together her proudest masts out of Riga fir (also Scots pine or *Pinus sylvestris*). But Prussia, Russia, and Sweden held monopolies in it upon which England was dependent, to her own great discomfort. The Danes had only to close the Baltic Sea to cut off her supply entirely. So the arrival of the first White Pine masts created a sensation in the Navy Board. Contracts were let at once to American agents like the Wentworth family of New Hampshire and, with great mast sticks selling at £100 apiece, it is no wonder that the Wentworths grew rich and occupied a position of political power commensurate with their wealth.

IN the meantime other colonists also were growing rich. A great three-cornered trade was set up when, in all-pine ships of their own construction, the New England merchants exported White Pine to the Guinea coast of Africa, shipped on a load of slaves, sold them into bondage in the West Indies, loaded up with sugar and rum, and finally raised sail for Portsmouth, Boston, Newburyport or Salem. Of White Pine boards, and of the wealth that came from this trade, were built the quiet mansions of the seaport cities, the dignified doors, the exquisite fanlights. As tastes grew more sumptuous, exchanges were made direct with the West Indies: light, utilitarian pine was exchanged directly for heavy Santo Domingo mahogany that was made into the most elegant of early American furniture.

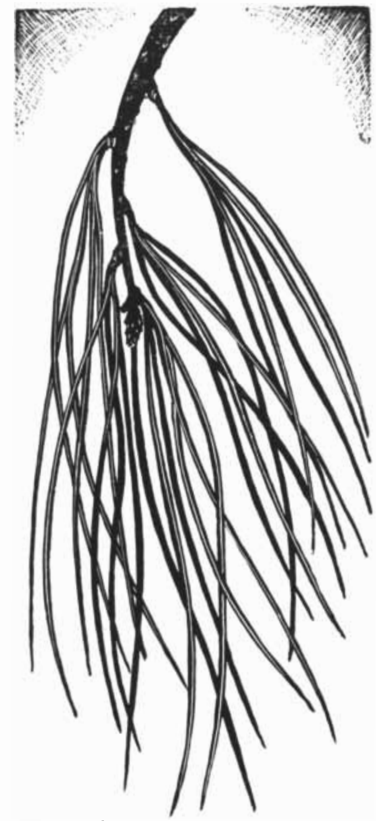
More and more the New England sailing ships came to be decorated by the famous American wood carvers with figureheads of a very special sort of White Pine, so smooth and soft of grain that it could be cut with almost equal ease in any direction. The woodsmen called it "pumpkin pine," contrasting it with the coarser-grained "sapling pine." To the lumberman, as to the wood carver, the distinction was profound. They asserted that sapling pine had more sapwood and that its trunk tapered more from base to crown, while the pumpkin grew on uplands and "held its contour better." Botanists and foresters today believe that the difference was a matter of age; they point out that in our day of second-growth pine, pumpkin is almost unobtainable; it was a product of centuries of undisturbed virgin timber growth.

Few historians mention it, but White Pine was one of the chief economic and psychological factors in the gathering storm of the American Revolution, at least in New Hampshire and Maine. It is also of more than historical interest, for the contest of Great Britain and her American colonies for pine masts engaged forces that are still locked in struggle over the trees of America, however much the values and shibboleths may have changed. These are the forces of conservation and of exploitation, each with its rights and its compulsions.

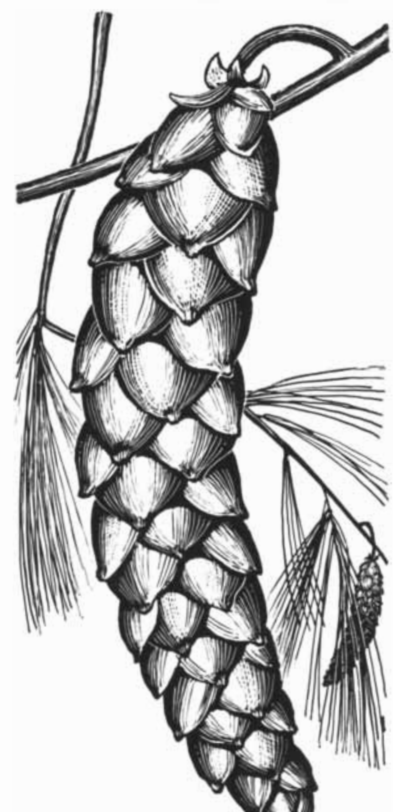
The trouble began in the reign of William and Mary, when by decree those monarchs began to reserve the grandest specimens for the use of the Royal Navy. In her desperate timber shortage, and her endless wars to rule the seas, the mother country naturally looked on aghast when pioneers, advancing far beyond the land grants into the "crown lands" or public domain, chopped down or even burned down the finest trees along with the least, simply to farm the land. It seemed to the British that they were fighting the Empire's battles for the colonists as well as the home country; they could not understand what looked to them like the greed and shortsightedness and refractory spirit of the American pioneers.

To the colonists the same facts looked entirely otherwise. What the Crown called crown lands, reserved to His Britannic Majesty perhaps for sale to London land speculators, appeared to the Americans then as the wilderness was to appear for centuries—as Indian country, theirs for the taking. Unexploited, it was at once an impregnable fortress for cruel savages and the repository of vast wealth desperately needed by a struggling people. The man who could find his way into the primeval forest 50 miles beyond the nearest settlement, cut down gigantic pines, "swamp" them with boom and tackle to the river, ride and pole them down the whirlpools and falls to a secret market in another colony was, whatever else you called him, a man indeed. And as for masts for the wars of the English, the colonists had their own wars with the Indians, and felt capable of winning them if not called on to help fight Spain and Holland and France.

So one law, proclamation, or royal instruction after another was passed to restrain the colonists from what on one side of the Atlantic was called timber-stealing and on the other was considered practically the Lord's work. John Wentworth, baron of the New Hampshire pineries, later to become the last royal governor of that colony, was made Inspector General of His Majesty's Woods in America, possessing authority to mark for the Navy Board every great pine in America with a blaze known as the King's Broad Arrow. Tactful, cultivated, genial, he was a conscientious servant of his king. But though he was personally liked by his fellow Americans, the King's Broad Arrow infuriated the pioneer, as the Stamp and Townshend



NEEDLES of White Pine, unlike those of other pine species, hang five, and sometimes four, in a bunch.



CONE of White Pine is flexible and sinuous, hanging from a short stem. Its scales are thin and pale brown.

acts infuriated the merchant, as the tax on tea infuriated the city dweller. Not for this did the woodsman fight his way into the wilderness to make himself a home—only to find that his trees, as he thought of them, had been branded with that hateful symbol of royal privilege. No wonder that he chopped them down, obliterated the blaze, sawed the giants into smaller lengths and floated them down the Connecticut River to New London or some other Sound port for sale and export, perhaps to England's enemies.

The Crown retaliated. In 1761, it instructed the royal governor that in all future land grants a clause was "to be inserted to reserve all white or other Sort of Pine Trees fit for Masts, of the growth of 24 Inches Diameter and upwards at 12 inches from the Earth, to Us our Heirs & Successors, for the Masting of our Royal Navy, and that no such Trees shall be cut —without our Licence—on Penalty of the Forfeiture of such Grant, & of the Land so granted reverting to the Crown; & all other Pains and Penalties as are or shall be enjoined or inflicted by any Act or Acts of Parliament passed in the Kingdom of Great Britain."

To make matters worse, a spy system was set up against those who cut trees in violation of these instructions, the spy to receive the land grant of the lawbreaker. In retaliation, the pioneers disguised themselves as Indians and did their cutting at night. A law decreeing that all using such disguises to cut trees should be flogged had no known deterrent effects. American officers would not arrest other Americans for breaking British forest laws made in Britain for the sake of Britons, nor would juries convict them, nor judges impose sentences. British agents drove the loggers from their homes and burned their sawmills, but the loggers had their own laws —"swamp law" they called it—and the territory was not healthy for agents unaccompanied by troops.

