FOR THE INCREASE AND DIFFVSION OF KNOWLEDGE AMONG MEN

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SMITHSONIAN INSTITVTION WASHINGTON 1846

ANNUAL REPORT OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING JUNE 30

1926

(Publication 2879)

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II

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30, 1926

SMITHSONIAN INSTITUTION,
Washington, November 18, 1926.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1926. I have the honor to be,

Very respectfully, your obedient servant,

C. D. WALCOTT,
Secretary.

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2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1926.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1926.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1926.

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THE SMITHSONIAN INSTITUTION

June 30, 1926

Presiding officer ex officio.—CALVIN COOLIDGE, President of the United States.
Chancellor.—WILLIAM HOWARD TAFT, Chief Justice of the United States.

Members of the Institution:

CALVIN COOLIDGE, President of the United States.
CHARLES G. DAWES, Vice President of the United States.
WILLIAM HOWARD TAFT, Chief Justice of the United States.
FRANK B. KELLOGG, Secretary of State.
ANDREW W. MELLON, Secretary of the Treasury.
DWIGHT FILLEY DAVIS, Secretary of War.
JOHN G. SARGENT, Attorney General.
HARRY S. NEW, Postmaster General.
CURTIS D. WILBUR, Secretary of the Navy.
HUBERT WORK, Secretary of the Interior.
WILLIAM M. JARDINE, Secretary of Agriculture.
HERBERT CLARK HOOVER, Secretary of Commerce.
JAMES JOHN DAVIS, Secretary of Labor.

Regents of the Institution:

WILLIAM HOWARD TAFT, Chief Justice of the United States, Chancellor.
CHARLES G. DAWES, Vice President of the United States.
REED SMOOT, Member of the Senate.
GEORGE WHARTON PEPPER, Member of the Senate.
WOODBRIDGE N. FERRIS, Member of the Senate.
ALBERT JOHNSON, Member of the House of Representatives.
R. WALTON MOORE, Member of the House of Representatives.
WALTER H. NEWTON, Member of the House of Representatives.
CHARLES F. CHOATE, Jr., citizen of Massachusetts.
HENRY WHITE, citizen of Washington, D. C.
ROBERT S. BROOKINGS, citizen of Missouri.
IRWIN B. LAUGHLIN, citizen of Pennsylvania.
FREDERIC A. DELANO, citizen of Washington, D. C.
DWIGHT W. MORROW, citizen of New Jersey.

Executive committee.—HENRY WHITE, FREDERIC A. DELANO, R. WALTON MOORE.
Secretary of the Institution.—CHARLES D. WALCOTT.
Assistant Secretary.—C. G. ABBOT.
Assistant Secretary.—ALEXANDER WETMORE.
Chief Clerk.—HARRY W. DORSEY.
Accounting and disbursing agent.—N. W. DORSEY.
Editor.—W. P. TRUE.
Librarian.—WILLIAM L. CORBIN.
Appointment clerk.—JAMES G. TRAYLOR.
Property clerk.—J. H. HILL.

NATIONAL MUSEUM

Keeper ex officio.—CHARLES D. WALCOTT, Secretary of the Smithsonian Institution.

Assistant Secretary (in charge).—ALEXANDER WETMORE.

Administrative assistant to the Secretary.—W. DE C. RAVENEL.

Head curators.—WALTER HOUGH, LEONHARD STEJNEGER, GEORGE P. MERRILL.

Curators.—PAUL BARTSCH, R. S. BASSLER, T. T. BELOTE, AUSTIN H. CLARK, F. W. CLARKE, F. V. COVILLE, W. H. DALL, CHARLES W. GILMORE, WALTER HOUGH, L. O. HOWARD, ALEŠ HRDLIČKA, NEIL M. JUDD, H. W. KRIEGER, FREDERICK L. LEWTON, GEORGE P. MERRILL, GERRIT S. MILLER, jr., CARL W. MITMAN, ROBERT RIDGWAY, WALDO L. SCHMITT, LEONHARD STEJNEGER.

Associate curators.—J. M. ALDRICH, W. R. MAXON, CHARLES W. RICHMOND, J. N. ROSE, PAUL C. STANDLEY, DAVID WHITE.

Chief of correspondence and documents.—H. S. BRYANT.

Disbursing agent.—N. W. DORSEY.

Superintendent of buildings and labor.—J. S. GOLDSMITH.