WHEN the storm of the Revolution broke, the Americans foresaw that their own White Pines might come back to them as the masts of armed ships, bringing armed men. In 1774, Congress stopped the export of everything, mastwood included, to Britain. In April 1775, after Lexington had been fought, the lumbermen were patriots to a man. A British agent and his mastwrights were captured on the Kennebec River with several masts. When the armed ship *Canceau* sailed into Falmouth, Maine, to protect a Tory rigging and fitting of the mastship *Minerva*, Maine men drove her off. Putting to sea, the men of Machias overtook the armed ship *Margaretta*, boarded and captured her and fitted her out as a privateer. In revenge, the British flattened Falmouth to earth with shot. Down at Portsmouth the patriots seized the great masting pools on Strawberry Bank. The last cargo of American White Pine reached England shortly after Bunker Hill. From then on, the British fought on sea with heavy, jointed masts of Riga fir, while coasting within sight of pines that would have enabled their ships to fight on equal terms.

The first flag of our Revolutionary forces bore for its emblem a White Pine tree. But out of Portsmouth on November 1, 1777, sailed the *Ranger* of Captain John Paul Jones, fitted with three of the tallest White Pine masts that ever went to sea, and from the mainmast fluttered the Stars and Stripes.

The Revolution won, the New Englanders turned to their pineries as the richest natural resource they had. This is not the place to tell the story of White Pine lumbering, the greatest chapter in the history of any nation's forests. There is an extensive literature of the American lumberjack, the old-style lumber baron, the whirlwind exploitation, romanticized in such classics as John S. Springer's *Forest Life and Forest Trees* (1851); bemoaned by Thoreau in our most beautiful forest idyll, *The Maine Woods;* detailed in some 1,200 pages in Defebaugh's unfinished monument, *The History of the Lumber Industry in America;* recounted with gusto for the Rabelaisian details in Stewart Holbrook's *Holy Old Mackinaw;* keened as a wake in his *Burning an Empire;* and exposed in all its grime of ruthless waste, greedy exploitation, bribery, corruption, labor wars and timber thefts in *The Great Forest* by Richard G. Lillard. To sum up a mighty epic in a few lines: it was under the boughs of the White Pine that there evolved the greatest woodsman the world has ever seen, the American lumberjack (though much of the time he was a Finn, Dane, Swede, Norwegian, or Russian by birth). He was an embodiment of the Paul Bunyan legend, a hero of courage and skill amidst toppling giants and river jams, a demon of accelerating destruction. The industry built fortune after fortune, acquired by ruthless exploitation and spent, in many a case, with the highest benevolence. It evolved ever new methods, ever higher efficiency, including efficiency at waste and at lobbying and holding the forces of conservation at bay until the end of the northern pineries was reached.

"RANGER" of John Paul Jones carried the three tallest White Pine masts when she put to sea in 1777.

IN the days of its greatest utility and exploitation, White Pine gained its importance from factors partly environmental, partly inherent in the special properties of its wood. Most of the White Pines grew in a region of heavy snowfall, so the logs could be inexpensively sledded with oxen power to the river. The profusion of rivers made transportation to the mill easy. Add to this the extreme lightness of White Pine that greatly aids it in flotation. Heavy logs like white oak or black locust can be floated with much less success. The great abundance of the forest and the continuity of its stands made it possible to develop a concentrated industry, with mass production and mass marketing and correspondingly cheap rates to the consumer. Then, too, the old-time lumberman was able to operate, in successive localities, on virgin timber. This yielded a much finer grade of wood—longer, smoother, free of defect and knot, and more easily worked than any second growth can ever be.

In the 300 years of its exploitation White Pine, more than any other tree, built this nation, literally and figuratively. It would be impossible here even to list all the uses of White Pine, the most generally useful wood our country has ever possessed. They range from the paneling of fine old colonial interiors to the famed bobsleds of New England, from hobby horses to the annual 72 million board feet of this now precious wood which was still being split into matches in the year 1912. (Western White Pine has now taken over the burden of matchwood.) According to François Michaux, by 1805 half a million American homes were built of White Pine. These were the frame houses that are our most typical form of dwelling, save in great cities, from Maine to Florida and west as far as White Pine was ever shipped on the treeless plains—houses viewed with amazement by foreigners, accepted complacently by natives. No other wood served so well for window sash material; it could be moved at a touch of the hand, yet it did not warp. No other furnished such great clear boards for doors and interior finish. In every sort of millwork White Pine reigned supreme while it lasted. It was the favorite material for heddles of looms, since the weaver had to lift or lower the heddle for every thread that went into the woof. Because it is so light, smooth, easily planed and polished, untold amounts of cheap furniture have been made of it. It takes paint and gilt better than almost any rival.

The number of shingles made of White Pine for the roofs of American homes is beyond calculation. In one 24-year period, Michigan, Wisconsin and Minnesota produced 85 billion. For two centuries they were hand-rived with a drawing knife. An expert (and he was an artist at his profession) could rive 500 a day and earn a dollar doing it. He professed to know when a given specimen in the forest would rive well, but if he had any doubt he whacked out a big block from the standing tree to test its splitting qualities. If these were unsatisfactory, he simply permitted the tree to bleed its rosin from the cut, leaving thereby a wick that would ignite the tree to its crown in the next forest fire. "The pioneer custom in Kentucky of killing buffaloes for their tongues was little more wasteful than the primitive white pine shingle maker's procedure," say William Hall and Hu Maxwell in a 1911 government bulletin on the uses of commercial woods. "He used only the choicest parts of pine trees. The sapwood, the knots, much of the heart, and practically the whole trunk above the first 20 feet were left in the woods to rot. It was not unusual to sacrifice a 3,000-foot tree to get 1,000 shingles—throwing away about fourteen-fifteenths and using one-fifteenth. The introduction of shingle-making machinery put a stop to that enormous waste, for the saws could make shingles of knots, slabs, tops, cross grains, and all else, from stump to crown. The old-style method of shingle-making died hard, for the shavers opposed the introduction of machines, and declared the ruination of the country would follow so radical a revolution in a widespread industry."

THE famed covered bridges of America were built of White Pine in preference to almost any other wood because of its long-lasting qualities and its lightness in proportion to its strength. Of this wood was built the bridge over the Charles River, connecting Boston and Cambridge, the same on which John Marshall delivered his momentous decision in the Charles River Bridge case, dealing a blow at monopoly. The Delaware River bridge at Trenton (where Washington had crossed through ice floes) and the aqueduct for the State Canal over the Allegheny River at Pittsburgh were White Pine structures. This aqueduct, considered a miracle of its day, was 16 feet wide and 1,020 feet long, with seven spans. It carried one water-course, and the commerce borne upon it, over another.

"Many of the bridges in the interior of Pennsylvania and West Virginia, by which the old pikes crossed the numerous streams, were built of white pine," say Hall and Maxwell, "and it is said of some of them that no man had lived long enough to witness their building and their failure through decay. Some of these structures were marvels of efficiency. Extra large timbers were unnecessary. Though slight in appearance, they carried every load that came during periods often exceeding half a century. They were roofed—usually with white pine shingles—and were weatherboarded with white pine or yellow poplar, and though painted only once or twice in a generation they stood almost immune from decay."

In each state the White Pine brought sudden wealth; all the great rivers of northeastern America, except the Hudson with its alternating tides, were choked at one time or another with tremendous rafts of logs, each bearing its owner's mark or brand, like cattle going to market. The longest haul was from the pineries of Pennsylvania, 200 miles above Pittsburgh, to New Orleans, 2,000 miles distant by the windings of the streams. One raft that passed Cincinnati covered three acres and contained a million and a half board feet of pine, valued at five dollars a thousand in Pittsburgh, at $40 a thousand in

FIGUREHEAD of sailing ships was generally carved from "pumpkin" pine, wood of especially fine grain.

the Creole capital. When the timber was gone, the farmer came in at a temporal distance of about 25 years.

That is to say, the most rosy accounts pictured him as doing so. Actually much of the land could never be profitably farmed. Between the millions of stumps it was acid or rocky; in place of the forest giants of yesterday sprang up the aspen and spruce, the stunted, knotty gray pine, the brambles and the fireweed. Too often the end came in fire and smoke. Forest fires in northern Michigan in the 1890's sent palls of smoke 200 miles down Lake Michigan to Chicago. The Peshtigo fire in Wisconsin killed more people than the great fire of Chicago that began on the same day. The story of what happened to Hinckley, Minn., is an almost unbearable record of human agony. The end was miles of ashes, like a landscape of hell.

By 1900 there was nowhere to turn for virgin White Pine except the southern Appalachians. And certainly there were some dense stands of White Pine in the high coves. Trees 150 feet tall were then known there. At Shady Valley, Va., the yield reached an all-time record, for the South, of 100,000 board feet of White Pine to the acre. So here the industry turned for a last skid to the mills. Not that many of the old-time lumberjacks of Maine or Michigan came this way; they followed the lumber barons and the saws to the "big sticks" of Oregon. In the Appalachians, the industry developed with local resident labor; no great lumber camps ever evolved. Everything that had given lumbering in the North Woods its characteristics was lacking in North Carolina; there was no snow, there were no rivers capable of carrying big logs, no great central mills. Instead, steep inclines, narrow-gauge railroads, migratory mills and stationary labor created a pattern far less picturesque, though not lacking in effectiveness.

The wood also was different. Appalachian White Pine is heavier and coarser than the northern grades, with a somewhat reddish color. In consequence it has never commanded the high price of the best northern pine. The southern "boom" in White Pines lasted from 1900 to 1915.

"No large region of virgin timber remains," said Hall and Maxwell in 1911. "It is not to be expected that this country will ever again see the quality of this lumber it has seen in the past. The large, clear timber, such as once came from the northern pine regions, will never come from there again, because it was sawed or hewed from trees centuries old. It is too much to expect that forests of second growth will be permitted to attain that age or that the owners of trees will wait for them to attain a height of 150 and a diameter of 4 feet."

TODAY the stand of White Pine is in the neighborhood of 14 billion board feet in the U.S. and 8,700 million feet in Canada. Maine, which was one of the first states to lose its paramount position in White Pine production, is once again the leading region in the U.S. This is because the second growth has, after nearly a century, reached maturity.

The glory and tragedy of the White Pine epic had its lessons and its lasting results. The "boom" was, in the nature of historical factors and economic and social pressures, inevitable. The "bust," by dramatizing the situation as in the case of no other American tree, roused public opinion to the support of the conservationists, who had fought for years without allies. Though public opinion came too late to save the virgin White Pine, it made itself felt just in time to save a part of the great forests of the western states, to back Theodore Roosevelt and the Forest Service and National Parks in their battle with Congress and the lumber interests.

Donald Culross Peattie is a botanist and a writer on botanical and other scientific subjects.

SRINIVASA RAMANUJAN

The "profound and invincible originality" of the obscure Hindu mathematician who died in 1920 made possible one of the most prodigious feats in the history of human thought

by James R. Newman

I HAVE here set down, from the scanty materials available, a brief account of the poor Indian boy who became, as one eminent authority has written, "quite the most extraordinary mathematician of our time." Srinivasa Ramanujan died in India of tuberculosis on April 26, 1920, at the age of 33. Except among mathematicians, his name is almost unknown. He was a mathematician's mathematician, and as such, did not attract wide attention outside his field. But his work has left a memorable imprint on mathematical thought.

There are two points which will provide the background for this sketch. The first is that, despite a very limited formal education, Ramanujan was already a brilliant mathematician when he came to England to study in 1914. On the foundation of a volume known as Carr's *Synopsis of Pure Mathematics*, the only book on higher mathematics to which he had access, he had built "an astounding edifice of analytical knowledge and discovery." The nature of Ramanujan's achievement is made clear on examining this one text at his disposal. While a work of real merit and scholarship, it was in fact no more than a synopsis of some 6,000 theorems of algebra, trigonometry, calculus and analytical geometry, with proofs "which are often little more than cross-references." In general the mathematical knowledge contained in Carr's book went no further than the 1860's. Yet in areas that interested him, Ramanujan arrived in England abreast, and often ahead of contemporary mathematical knowledge. Thus in a lone, mighty sweep he had succeeded in recreating in his field, through his own unaided powers, a rich half century of European mathematics. One may doubt that so prodigious a feat had ever before been accomplished in the history of thought.

The second noteworthy point is that Ramanujan was a particular kind of mathematician. He was not as versatile as Karl Friedrich Gauss or Henri Poincaré. He was not a geometer; he cared nothing for mathematical physics, let alone the possible "usefulness" of his mathematical work in other disciplines. Instead, Ramanujan's intuition was most at ease in the bewildering interstices of the number system. Numbers, as will appear, were his friends; in the simplest array of digits he detected wonderful properties and relationships which escaped the notice of even the most gifted mathematicians. The modern theory of numbers is at once one of the richest, most elusive and most difficult branches of mathematics. Some of its principal theorems, while self-evident and childishly simple in statement, defy the most strenuous efforts to prove them. A good example is Goldbach's Theorem, which states that every even number is the sum of two prime numbers. Any fool, as one noted mathematician remarked, might have thought of it; it is altogether obvious and, indeed, no even number has ever been found which does not obey it. Yet no proof which demonstrates its application to *every* even number has ever been adduced. It was in dealing with such problems as this that Ramanujan showed his greatest gifts.

The late G. H. Hardy of Cambridge, a leading mathematician of his time, was professionally and personally closest to Ramanujan during his fruitful five years in England. I have taken from Hardy's well-known obituary of Ramanujan and from his notable course of Ramanujan lectures at Harvard the bulk of the material to be found here; the rest comes from a brief biographical sketch by P. V. Seshu Aiyar and R. Ramachandra Rao to be found in Ramanujan's *Collected Works*. Some of the material is understandable only to the professional mathematician. There is enough, I think, of general interest to justify bringing before the interested layman even this inadequate notice of a true genius' life and work.

SRINIVASA Ramanujan Aiyangar, according to his biographer Seshu Aiyar, was a member of a Brahman family in somewhat poor circumstances in the Tanjore district of the Madras presidency. His father was an accountant to a cloth merchant at Kumbakonam, while his mother, a woman of "strong common sense," was the daughter of a Brahman petty official in the Munsiff's (or legal judge's) Court at Erode. For some time after her marriage she had no children, "but her father prayed to the famous goddess Namagiri, in the neighboring town of Namakkal, to bless his daughter with offspring. Shortly afterwards, her eldest child, the mathematician Ramanujan, was born on 22nd December 1887."

He first went to school at five and was transferred before he was seven to the Town High School at Kumbakonam, where he held a scholarship. His extraordinary powers appear to have been recognized almost immediately. He was quiet and meditative and had an extraordinary memory. He delighted in entertaining his friends with theorems and formulae, with the recitation of complete lists of Sanskrit roots and with repeating the values of *pi* and the square root of two to any number of decimal places.

When he was 15 and in the sixth form at school, a friend of his secured for him the loan of Carr's *Synopsis of Pure Mathematics* from the library of the local Government College. Through the new world thus opened to him Ramanujan ranged with delight. It was this book that awakened his genius. He set himself at once to establishing its formulae. As he was without the aid of other books, each solution was for him a piece of original research. He first devised methods for constructing magic squares. Then he branched off to geometry, where he took up the squaring of the circle and went so far as to get a result for the length of the equatorial circumference of the earth which differed from the true length by only a few feet. Finding the scope of geometry limited, he turned his attention to algebra. Ramanujan used to say that the goddess of Namakkal inspired him with the formulae in dreams. It is a remarkable fact that, on rising from bed, he would frequently note down results and verify them, though he was not always