Editor.—MARCUS BENJAMIN.

Photographer.—ARTHUR J. OLMSTED.

Property clerk.—W. A. KNOWLES.

Engineer.—C. R. DENMARK.

Shipper.—L. E. PERRY.

NATIONAL GALLERY OF ART

Director.—WILLIAM H. HOLMES.

FREER GALLERY OF ART

Curator.—JOHN ELLERTON LODGE.

Associate curator.—CARL WHITING BISHOP.

Assistant curator.—GRACE DUNHAM GUEST.

Associate.—KATHARINE NASH RHOADES.

Superintendent.—JOHN BUNDY.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—J. WALTER FEWKES.

Ethnologists.—JOHN P. HARRINGTON, J. N. B. HEWITT, FRANCIS LA FLESCHE, TRUMAN MICHELSON, JOHN R. SWANTON.

Editor.—STANLEY SEARLES.

Librarian.—ELLA LEARY.

Illustrator.—DE LANCEY GILL.

INTERNATIONAL EXCHANGES

Assistant secretary (in charge).—C. G. ABBOT.

Chief clerk.—C. W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK

Director.—WILLIAM M. MANN.

Assistant director.—A. B. BAKER.

ASTROPHYSICAL OBSERVATORY

Director.—C. G. ABBOT.

Research assistant.—F. E. FOWLE, Jr.

Research assistant.—L. B. ALDRICH.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Assistant in charge.—LEONARD C. GUNNELL.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

CHARLES D. WALCOTT

FOR THE YEAR ENDING JUNE 30, 1926

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith the customary annual report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1926. The first 33 pages of the report contain an account of the affairs of the Institution, and in Appendixes 1 to 10 are given more detailed summaries of the operations of the United States National Museum, the National Gallery of Art, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the United States Regional Bureau of the International Catalogue of Scientific Literature, the Smithsonian Library, and of the publications issued under the direction of the Institution.

THE SMITHSONIAN INSTITUTION

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America, "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice, three Members of the Senate, and three Members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of them of the same State." One of the Regents is elected chancellor by the board; in the past the selection has fallen upon the Vice President or the Chief Justice; and a suitable person is chosen by the Regents as secretary of the Institution, who is also secretary of the Board of Regents and the executive officer directly in charge of the Institution's activities.

The following changes occurred in the personnel of the board during the year: The Hon. George Gray, of Delaware, died August 7, 1925, and Mr. Dwight W. Morrow, of New Jersey, was appointed a citizen Regent on January 7, 1926, to fill the vacancy thus created.

The roll of Regents at the close of the fiscal year was as follows: William H. Taft, Chief Justice of the United States, chancellor; Charles G. Dawes, Vice President of the United States; members from the Senate—Reed Smoot, George Wharton Pepper, Woodbridge N. Ferris; members from the House of Representatives—Albert Johnson, R. Walton Moore, Walter H. Newton; citizen members—Charles F. Choate, jr., Massachusetts; Henry White, Washington, D. C.; Robert S. Brookings, Missouri; Irwin B. Laughlin, Pennsylvania; Frederic A. Delano, Washington, D. C.; and Dwight W. Morrow, New Jersey.

GENERAL CONSIDERATIONS

The Smithsonian Institution is a private establishment given to the American people by a philanthropic English gentleman for the increase and diffusion of knowledge among men. Out of its private investigations and collections grew up activities of immense public value. They have been the foundation of nine prominent Government bureaus. Of these, seven are still, by direction of Congress, administered by the Smithsonian Institution for the use of the public and for these public bureaus Congressional appropriations are made. These appropriations are strictly limited to these special objects. It was out of investigations made by the Smithsonian Institution, not out of any Government initiative, that these valuable public bureaus, including the Weather Bureau and the Fish Commission, grew up. Similarly, it is logical to suppose that out of the free activities of the Smithsonian Institution great public benefits would arise in future if it had means appropriate to its position as the national research institution. But in these days of high wages, high salaries, and high prices, the small income from the Smithsonian endowment, $65,000 annually—only as much in a year as the Carnegie Institution has for research in two weeks—is quite insufficient to make any considerable showing.

This is what the Smithsonian Institution does:

1. It carries on original scientific investigations by its own staff.

2. It prints large memoirs and smaller original papers, publishes useful tables and formulas, and reprints informing articles on scientific progress suitable for the intelligent general reader, and distributes these free to scientific and learned societies throughout the world.

3. It answers by mail an average of 8,000 inquiries on scientific subjects annually, gratis.

4. It gives occasional lectures and courses of lectures by eminent scientists.

5. It confers medals of honor on eminent discoverers.

6. It subsidizes, if funds can be secured, approved researches by outside workers.

7. It procures foreign diplomatic and learned recognition and assistance for expeditions going abroad.

8. It fosters scientific development of schools, museums, and institutions throughout the world by cooperation in the loan of research men, in the free distribution of over a million specimens, and in giving its advice and its publications.

9. It is the headquarters of the American Association for the Advancement of Science. Until 1924 it was the headquarters and meeting place of the National Academy of Sciences.

10. It is the official channel of exchange of scientific intelligence between the United States and the world.

11. It contributes continually to the Library of Congress a large flow of foreign periodical and occasional scientific literature, which has now accumulated to over 500,000 volumes.

12. It administers seven public governmental bureaus besides the Freer Gallery.

13. It disburses annually funds from four sources:

(*a*) The income of its endowment, $65,000.

(*b*) Sums intrusted by private individuals for special objects. Average five years—$70,000.

(*c*) The income of the Freer bequest. Average five years—$190,000.

(*d*) Congressional appropriations for seven public bureaus—$850,000.

What the Smithsonian desires to do and be.—The Smithsonian Institution, ward of the American Nation, desires to bring out the hidden treasures of knowledge from the great collections under its care; to prosecute vigorously for the ultimate benefit of mankind its researches in astronomy, physics, chemistry, mathematics, geology, meteorology, and the life sciences; to publish amply, both for the specialist and the general reader; to answer generously those who seek its information. The Smithsonian Institution desires to continue worthy of being, as it must forever be, the national institution for the increase and diffusion of knowledge among men. With these objects, it is unfitting that the endowment of the Smithsonian Institution should be inadequate and so far inferior to the endowments of first-rank private institutions having no national status.

In the report for 1925 I called attention to the fact that a substantial addition to the Institution's resources was imperative. The support of the few major researches at present carried on through gifts for specific investigations is becoming more and more precarious and the publications of the Institution are reduced to one-third of their former number. To meet this situation, a direct effort was determined upon to increase the permanent endowment, and one step mentioned last year was an agreement made with the William T. De Van Corporation, of New York, to issue the Smithsonian Scientific Series, a series of illustrated popular science books to be written by members of the staff, describing in attractive form the activities of the Institution and the bureaus under its direction in many branches of science. The method at first proposed of publishing the series was found to be impractical, and toward the close of the past fiscal year a new method was evolved which it is believed will be more successful.

It was further noted in last year's report that another project for increasing the Institution's resources was under consideration but had not been definitely entered into by the close of the year. This project has since taken shape, and in November, 1925, the Board of Regents announced publicly that the Institution would go before the American public to raise an addition of $10,000,000 to its endowment fund. Since that time the officials of the Institution have been engaged in laying the necessary groundwork for such a campaign, and it is expected that the actual raising of money will begin during the coming autumn. The official announcement of the Board of Regents called attention to the totally inadequate present income of the Smithsonian, outlined briefly its past achievements and world-wide reputation, and mentioned the many important projects in the realm of pure science which it was equipped to undertake but had not the means for. The announcement concluded as follows:

Current history proves that nations climb to higher standards of living on the ladder of science. It was Pasteur who claimed that "science is the soul of prosperity of nations and the living source of all progress. What really leads us forward are a few scientific discoveries and their application." It is the recognition of this fact and of the part which the Smithsonian is called upon to play in contributing to the prosperity of the nation which leads the Board of Regents to turn to the people of the country for an addition of $10,000,000 to the Institution's endowment.

A number of major expeditions in the interests of science went out during the year under Smithsonian direction, through funds provided by friends of the Institution for these special projects. There should be mentioned particularly the Smithsonian-Chrysler expedition to East Africa for the purpose of obtaining live wild animals for the National Zoological Park; the National Geographic Society Solar Radiation Expedition Cooperating with the Smithsonian Institution, to equip and maintain for a period of years a solar radiation station in the Eastern Hemisphere to cooperate with the two now operated by the Smithsonian; Dr. Aleš Hrdlička's anthropological expedition to southern Asia, Java, Australia, and South Africa, which covered over 50,000 miles, under the joint auspices of the Institution and the Buffalo Society of Natural Sciences; and the first award of the Smithsonian's Walter Rathbone Bacon Traveling Scholarship, under which Dr. Waldo L. Schmitt, of the National Museum, conducted an extensive survey of the crustacean fauna of South America. All of these expeditions are briefly described elsewhere in this report.