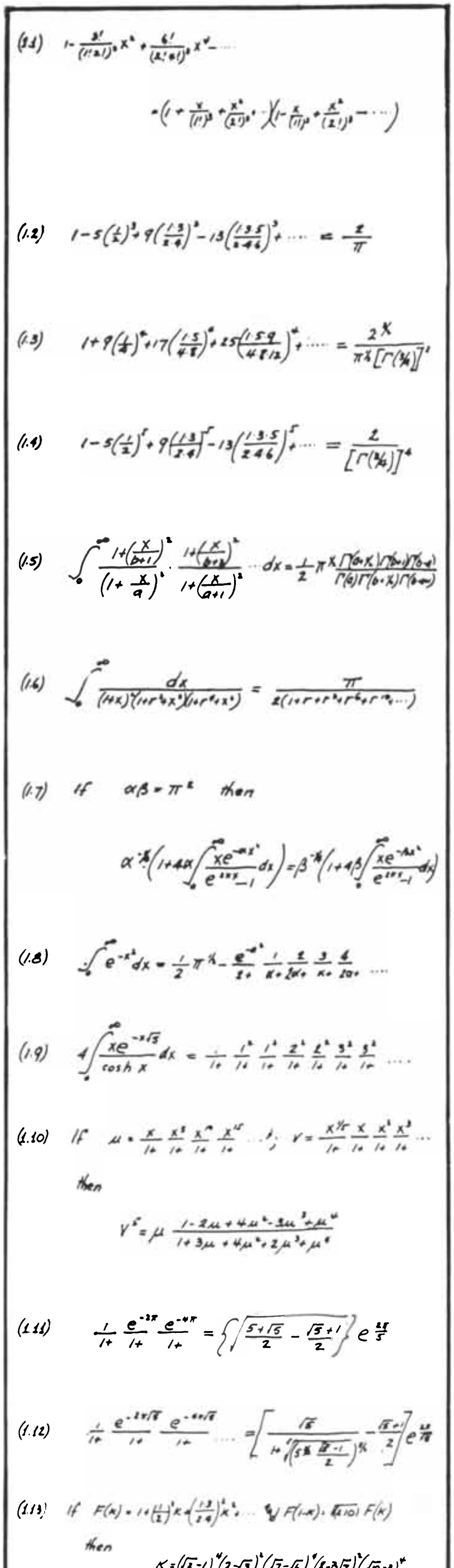
RAMANUJAN, wrote a friend, was "a short uncouth figure . . . with one conspicuous feature—shining eyes . . ."

able to supply a rigorous proof. This pattern repeated itself throughout his life.

He passed his matriculation examination to the Government College at Kumbakonam at 16, and secured the "Junior Subrahmanyam Scholarship." Owing to weakness in English—for he gave no thought to anything but mathematics—he failed in his next examination and lost his scholarship. He then left Kumbakonam, first for Vizagapatam and then for Madras. Here he presented himself for the "First Examination in Arts" in December 1906, but failed and never tried again. For the next few years he continued his independent work in mathematics. In 1909 he was married and it became necessary for him to find some permanent employment. In the course of his search for work he was given a letter of recommendation to a true lover of mathematics, Diwan Bahadur R. Ramachandra Rao, who was then Collector at Nelore, a small town 80 miles north of Madras. Ramachandra Rao had already seen one of the two fat notebooks kept by Ramanujan into which he crammed his wonderful ideas. His first interview with Ramanujan is best described in his own words.

"Several years ago, a nephew of mine perfectly innocent of mathematical knowledge said to me, 'Uncle, I have a visitor who talks of mathematics; I do not understand him; can you see if there is anything in his talk?' And in the plenitude of my mathematical wisdom, I condescended to permit Ramanujan to walk into my presence. A short uncouth figure, stout, unshaved, not overclean, with one conspicuous feature—shining eyes—walked in with a frayed notebook under his arm. He was miserably poor. He had run away from Kumbakonam to get leisure in Madras to pursue his studies. He never craved for any distinction. He wanted leisure; in other words, that simple food should be provided for him without exertion on his part and that he should be allowed to dream on.

"He opened his book and began to explain some of his discoveries. I saw quite at once that there was something out of the way; but my knowledge did not permit me to judge whether he talked sense or nonsense. Suspending judgment, I asked him to come over again, and he did. And then he had gauged my ignorance and



(1.1) $1-\frac{3!}{(1!2!)^3}x^2+\frac{6!}{(2!4!)^3}x^4-\cdots = \left(1+\frac{x}{(1!)^3}+\frac{x^2}{(2!)^3}+\cdots\right)\left(1-\frac{x}{(1!)^3}+\frac{x^2}{(2!)^3}-\cdots\right)$

(1.2) $1-5\left(\frac{1}{2}\right)^3+9\left(\frac{1\cdot3}{2\cdot4}\right)^3-13\left(\frac{1\cdot3\cdot5}{2\cdot4\cdot6}\right)^3+\cdots=\frac{2}{\pi}$

(1.3) $1+9\left(\frac{1}{4}\right)^4+17\left(\frac{1\cdot5}{4\cdot8}\right)^4+25\left(\frac{1\cdot5\cdot9}{4\cdot8\cdot12}\right)^4+\cdots=\frac{2^{3/2}}{\pi^{1/2}\left[\Gamma\left(\frac{3}{4}\right)\right]^2}$

(1.4) $1-5\left(\frac{1}{2}\right)^5+9\left(\frac{1\cdot3}{2\cdot4}\right)^5-13\left(\frac{1\cdot3\cdot5}{2\cdot4\cdot6}\right)^5+\cdots=\frac{2}{\left[\Gamma\left(\frac{3}{4}\right)\right]^4}$

(1.5) $\int_0^\infty \frac{1+\left(\frac{x}{b+1}\right)^2}{1+\left(\frac{x}{a}\right)^2}\cdot\frac{1+\left(\frac{x}{b+2}\right)^2}{1+\left(\frac{x}{a+1}\right)^2}\cdots dx=\frac{1}{2}\pi^{1/2}\frac{\Gamma(a+\frac{1}{2})\Gamma(b+1)\Gamma(b-a+\frac{1}{2})}{\Gamma(a)\Gamma(b+\frac{1}{2})\Gamma(b-a+1)}$

(1.6) $\int_0^\infty \frac{dx}{(1+x^2)(1+r^2x^2)(1+r^4x^2)\cdots}=\frac{\pi}{2(1+r+r^3+r^6+r^{10}+\cdots)}$

(1.7) If $\alpha\beta=\pi^2$ then

$$\alpha^{-1/4}\left(1+4\alpha\int_0^\infty\frac{xe^{-\alpha x^2}}{e^{2\pi x}-1}dx\right)=\beta^{-1/4}\left(1+4\beta\int_0^\infty\frac{xe^{-\beta x^2}}{e^{2\pi x}-1}dx\right)$$

(1.8) $\int_0^a e^{-x^2}dx=\frac{1}{2}\pi^{1/2}-\frac{e^{-a^2}}{2a+}\frac{1}{a+}\frac{2}{2a+}\frac{3}{a+}\frac{4}{2a+}\cdots$

(1.9) $4\int_0^\infty\frac{xe^{-x\sqrt{5}}}{\cosh x}dx=\frac{1}{1+}\frac{1^2}{1+}\frac{1^2}{1+}\frac{2^2}{1+}\frac{2^2}{1+}\frac{3^2}{1+}\frac{3^2}{1+}\cdots$

(1.10) If $u=\frac{x}{1+}\frac{x^5}{1+}\frac{x^{10}}{1+}\frac{x^{15}}{1+}\cdots$, $v=\frac{x^{1/5}}{1+}\frac{x}{1+}\frac{x^2}{1+}\frac{x^3}{1+}\cdots$

then

$$v^5=u\,\frac{1-2u+4u^2-3u^3+u^4}{1+3u+4u^2+2u^3+u^4}$$

(1.11) $\frac{1}{1+}\frac{e^{-2\pi}}{1+}\frac{e^{-4\pi}}{1+}\cdots=\left(\sqrt{\frac{5+\sqrt{5}}{2}}-\frac{\sqrt{5}+1}{2}\right)e^{2\pi/5}$

(1.12) $\frac{1}{1+}\frac{e^{-2\pi\sqrt{5}}}{1+}\frac{e^{-4\pi\sqrt{5}}}{1+}\cdots=\left[\frac{\sqrt{5}}{1+\sqrt[5]{5^{3/4}\left(\frac{\sqrt{5}-1}{2}\right)^{5/2}-1}}-\frac{\sqrt{5}+1}{2}\right]e^{2\pi/\sqrt{5}}$

(1.13) If $F(k)=1+\left(\frac{1}{2}\right)^2k+\left(\frac{1\cdot3}{2\cdot4}\right)^2k^2+\cdots$ and $F(1-k)=\sqrt{210}\,F(k)$

then

$$k=(\sqrt{2}-1)^4(2-\sqrt{3})^2(\sqrt{7}-\sqrt{6})^4(8-3\sqrt{7})^2(\sqrt{10}-3)^4\times(4-\sqrt{15})^4(\sqrt{15}-\sqrt{14})^2(6-\sqrt{35})^2$$

THEOREMS of Ramanujan's letter (*here copied from original*) astounded the mathematician Hardy.

showed me some of his simpler results. These transcended existing books and I had no doubt that he was a remarkable man. Then, step by step, he led me to elliptic integrals and hypergeometric series and at last his theory of divergent series not yet announced to the world converted me. I asked him what he wanted. He said he wanted a pittance to live on so that he might pursue his researches."

RAMACHANDRA RAO undertook to pay Ramanujan's expenses for a time. After a while, other attempts to obtain a scholarship having failed and Ramanujan being unwilling to be supported by anyone for any length of time, he accepted a small appointment in the office of the Madras Port Trust.

But he never slackened his work in mathematics. His earliest contribution was published in the *Journal of the Indian Mathematical Society* in 1911, when Ramanujan was 23. His first long article was on "Some Properties of Bernoulli's Numbers" and was published in the same year. In 1912 he contributed two more notes to the same journal and also several questions for solution.

By this time Ramachandra Rao had induced a Mr. Griffith of the Madras Engineering College to take an interest in Ramanujan, and Griffith spoke to Sir Francis Spring, the chairman of the Madras Port Trust, where Ramanujan was employed. From that time on it became easy to secure recognition of his work. Upon the suggestion of Seshu Aiyar and others, Ramanujan began a correspondence with G. H. Hardy, then Fellow of Trinity College, Cambridge. His first letter to Hardy, dated January 16, 1913, which his friends helped him put in English, follows:

"Dear Sir,

"I beg to introduce myself to you as a clerk in the Accounts Department of the Port Trust Office at Madras on a salary of only £20 per annum. I am now about 23 years of age. [*He was actually 25—Ed.*] I have had no University education but I have undergone the ordinary school course. After leaving school I have been employing the spare time at my disposal to work at Mathematics. I have not trodden through the conventional regular course which is followed in a University course, but I am striking out a new path for myself. I have made a special investigation of divergent series in general and the results I get are termed by the local mathematicians as 'startling'....

"I would request you to go through the enclosed papers. Being poor, if you are convinced that there is anything of value I would like to have my theorems published. I have not given the actual investigations nor the expressions that I get but I have indicated the lines on which I proceed. Being inexperienced I would very highly value any advice you give me. Requesting to be excused for the trouble I give you.

I remain, Dear Sir, Yours truly,
S. Ramanujan."

To the letter were attached about 120 theorems, of which the 13 here presented *(see box)* were part of a group selected by Hardy as "fairly representative." Hardy commented on these:

"I should like you to begin by trying to reconstruct the immediate reactions of an ordinary professional mathematician who receives a letter like this from an unknown Hindu clerk.

"The first question was whether I could recognise anything. I had proved things rather like (1.7) myself, and seemed vaguely familiar with (1.8). Actually (1.8) is classical; it is a formula of Laplace first proved properly by Jacobi; and (1.9) occurs in a paper published by Rogers in 1907. I thought that, as an expert in definite integrals, I could probably prove (1.5) and (1.6), and did so, though with a good deal more trouble than I had expected....

"The series formulae (1.1)-(1.4) I found much more intriguing, and it soon became obvious that Ramanujan must possess much more general theorems and was keeping a great deal up his sleeve. The second is a formula of Bauer well known in the theory of Legendre series, but the others are much harder than they look....

"The formulae (1.10)-(1.13) are on a different level and obviously both difficult and deep. An expert in elliptic functions can see at once that (1.13) is derived somehow from the theory of 'complex multiplication,' but (1.10)-(1.12) defeated me completely; I had never seen anything in the least like them before. A single look at them is enough to show that they could only be written down by a mathematician of the highest class. They must be true because, if they were not true, no one would have had the imagination to invent them. Finally . . . the writer must be completely honest, because great mathematicians are commoner than thieves or humbugs of such incredible skill....

"While Ramanujan had numerous brilliant successes, his work on prime numbers and on all the allied problems of the theory was definitely wrong. This may be said to have been his one great failure. And yet I am not sure that, in some ways, his failure was not more wonderful than any of his triumphs. . . ."

Ramanujan's notation of one mathematical term in this area, wrote Hardy, "was first obtained by Landau in 1908. Ramanujan had none of Landau's weapons at his command; he had never seen a French or German book; his knowledge even of English was insufficient to qualify for a degree. It is sufficiently marvellous that he should have even dreamt of problems such as these, problems which it has taken the finest mathematicians in Europe a hundred years to solve, and of which the solution is incomplete to the present day."

AT last, in May of 1913, as the result of the help of many friends, Ramanujan was relieved of his clerical post in the Madras Port Trust and given a special scholarship. Hardy had made efforts from the first to bring Ramanujan to Cambridge. The way seemed to be open, but Ramanujan refused at first to go because of caste prejudice and lack of his mother's consent.

"This consent," wrote Hardy, "was at last got very easily in an unexpected manner. For one morning his mother announced that she had had a dream on the previous night, in which she saw her son seated in a big hall amidst a group of Europeans, and that the goddess Namagiri had commanded her not to stand in the way of her son fulfilling his life's purpose."

When Ramanujan finally came, he had a scholarship from Madras of £250, of which £50 was allotted to the support of his family in India, and an allowance of £60 from Trinity.

"There was one great puzzle," Hardy observes of Ramanujan. "What was to be done in the way of teaching him modern mathematics? The limitations of his knowledge were as startling as its profundity. Here was a man who could work out modular equations, and theorems of complex multiplication, to orders unheard of, whose mastery of continued fractions was, on the formal side at any rate, beyond that of any mathematician in the world, who had found for himself the functional equation of the Zeta-function and the dominant terms of many of the most famous problems in the analytic theory of numbers; and he had never heard of a doubly periodic function or of Cauchy's theorem, and had indeed but the vaguest idea of what a function of a complex variable was. His ideas as to what constituted a mathematical proof were of the most shadowy description. All his results, new or old, right or wrong, had been arrived at by a process of mingled argument, intuition, and induction, of which he was entirely unable to give any coherent account.

"It was impossible to ask such a man to submit to systematic instruction, to try to learn mathematics from the beginning once more. I was afraid too that, if I insisted unduly on matters which Ramanujan found irksome, I might destroy his confidence or break the spell of his inspiration. On the other hand there were things of which it was impossible that he should remain in ignorance. Some of his results were wrong, and in particular those which concerned the distribution of primes, to which he attached the greatest importance. It was impossible to allow him to go through life supposing that all the zeros of the Zeta-function were real. So I had to try to teach him, and in a measure I succeeded, though obviously I learnt from him much more than he learnt from me. . . .

"I should add a word here about Ramanujan's interests outside mathematics. Like his mathematics, they shewed the strangest contrasts. He had very little interest, I should say, in literature as such, or in art, though he could tell good literature from bad. On the other hand, he was a keen philosopher, of what appeared, to followers of the modern Cambridge school, a rather nebulous kind, and an ardent politician, of a pacifist and ultra-radical type. He adhered, with a severity most unusual in Indians resident in England, to the religious observances of his caste; but his religion was a matter of observance and not of intellectual conviction, and I remember well his telling me (much to my surprise) that all religions seemed to him more or less equally true. Alike in literature, philosophy, and mathematics, he had a passion for what was unexpected, strange, and odd; he had quite a small library of books by circle-squarers and other cranks . . . He was a vegetarian in the strictest sense—this proved a terrible difficulty later when he fell ill—and all the time he was in Cambridge he cooked all his food himself, and never cooked it without first changing into pyjamas. . . .

"It was in the spring of 1917 that Ramanujan first appeared to be unwell. He went to a Nursing Home at Cambridge in the early summer, and was never out of bed for any length of time again. He was in sanatoria at Wells, at Matlock, and in London, and it was not until the autumn of 1918 that he shewed any decided symptom of improvement. He had then resumed active work, stimulated perhaps by his election to the Royal Society, and some of his most beautiful theorems were discovered about this time. His election to a Trinity Fellowship was a further encouragement; and each of those famous societies may well congratulate themselves that they recognized his claims before it was too late."

Early in 1919 Ramanujan went home to India, where he died in the following year.