FINANCES

The permanent investments of the Institution consist of the following:

Deposited in the Treasury of the United States ______ $1,000,000.00

CONSOLIDATED FUND

Miscellaneous securities, etc., either purchased or acquired by gift; cost or value at date acquired ______ 218,186.50

Charles D. and Mary Vaux Walcott research fund, stock (gift); value ______ 11,520.00

The sums invested for each specific fund or securities, etc., acquired by gift are described as follows:

Fund	United States Treasury	Consolidated fund	Walcott research fund	Total
Avery fund	$14,000.00	$34,690.87		$48,690.87
Virginia Purdy Bacon fund		62,272.93		62,272.93
Lucy H. Baird fund		1,528.09		1,528.09
Chamberlain fund		35,000.00		35,000.00
Habel fund	500.00			500.00
Hamilton fund	2,500.00	500.00		3,000.00
Caroline Henry fund		1,223.33		1,223.33

Fund	United States Treasury	Consolidated fund	Walcott research fund	Total
Hodgkins fund:				
General	$116,000.00	$37,275.00		$153,275.00
Specific	100,000.00			100,000.00
Bruce Hughes fund		13,839.90		13,839.90
Morris Loeb fund		3,519.00		3,519.00
Lucy T. and George W. Poore fund	26,670.00	18,536.42		45,206.42
Addison T. Reid fund	11,000.00	7,299.16		18,299.16
Rhees fund	590.00	357.34		947.34
George H. Sanford fund	1,100.00	675.72		1,775.72
Smithson fund	727,640.00	1,468.74		729,108.74
Charles D. and Mary Vaux Walcott research fund			$11,520.00	11,520.00
Total	1,000,000.00	218,186.50	11,520.00	1,229,706.50

The Institution gratefully acknowledges gifts from the following donors:

American Association for the Advancement of Science, for botanical explorations in Jamaica.

Mr. Oakes Ames, for botanical explorations in Costa Rica.

Mrs. Laura Welsh Casey, for expenses in connection with Casey collection of Coleoptera.

Mr. Walter Chrysler, for expedition to Africa to collect animals, etc. for the National Zoological Park.

Mr. E. W. Marland, for Missouri Historical Society, for study of the language of the Osage Indians.

National Academy of Sciences, for paleontological researches.

New York Botanical Garden, for botanical explorations in Jamaica.

Mr. John A. Roebling, for solar researches, etc.

Mr. Washington A. Roebling, for purchase of minerals, etc.

Mr. Charles T. Simpson, for work on West Indian shells.

Dr. Frank Springer, for publication of "American Silurian Crinoids."

Mr. B. H. Swales, for purchase of specimens.

University of Pennsylvania, department of botany, for botanical explorations in Jamaica.

The Institution has also received contributions from the following friends for the funds as listed below:

Endowment campaign expense fund: Dr. Charles G. Abbot, Mr. Robert S. Brookings, Mr. Frederic A. Delano, Hon. Andrew W. Mellon, Dr. Charles D. Walcott, and the Hon. Henry White.

Endowment fund: Mr. John Baker, Mr. H. E. Bouwknegt, Miss Elizabeth W. C. Campbell, Mr. J. M. Chadwell, Mr. L. French, Mr. Leo Henle, Mr. Sol. Isler, Mr. William F. Kemble, Mr. D. Kinnear, Mr. George G. Marshall, Mr. Harold M. Mayo, Master Orrin F. Nash, Mr. John H. Powers, Mr. Henry S. Ritter, Dr. Rudolf Ruedemann, Dr. Charles S. Schuchert, Mrs. Eleanor H. Wheelwright, Mr. George McLane Wood, and Mr. F. R. Wulsin.

Smithsonian Scientific Series: Mr. Wyllys W. Baird, Mrs. Elizabeth B. Blossom, Hope Natural Gas Co., Mr. William W. Laird, Mr. James H. Lockhart, Peoples Natural Gas Co., Philadelphia Company and Affiliated Corporations, and Mr. George M. Reynolds.

The Institution wishes to express its gratitude to Mr. John Poole for his deep interest and help in connection with the endowment fund campaign and also to the following gentlemen who, through him, extended very welcome aid to the same:

Mr. Byron S. Adams, Mr. Thomas P. Bones, Mr. Alexander Britton, Mr. Charles I. Corby, Mr. John Dolph, Mr. T. C. Dulin, Mr. William John Eynon, Mr. W. T. Galliher, Julius Garfinckel & Co., Mr. Fred. S. Gichner, Mr. William F. Ham, Mr. Morton J. Luchs, H. L. Rust Co., Mr. James Sharp, Mr. H. C. Sheridan, and Mr. George E. Walker.

Freer Gallery of Art.—The invested funds of the Freer bequest are classified as follows:

Court and grounds fund	$278, 825. 50
Court and grounds, maintenance fund	69, 683. 75
Curator fund	278, 825. 50
Residuary legacy	2, 842, 080. 19
Sinking fund	350, 261. 25
Total	3, 819, 676. 19

The practice of depositing on time, in local trust companies and banks, such revenues as may be spared temporarily, has been continued during the past year, and interest on these deposits has amounted to $1,748.21. The income during the year for current expenses, consisting of interest on permanent investments and other miscellaneous sources, amounted to $61,171.52. Revenues and principal of funds for specific purposes, except the Freer bequest, amounted to $166,214.79. Revenues on account of Freer bequest amounted to $255,354.66, amount received from sale of stocks and bonds $988,510, aggregating a total of $1,471,016.97.

The disbursements, described more fully in the annual report of the executive committee, were classed as follows: General objects of the Institution, $60,782.56; for specific purposes (except the Freer bequest), $181,647.45; and expenditures pertaining to the Charles L. Freer bequest, $1,265,884.31. The balance on hand on June 30, 1926, was $134,889.40.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1926:

International Exchanges		$46, 260
American Ethnology		57, 160
International Catalogue of Scientific Literature		8, 000
Astrophysical Observatory		31, 180
Additional assistant secretary		6, 000
National Museum:		
Furniture and fixtures	$21, 800	
Heating and lighting	77, 560	
Preservation of collections	441, 082	

National Museum—Continued.		
Building repairs	$12,000	
Books	1,500	
Postage	450	
		$554,392
National Gallery of Art		21,028
National Zoological Park		157,000
Printing and binding		90,000
Total		971,020

RESEARCHES AND EXPLORATIONS

Field expeditions play an important part in the work of a research institution. The Smithsonian, although handicapped particularly in this phase of its work by inadequate income, sends out or participates in many such expeditions each year. It is often found advantageous to cooperate in field work with other institutions, thus dividing the expense and enabling the participating institutions to share the collections and other benefits resulting from the expedition. The Smithsonian's explorations cover biology, anthropology, geology, and astrophysics, and in addition to furnishing important new facts in these sciences, the material brought back by the explorers has done much toward building up the collections of the National Museum and filling in gaps in the scientific study series. During the past year the Institution has engaged in about the usual number of field expeditions. These have conducted scientific exploration or field work in many States of the United States, Canada, Haiti, several regions in South America, Europe, southern Asia, Java, Australia, South Africa, and China. Some of these are described in the reports of the National Museum and the Bureau of American Ethnology, appended hereto, and a few of the others will be mentioned briefly here in order to show the character and diversity of the Institution's field work.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

Your secretary continued during the 1925 field season his geological field work in the Canadian Rockies, starting from Lake Louise Station in Alberta on July 9 with a pack train bearing the camp outfit. The season was unusually unfavorable, forest-fire smoke interfering with photography and the large number of snow squalls making field work extremely difficult. Regarding the progress of the geological work, I wrote at the close of the season:

Only eight camps were made while on the trail. It was more through good fortune than favorable conditions that a fine series of fossils from critical horizons in the great lower Paleozoic section north of Bow Valley was discovered and collected. These fossils increase our knowledge of the history and life of the Cordilleran Sea of this time and afford the data for comparison with life and conditions in the Appalachian Trough and the great upper Mississippi embayment of Upper Cambrian time.

In the interval between the snow storms of September 5 and 9 several new fossil zones were found in the Lower Ordovician rocks of the Johnston-Wild Flower Canyon Pass section, and also in the Upper Cambrian west of Badger Pass. The latter find enabled Doctor Walcott to identify the Arctomys formation of the Glacier Lake section and to clear up the uncertainty as to the position of the strata hitherto referred to the lower portion of the Bosworth formation.