FOR an evaluation of Ramanujan's method and work in mathematics we must again quote from Hardy. "I have often been asked whether Ramanujan had any special secret; whether his methods differed in kind from those of other mathematicians; whether there was anything really abnormal in his mode of thought. I cannot answer these questions with any confidence or conviction; but I do not believe it. My belief is that all mathematicians think, at bottom, in the same kind of way, and that Ramanujan was no exception. He had, of course, an extraordinary memory. He could remember the idiosyncrasies of numbers in an almost uncanny way. It was Mr. Littlewood (I believe) who remarked that 'every positive integer was one of his personal friends.' I remember once going to see him when he was lying ill at Putney. I had ridden in taxi-cab No. 1729, and remarked that the number seemed to me rather a dull one, and that I hoped it was not an unfavourable omen. 'No,' he replied, 'it is a very interesting number; it is the smallest number expressible as a sum of two cubes in two different ways.' I asked him, naturally, whether he knew the answer to the corresponding problem for fourth powers; and he replied, after a moment's thought, that he could see no obvious example, and thought that the first such number must be very large. His memory, and his powers of calculation, were very unusual, but they could not reasonably he called 'abnormal.' If he had to multiply two large numbers, he multiplied them in the ordinary way; he could do it with unusual rapidity and accuracy, but not more rapidly or more accurately than any mathematician who is naturally quick and has the habit of computation.

"It was his insight into algebraical formulae, transformations of infinite series, and so forth, that was most amazing. On this side most certainly I have never met his equal, and I can compare him only with Euler or Jacobi. He worked, far more than the majority of modern mathematicians, by induction from numerical examples; all of his congruence properties of partitions, for example, were discovered in this way. But with his memory, his patience, and his power of calculation, he combined a power of generalisation, a feeling for form, and a capacity for rapid modification of his hypotheses, that were often really startling, and made him, in his own field, without a rival in his day.

"It is often said that it is much more difficult now for a mathematician to be original than it was in the great days when the foundations of modern analysis were laid; and no doubt in a measure it is true. Opinions may differ as to the importance of Ramanujan's work, the kind of standard by which it should be judged, and the influence which it is likely to have on the mathematics of the future. It has not the simplicity and the inevitableness of the very greatest work; it would be greater if it were less strange. One gift it has which no one can deny—profound and invincible originality. He would probably have been a greater mathematician if he had been caught and tamed a little in his youth; he would have discovered more that was new, and that, no doubt, of greater importance. On the other hand he would have been less of a Ramanujan, and more of a European professor and the loss might have been greater than the gain."

James R. Newman is co-author (with Edward Kasner) of Mathematics and the Imagination.

BOOKS

Posthumous essays by Bronislaw Malinowski

by Abram Kardiner

THE name of the late Bronislaw Malinowski has rightly been associated with the transition of anthropology, once a mere handmaiden of the theory of evolution, to a basic discipline in the study of man. The posthumous collection of five of Malinowski's essays entitled "Magic, Science and Religion" (Beacon Press and Free Press) cuts a swath across the development of his thought. These essays afford an opportunity to appraise Malinowski's place in the social sciences, the current ferment of which he helped set in motion.

The science of man is basically contingent on the degree of insight the social scientist has into the nature of man's mind and emotional life. Such knowledge has been accumulating at a very slow pace indeed. This story of man's growing insight into himself is one still in the making, its greatest chapters yet to come. It is a story in which Bronislaw Malinowski played a significant role.

Malinowski, who died in 1942, was a transitional figure standing squarely astride two important anthropological movements, one impelled by the evolutionary point of view and the other by the psychodynamic. Each of these viewpoints supplied a program specifying the data to be sought and the information to be drawn from them. The evolutionists investigated cultural institutions in the quest for origins and progress in human social organization. The psychodynamic point of view restores man himself as the prime object of investigation; it attempts to describe institutions as implements of adaptation which are predicated on man's basic drives, needs, wishes and anxieties.

The most powerful influence that shook the authority of the early theological assumptions about man and society was Darwin's theory of evolution. This theory gave rise to many new types of investigation, and among its many offspring was the discipline of anthropology. The study of "primitive" man held out high hopes that it would supply valuable information about man's cultural evolution. In a measure—a small one—this hope was satisfied. But when a new area of investigation is the by-product of a parent hypothesis, it is natural that its first efforts will be directed to sustaining its progenitor.

The study of primitive man was therefore biased at its inception. The great names of Edward B. Tylor, James Frazer, Lucien Lévy-Brühl, and Émile Durkheim were associated with these early efforts. They were determined to show cultural evolution by demonstrating that archaic, simple forms of thought and social organization changed into more complex and integrated forms.

The fallacy of this early approach was not only that it colored the conclusions from observed data, but also that it dictated what data should be considered relevant. This is where the theory of cultural evolution did its greatest damage. For these evolutionists were not studying the adaptation of primitive man to his environment. They hopped, skipped and jumped from one culture to another, picked what they wanted from each, and fitted it into their master plan.

This was the scientific atmosphere surrounding Malinowski's introduction to anthropology when he was a student in Cracow. He was determined to follow in the path of Frazer, and would have done so had it not been for an accident. This accident was that during the first World War he was interned by the British in the Trobriand Islands. Here, perforce, he lived for a time with the natives. Thus Malinowski became more than a student of the culture; he acquired almost the status of a participant. From this vantage point Malinowski uncovered new data and developed a new style of interpreting it.

HE WAS not alone in his project. William H. R. Rivers of Cambridge and Franz Boas of Columbia University had also charted out new fields. But Malinowski showed that the methods of the evolutionists were faulty. He stated that societies should not be studied as events in a historical scheme but as entities in themselves. Their institutions, he argued, had to be interpreted in the light of the role they played in the adaptation of the community to its natural and human environment. Institutions were not merely gratuitous hang-overs from the past, however they were modified. They had an immediate adaptive function; they aided man in his struggle for survival. Malinowski's new school of thought was called *functionalism*.

The essays reprinted in "Magic, Science and Religion" are all illustrative of Malinowski's techniques for making sense from the data of primitive society. He takes up topics such as magic, science, religion, myth, death, language and war and subjects them to a brilliant functional analysis.

Malinowski's field work was remarkable for its precision and meticulousness. In contrast with other ethnographers, he found his primitive men both reasonable and logical. if one knew their assumptions and frames of reference. Notwithstanding these merits. his account of the Trobrianders does not quite satisfy the specifications for a completely integrated account of a primitive society. His explanations sound very thin today.

The essay in this book which best demonstrates both the strength and weakness of functionalism is entitled *Baloma—The Spirits of the Dead*. Here Malinowski makes a long inventory of the functions of the departed soul after death. and the role it plays among the living Trobrianders. The departed soul has a benevolent and mischievous aspect. No fear is created by either of these in the living. There is. however, great fear of the evil sorceresses who attack the dead. These latter ghoulish figures are not explained anywhere. The functions of the Baloma, or soul, are (among others) to uphold morality and to play some mysterious role in impregnating women. The Trobrianders seem to be ignorant of the relation between coitus and impregnation. Malinowski attempts many explanations of this ignorance. The one which he finally accepts, with some reservation. is that. since the natives usually do not become pregnant before marriage in spite of the fact that they begin intercourse as soon as they can, they assume that this particular act cannot be the decisive factor in creating the child after marriage. Accidents do occasionally happen, *i.e.*, children are born out of wedlock. This discrepancy the natives can calmly tolerate without losing their basic belief that impregnation is affected by the Baloma.

One can accept without contest Malinowski's further explanation that the Baloma helps to sustain morality. But one also feels obliged to ask how the natives procure the cooperation of the Baloma, and what is the origin of this particular kind of behavior. Why do the Trobrianders not fear the departed dead as men do in other primitive societies? To answer this question one must know something about the role that all fantasy life plays in adaptation, and why fantasies differ as one varies the conditions which make fantasy necessary. These questions Malinowski neither raises nor answers. However satisfying Malinowski's explanations may have seemed earlier, today they can rate only as partial answers.

This poverty of specific explanation. in spite of a plausible over-all program, points to a deficiency in Malinowski's technical equipment. He was not prepared for new demands which the science of anthropology was beginning to make. Anthropology had outgrown its original charter. It was now undertaking to understand the entire field of human adaptation under a wide variety of conditions. Such understanding could not be achieved simply by applying a relentless rationalism to the circumstances of a given case. One weakness of Malinowski's method was that it projected upon totally foreign situations the particular brand of rationalism more or less peculiar to Western man.

THIS IS the crucial problem not only of the whole functionalist approach, but of the social sciences in general. Any truly scientific study of man and his institutions requires a technique that takes account of the fact that man's implements of adaptation vary according to the context of conditions in which they develop, and at the same time recognizes the common elements in the motivations and behavior of all men. One must explain. for example, why the fantasy life of the Trobriander is very different from that of the Marquesan. Without a technique that can reduce the fantasy life of both Marquesan and Trobriander to a common denominator. there can be no such explanation.