* * * * * * *

This year probably completes the field work in the Canadian Rockies. A few of the problems encountered have been cleared up in the past nine years, but many remain to be studied by young, well-trained men with strong hearts, vigorous muscles, and the high purpose of the research student seeking to discover the truth regarding the development of the North American Continent and of the life of the waters in which the miles in thickness of sands, clay, and limey muds accumulated during a period of several million years of lower Paleozoic time.

Your secretary was engaged at the close of the year, during such times as he was able to spare from administrative duties, in preparing for publication the geological results of many seasons of work in the Canadian Rockies. This summary of the Canadian work will appear as one of his series on Cambrian Geology and Paleontology in the Smithsonian Miscellaneous Collections.

COLLECTING FOSSIL FOOTPRINTS IN ARIZONA

Through a cooperative arrangement with the National Park Service, Mr. C. W. Gilmore, curator of vertebrate paleontology in the National Museum, visited the Grand Canyon during the past field season for the double purpose of preparing a permanent exhibit of fossil footprints in the rock along the Hermit Trail, and of making for the National Museum a collection of these footprints to send back to Washington. Mr. Gilmore succeeded in both of these projects, and in his preliminary report on the work, he writes:

A series of slabs, some 1,700 pounds in weight, carrying good examples of the various kinds of imprints occurring there, were collected and shipped to the Museum. The tracks occur in the Coconino sandstone in Hermit Basin, on the trail down to Hermit Camp, and from 900 to 1,080 feet below the rim of the canyon. Their excellent preservation and variety of kind, coupled with their great antiquity, make this collection of more than usual interest. Preliminary study of the tracks has demonstrated that they represent not only a new Ichnite fauna but probably the best preserved and most extensive series of Permian footprints known anywhere in the world.

It was found that the natural conditions were most favorable for the preparation of an exhibit of fossil tracks in situ. The rather steep slope of the sandstone on whose surfaces the tracks are impressed stands at an inclination of 30° facing toward the Hermit Trail, over which in the course of the year hundreds of tourists travel on mule back in making their pilgrimage to the bottom of the Grand Canyon. The upper layers of the sandstone cleared off in large sheets, thus uncovering whatever tracks and trails there were to be found beneath. The work of preparing this exhibit consisted, therefore, of removing the overburden of loose dirt and broken rock, then quarrying off the loose upper laminae until a solid and continuous face covered with footprints was reached. This was done, and a smooth surface 8 feet wide and 25 feet long was carefully uncovered.

At the side of the slab leading up from the trail a series of stone steps was laid in order to facilitate examination by those interested in the footprints covering its surface. Although this slab constituted the main exhibit, other large surfaces were similarly uncovered, so that in all there are several hundred square feet of rock surface showing imprints of feet, thus forming a permanent exhibit of the various tracks and trails to be found here.

The great antiquity of these footprints is clearly demonstrated at this locality, for it is evident that since the day when those animals impressed their feet in what at that time was moist sand more than 1,000 feet of rock-making materials were piled up in successive strata above them, and this does not take into account many hundreds of feet more that have been eroded off the present top of the canyon wall.

The great length of time necessary for the cutting away or erosion of the rock to form the deep canyon and the even longer time necessary for the original deposition of this great vertical mass of stone when translated into terms of years, if that were possible, would be so stupendous as to be almost beyond human comprehension.

BIOLOGICAL COLLECTING IN WESTERN CHINA

The collecting of biological material for the National Museum was continued in the Province of Szechwan, western China, by the Rev. David C. Graham. Various trips which he had proposed to take had to be abandoned because of the presence of numerous bandits in certain areas, and his work was greatly handicapped by civil-war conditions in that part of China. Nevertheless, Mr. Graham succeeded in making large collections of valuable biological material for the Museum.