In Malinowski's working years neither anthropology nor any other social science had such a technique at its disposal. So this deficiency cannot be laid at Malinowski's doorstep. The clues for the development of such a technique had to—and did—come from another discipline. The discipline was the psychodynamics originated by Sigmund Freud. who defined the laws which govern the integrative processes in man and the general laws which determine the consequences of the satisfaction or frustration of basic drives. He also described the manner in which the functions of personality are constructed. With these implements the functionalist program could in part. at least. be realized. When these psychodynamic tools are put to work on the raw data of the ethnographer, we can answer some of the questions which Malinowski could not. We can get a very complete picture of the general personality traits of the Trobrianders and demonstrate the institutional sources of these traits.

Having no such tools. Malinowski got lost in the formal aspects of analyzing and classifying ethnographic data. He lived long enough to see the fruitful application of psychodynamics to the program he had so brilliantly formulated. To this effort he first gave his hearty support, but later. for reasons unknown to the reviewer, his enthusiasm cooled.

The volume here reviewed is probably the last of several posthumous works gathered by Malinowski's literary executors. It is a book everyone interested in the history of the science of man should read. To the reviewer it was the occasion for a fresh tribute to a great scientist whose influence is very much alive in the minds and activities of all those who today are trying to make an accurate and authoritative discipline out of our still fragmentary knowledge of human relations.

Abram Kardiner is co-author (with Ralph Linton) of The Psychological Frontiers of Society.

THE AMATEUR

by Albert G. Ingalls

USUALLY the domed part of an astronomical observatory rotates on top of a fixed cylindrical dome ring, or round wall, but E. K. White of Chapman Camp, British Columbia, has built the two as a single unit which he is easily able to turn by hand on rollers at ground level.

White's North Star Observatory, highest in Canada (3,600 feet elevation), is set on a round concrete slab 18 feet in diameter. To this slab eight five-inch wheels (adapted from V-belt drive pulleys) and their bearings are bolted. An angle iron track is attached to the dome unit and thus rests on the wheels.

The observatory walls are made of quarter-inch, three-ply, resin-bonded fir veneer that is screw-nailed to a base ring made from two layers of overlapping spruce segments and 32 light cedar studs. There is also an upper spruce ring like the first. The dome is made of quarter-inch veneer gores screw-nailed to ribs three inches deep. The ribs, like the rings, are built of overlapped segments.

White's double shutters open and close on eight three-inch roller-bearing tackle block sheaves, using Scanlon's method of endless cable described in *Amateur Telescope Making—Advanced.* Unlike most others, White's shutters open a full quarter the diameter of the dome, as recommended by Scanlon, and they extend to the zenith and 10 inches beyond. Prospective observatory builders who discount the importance of a wide slit opening and a large observatory diameter (White's is 15 feet) to accommodate whatever telescope they might want to install in the future, might well consider making their first observatory a poor job. This will effect an ultimate saving when, after enough cussing, they finally tear it down and rebuild it right.

BECAUSE polishing is a far slower method of removing glass than fine grinding, amateur telescope makers have long stressed the importance of avoiding half a lifetime's needless work by bringing their concave mirrors to a truly spherical surface before departing from the grinding stages. In 1935 the recommendation "Get a Sphere Before Beginning to Polish" was inserted in *Amateur Telescope Making* and in an earlier edition (1928) another injunction appeared: "Getting Contact Before Polishing." Amateurs have long tested for sphericity before polishing by the pencil mark test or by the safer method of putting a quick superficial polish on their mirrors with a temporary pitch lap. The latter permits making a Foucault test for checking the sphere.

The Bausch and Lomb Optical Company now furnish details of their recent adoption of this principle and of a production method of accomplishing it with waxed surfaces and test plates which produce Newton's rings.

"The use of wax to test ground glasses started," they state, "in our development laboratory where a check on the flatness of optical surfaces was required. The fine-ground surface is covered with a hard wax. We have used shoe polish, soft red pencils, Johnson's Floor Wax and different types of liquid wax. The only requirement is that the wax be fast-drying and hard.

"After the surface has been coated with a liberal amount of wax it is allowed to dry. Then a hard cloth such as canvas or sheeting is used to wipe up the excess wax and shine the wax that remains between the grindings of the glass. Once one spot of the cloth is used we do not change, for the wax on the cloth tends to fill in any holes not completely filled previously.

The North Star Observatory

"After the piece is completely shined with wax, the test glass is used much the same as on a polished surface. To get a brilliant pattern of interference fringes a good monochromatic light source is needed, since the reflection from the wax is much lower than from polished glass. The pattern seen will be fuzzy but will give a very good indication of the over-all curvature of the lens or flat. We grind and polish until we have a grind fairly close to the test glass and free from zones, and then we clean the wax from the lens and polish.

"By this test we found we could save many hours of polishing by starting with a zone-free grinding job. The practice has spread to our production department, where we are checking grinding on both planes and weak spheres. This method is good in testing spheres of more than 100 mm radius of curvature but it is difficult to check lenses having a shorter radius."

Amateurs who make several identical mirrors or lenses, as is often the case, may find this use of wax and test plates valuable during fine grinding. It can also be used on single jobs when grinding flats.

One flat which could not be tested against a test plate at any stage was the 120-inch surface made at the California Institute of Technology optical shop some years ago as an accessory for testing the 200-inch mirror at the focus. (Since other tests were applied instead, this, the world's biggest flat, never has been used.) The flat was tested during grinding, Russell W. Porter says, by stretching a piano wire above it, calculating the wire's catenary sag, and measuring the vertical distances from flat to wire. It worked!

Next, after enough fine grinding to give specular reflection at grazing incidence, as shown in the accompanying drawing, a test similar in principle to the one in *Amateur Telescope Making*, page 242, was used. This was Ritchey's test.

Louis J. Rick of 685 North Ridge Road East, Lorain, Ohio, reports a valuable kink he accidentally stumbled upon while fine-grinding his first mirror. "I obtained a very soft drawing pencil, a 6B, with which I drew a broad 3/16-inch stripe across the horizontal diameter of the mirror. Under the Foucault test the stripe was a better reflector than a wet unpolished mirror and showed enough of the horizontal section of the Foucault shadow to permit determining the curve."

PROVIDENCE, in the state whose full and official name is Rhode Island and Providence Plantations, has for years been the center of an active group of amateur telescope makers. In wartime, the Providence group helped to train more than 50 persons in the technique of grinding and polishing glass and then made glass master gauges, optical flats and colored glass filters (thin plane-parallels) for bombsights and sextants. One of this group is Professor C. H. Smiley, head of the Department of Astronomy at Brown University, who as an amateur telescope maker contributes the following practical aid to the amateur "glass pusher."

"Two of the problems which beset the new hand at telescope making are determining whether tool and mirror are making good contact at a given stage of grinding, and estimating the quality of a given fine grind, especially the last one before polishing. If mirror and tool suddenly seize, it probably will be because of poor contact combined with inadequate lubrication. (If you do have such a seizure, be very careful to wash both mirror and tool after separation before going on, because in such an event some glass is almost always removed from one of the disks, usually at an edge, and bad scratches often result.)

"Hours of polishing may be saved by a little extra time and care spent on the last fine grind before polishing. It is proposed here to outline a method by which one can determine whether contact is being made and by which one can measure approximately the quality of a given fine grind.

"If you hold a mirror on your hand almost horizontally at arm's length in front of you, even in the coarser grades of grit you will be able to get a reflection of an electric light down the hall or diagonally across the room. The light ought to be the only bright light in that direction and there should be relatively little light coming in from the sides. An old-fashioned clear glass bulb with the filament showing is perhaps best for this purpose although a good bright frosted bulb will work almost as well. With the mirror well out in front of you, rock it back and forth in such a way that the reflected image of the light moves alternately toward you and away from you. Slowly lower the mirror. As this is done the reflected image grows reddish and dim, eventually is lost. Just before it goes, rock the mirror back and forth very slowly, watching to see whether the image grows dim at one spot more than at another. A dull gray area with poor reflection indicates a zone on the mirror which is not in good contact with the tool; you can judge better on the portion of the mirror away from you than on the nearer part. This is particularly true as the hand drops lower and lower with the finer grades. As a check on your judgment, rock the mirror sidewise a bit and see whether the gray areas seem to come in the same zones as when the image is rocked toward and away from you.

"This test does *not*, however, tell you whether the given grade of abrasive has been used long enough. One still needs a magnifying glass to see whether the pits that remain are essentially of uniform size.

"Now, as the fine grinding proceeds, one finds that the hand may be dropped lower and lower before the reflected image is lost. Also the region in which a red image is seen increases in size so that there is a generous warning before the image is lost entirely.

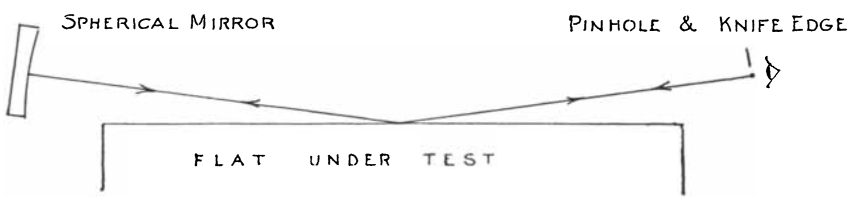
"If now the angle from the light down to the position of the mirror at which the image is lost is measured, the quality of the fine grind can be judged fairly well. A simple and rapid method by which the free hand may be used as a caliper to measure this angle is as follows.

"Suppose the reflected image has finally been lost when the mirror, held in the left hand, is seen in line with a particular crack in the floor or opposite a particular pattern in the carpet. The right arm is now extended in front, full length, parallel with the left. Its fingers and thumb are opened as widely as possible, as in thumbing your nose. The wrist is rotated so that the thumb is straight down, the little finger straight up. With the little finger in line with the light, the point at which the tip of the thumb lines up with the floor is now noted, and the arm is lowered until the little finger on top lines up with the same point. Only one eye is used and the head is, of course, held steady. This spacing off process is repeated on down to a point level with the center of the mirror and the number of 'hands' is counted.

"One then estimates that the mirror is good for about one, three, or so many hands down, as the case may be. Fractional hands may be counted but it is hardly worth while to estimate nearer than a half hand. In general, the number of hands measured by one person will agree fairly well with the number found by another person of radically different dimensions.

"Our experience has been that a good grind with 500 Carbo or Aloxite should show about three hands down; 303 emery will give four hands, and 303½ emery should give five and a half or six hands, but the average beginner usually wants to quit at five hands down and start polishing. In terms of time and energy this is a very expensive procedure. He should go back to 303½ for a final wet, adding only a little water from time to time and slowly working out the abrasive. The pressure of the hands should be lessened in the later stages of fine grinding until, in this final step, it should be just the weight of the mirror applying the pressure. If you hold your ear down close to the mirror as you move it back and forth in this final stage you will hear a faint swish reminiscent of silk. This 'repeated dilution of the final wet' resembles the 'Ferson technique' of drying up the final wets, adding only a very little water, and working the emery out to the finest possible state. The latter is described in detail by Ferson in *Amateur Telescope Making—Advanced.* [In printings subsequent to June 1944.—*Ed.*]

"When you get down to four or five hands you should take care that no oil or grease is applied to the mirror as you wipe the last bit of moisture from it. Only a small amount of grease is enough to mislead one seriously as to the quality of the fine grind. Just rubbing the hand over a mirror several times appears to provide the grease which misleads.



The testing of the biggest flat in the world

"Although this note is not meant to cover polishing, one of the commonest troubles encountered in polishing is the 'Mexican Hat.' Under the Foucault test. with the mirror in an intermediate position, there appears to be a turned-up edge (the brim of the hat) and a hill in the middle (the crown of the hat). As long as the hat is a fairly flat one, in comparison with its diameter, this is not a serious matter. Care taken in pressing the mirror on the lap each time before starting polishing, and in using a very short stroke, will usually prevent the appearance of a Mexican Hat and many times will remove one after it has appeared. It seems likely that the hat is a result of the natural curvature of a pitch lap near its edges due to surface tension."

EVERY year in their Science Talent Search the Science Clubs of America boil down several thousands of the nation's keenest high school seniors to award the Westinghouse Science Scholarships. A part of the boiling-down process is a written report on a science project selected by the candidate. Of the 40 finalists in the Science Talent Search this year, five chose telescope making as their project. roughly the same percentage as in the six previous annual talent searches. An examination of some of the essays which were written by the finalists reveals that the best of the contestants have mature. adult minds—keen and scientifically sophisticated.

Albert G. Ingalls is author of Amateur Telescope Making *and* Amateur Telescope Making—Advanced.

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.

NATIONAL SCIENCE FOUNDATION

A NATIONAL SCIENCE FOUNDATION. William C. Foster, Undersecretary of Commerce. *Science*, March 21, 1947.

SCIENCE AND PUBLIC POLICY. Report to the President by John R. Steelman. U. S. Government Printing Office, 1947.

HISTOPLASMOSIS

HISTOPLASMOSIS. A. C. Curtis and J. N. Grekin in *Journal of the American Medical Association*, August 9, 1947.

BENIGN HISTOPLASMOSIS. *Physicians' Bulletin*, March-April, 1948.

THE ARMY ANT

MASS ORGANIZATION IN THE SWARM-RAIDER. T. C. Schneirla in *Journal of Comparative Psychology*. Vol. 29, pages 401-60, 1940.

PROBLEMS IN THE BIOPSYCHOLOGY OF SOCIAL ORGANIZATION. T. C. Schneirla in *Journal of Abnormal and Social Psychology*, Vol. 41, pages 385-402, 1946.

THE ULTIMATE PARTICLES

WHY SMASH ATOMS? A. K. Solomon. Harvard University Press, 1945.

PARTICLES OF MODERN PHYSICS by J. D. Stranathan. Blakiston, 1945.

BIOLOGY OF OLD AGE

PROBLEMS OF AGING. E. V. Cowdry. Williams and Wilkins, 1942.

GERIATRIC MEDICINE. E. J. Stieglitz. Saunders, 1943.

"IF A SLAVE GIRL FLED . . ."

THE SUMERIAN LAW CODE COMPARED WITH THE CODE OF HAMMURABI. S. Langdon in *Journal of the Royal Asiatic Society*, pages 489-515, 1920.

THE LIPIT-ISHTAR LAW CODE. Francis R. Steele in *American Journal of Archaeology*. Vol. LI, No. 2, 1947.

WHITE PINE

THE GREAT FOREST. Richard Lillard. Knopf. 1947.

HISTORY OF THE LUMBER INDUSTRY IN AMERICA. James E. Defebaugh. *American Lumberman*, 1908.

SRINIVASA RAMANUJAN

RAMANUJAN. G. H. Hardy. Cambridge University Press, 1940.

COLLECTED PAPERS OF SRINIVASA RAMANUJAN. Edited by G. H. Hardy, P. V. Seshu Aiyar and B. M. Wilson. Cambridge University Press, 1947.

Mr. Micawber was only half-right!

Mr. Micawber's financial advice to young David Copperfield is justly famous.

Translated into United States currency, it runs something like this:

> "*Annual income, two thousand dollars; annual expenditure, nineteen hundred and ninety-nine dollars; result, happiness. Annual income, two thousand dollars; annual expenditure, two thousand and one dollars; result, misery.*"

Mr. Micawber was only half-right!

Simply *not* spending more than you make isn't enough. Every family must have a cushion of savings to fall back on . . . and to provide for their future security.

U. S. Savings Bonds offer one of the best ways imaginable to build savings.

Two convenient, automatic plans make the systematic purchase of Savings Bonds both sure and trouble-free:

1. If you work for wages or salary, join Payroll Savings—the *only* installment-buying plan.

2. If you're in business, or a farmer, or in a profession, and the Payroll Savings Plan is *not* available to you, then sign up at your bank for the Bond-A-Month Plan.

Each helps you build a nest egg of absolutely safe, 100% government-backed U. S. Savings Bonds. And these bonds make more money for you while you save. For after only ten years, they pay you back $400 for every $300 you put in them.

Join the Plan *you're* eligible for today! As Mr. Micawber would say: "Result, security!"

AUTOMATIC SAVING IS SURE SAVING - U.S. SAVINGS BONDS

Contributed by this magazine in co-operation with the Magazine Publishers of America as a public service.