While still undecided as to his summer's plans for collecting, Mr. Graham received notification that all foreigners were requested to go together to Kiating, with a heavy military escort for safety. Regarding his activities after this, a brief account prepared from Mr. Graham's letters reads in part as follows:

The party reached Kiating on July 7, and having gone thus far, Mr. Graham decided to try for Washan Mountain, and had actually started, when on the 12th a messenger arrived with a letter saying conditions were getting worse down the river, that many British subjects were leaving Szechwan, and that all foreigners might be ordered to leave, also advising that he abandon his plan to visit Washan. He notes: "It is a keen disappointment, but it seems unwise to go on, so to-morrow I'll go back toward Mount Omei and spend the summer as profitably as I can." On July 14 he received a letter stating that conditions were improving and that the foreign community withdrew its request that he should not attempt the trip to Washan. He thereupon again headed for that mountain, and on July 23 reached the summit, which he says is the highest point in central Szechwan. On every side "it is a sheer cliff several thousand feet high, with only one road to the top and back * * * The road made a few circles, and soon I found myself walking along the edge across the top of that cliff, with only a foot or more of dirt and some small bushes between me and the precipice. Later the road leads a long way on the edge of a narrow ridge, on each side a sheer precipice of thousands of feet. In one spot the path is about 3 feet wide, and I think a little less. It took all the grit I had to cross that place, and I'd hate to attempt it in rainy weather when the rocks are slippery. There is one place where there is no place to get a foothold, and the precipice is bridged by poles placed side by side; under the bridge is a chasm that one does not like to look at. To cap the climax, near the top are long ladders. It is practically perpendicular at these points, and without the ladders no one could reach the top."

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In preparing for his return journey, Mr. Graham decided to pack his summer's accumulation of specimens and mail them from the village of Shin Kai Si, to reduce the danger of loss from robbers. Over 70 parcels were packed and mailed from this place, after which he set out for Kiating, where he was to try and arrange for the safe transport of the Suifu foreigners from Kiating to Suifu.

Mr. Graham's return from Kiating to Suifu was filled with exciting incidents, due to war, brigands, and lack of food. He writes: "With over 100,000 troops engaged in civil war in the Province, with bands of robbers everywhere, and with the serious complications between China and the foreign powers, it may be considered a victory to have carried through the collecting trip and to have secured more specimens than were collected in any previous year."

STUDY OF THE CRUSTACEAN FAUNA OF SOUTH AMERICA

During the past year the first award was made of the Walter Rathbone Bacon scholarship of the Smithsonian Institution, created by the will of Virginia Purdy Bacon for the study of the fauna of countries other than the United States. The award was made to Dr. Waldo L. Schmitt, curator of marine invertebrates in the National Museum, for the purpose of undertaking a comprehensive study of the crustaceans of South America. He began work at Rio de Janeiro, Brazil, where museum collections were examined and some preliminary collecting done. The following extract is taken from a preliminary account of his work prepared at the National Museum:

On September 17, accompanied by Doctor Luderwaldt, Doctor Schmitt started for São Sebastiao, arriving the next morning after a most uncomfortable night on a small boat. The collecting here was good and many varieties of crustacea were obtained. Night collecting yielded valuable tow-net hauls. Upon this island several species of fresh-water shrimps were obtained. Doctor Schmitt is of the impression that these shrimps can travel considerable distances overland through the woods should their parent stream go dry. He states that tiny Euphausids produce a magnificent phosphorescence at night in the waters around the island.

He returned to Santos September 28, where several cases of specimens were prepared for shipment to Washington.

Passing down the coast, collections were made at São Francisco Island, then at Castro where several fresh-water streams were visited. Here, amongst other things, two species of an anomuran crab of the genus *Aeglea* were obtained. These Doctor Schmitt considered a great find, as they are rather rare in collections and there has been some uncertainty as to their status.

He left Castro October 21 and traveled by auto over the mountains to Blumenau. Here he met Fritz Schmitt, son-in-law of Fritz Müller, the celebrated naturalist, visited Müller's former home, and saw the very simple microscopes with which he did such excellent work.

He returned to São Francisco October 27, when several cases of specimens were packed for shipment to Washington. The weather and tides being favorable, some excellent collections of shrimps and amphipods were made at this station, and he says " I've extended the ranges of a number of species, and surely found a couple of new ones here."

He arrived off Itajahy at 8 p. m. November 2, after a cold, rainy trip, and early the next morning anchored off Florianopolis. Some tow-net hauls and shore collecting here produced excellent results.

Owing to the many unavoidable delays, Doctor Schmitt has not been able to progress as rapidly as he had hoped, but the ground has been as thoroughly worked as possible, and several cases of specimens have already been received at the Museum. His collections at this time comprise several thousand specimens and consist chiefly of Crustacea, Coelenterates, Porifera, Echinoderms, Annelids, Bryozoa, and Fishes.

ANTHROPOLOGICAL STUDIES IN SOUTHERN ASIA, JAVA, AUSTRALIA, AND SOUTH AFRICA

The most far-reaching expedition of the year was that undertaken by Dr. Aleš Hrdlička in the interests of physical anthropology, which covered some 50,000 miles through Europe, India, Ceylon, Java, Australia, and South Africa. The primary purpose of the expedition, under the joint auspices of the Smithsonian Institution and the Buffalo Society of Natural Sciences, was to make a thorough survey of the subject of ancient man and fossil apes in these regions.

Doctor Hrdlička's work began in the region of the Siwalik Hills of northern India, which he regards, as the result of his survey, as the richest and most promising region in the world in remains of fossil anthropoid apes. The following extracts from Doctor Hrdlička's first published account of his trip will give an impression of the vast amount of territory covered and of the importance and interest of the work:

From Simla Doctor Hrdlička proceeded to the Tibetan border to observe the types of the Tibetans who made their homes in Darjeeling or its vicinity, or come there from over the mountains, and who occasionally show types that resemble most closely the American Indian. At Darjeeling, with generous help from the Government, it was possible in a short time to see large numbers of the native population, consisting of mongoloid tribes who have overflowed into the northernmost parts of India, and a good many Tibetans. There is seen amongst these Tibetans, Chinese admixture—for the Chinese have been lords of Tibet for a long time—yet frequently true American Indian types are also to be found, so true that if they were transplanted into America nobody could possibly take them for anything but Indian. They—men, women and children—resemble the Indians in behavior, in dress, and even in the intonations of their language.

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From Calcutta the journey led to Madras, where Doctor Hrdlička wished to inspect the collections, and to see what could be learned of traces of the Negrito in the Indian population. One of the biggest problems in anthropology is the presence of the Negrito in the Philippines, the Andamans, and elsewhere in the far southeast. He is there—a clear but enigmatic type, without connection now in any direction. His nearest relatives are apparently the pygmies of Central Africa, but a great unbridged space has till now separated the two. The problem is, How did the Negrito get to his present homes? If he extended from Africa, he must have left traces of his passing in Arabia and India, from which, however, there has hitherto come no clear evidence of his presence. Such traces, so far at least as the Indian coast lands are concerned, Doctor Hrdlička became satisfied do exist. They occur in Parganas (northwest of Calcutta), in at least one area along the eastern coast, here and there among the Dravidians, and along larger parts of the western coast, more especially in the Malabar Hills. This brings unmistakable traces of the Negrito a long way farther to the westward and so much nearer to Africa, making his derivation from that continent so much the more probable.

A great collection of paleolithic implements is preserved in the museum at Madras. These implements are similar to those of other parts of India. They are all of one general class, so that there can hardly be a question as to their contemporary origin in the different parts of India, their connection with people of the same race, and belonging to the same, though perhaps a long, cultural period. They do not show great variety. They resemble some of the paleolithic implements of western Europe, but on the whole can not be associated with any one of the European cultural periods. In certain parts of India, such as the Santal country north of Calcutta, such implements have been collected in thousands. In other parts, especially near Madras, they are partly on the surface soil, partly from 1 to 4 or 5 feet and even deeper below the surface. In places they occur in the alluvium of the rivers and occasionally in the "laterite," a talus-like débris resulting from the disintegration of older rocks.

In short, there are plentiful paleolithic implements over large portions of the country, but as yet they do not definitely indicate a man of geological antiquity.

With regard to the bulk of the present population of India, Doctor Hrdlička believes he can say with confidence that it is mainly composed of three ethnic elements—the Mediterranean, the Semitic, and in certain parts the "Hamitic" or North African. The "Aryans" show everywhere either the Semitic or the Mediterranean type. There was seen nothing that could be referred to the types of central or northern Europe. It would seem therefore that the Aryans came from Persia and Asia Minor rather than from or through what is now European Russia.

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The visit to Java was made chiefly for the purpose of inspecting the site of the Pithecanthropus, but Doctor Hrdlička also desired to satisfy himself as to any possible cultural traces of early man, and as to the present population. As a result of the generous assistance given by the authorities, he was able to see the natives in practically the whole of the island and especially to examine that important region which gave the precious remains of the Pithecanthropus—the valley of the Bengawan or Solo River, a fairly large river, beginning in the south of the island and running north and then east to Surabaya. Here exists a veritable treasure house for anthropology and paleontology where nothing has been done since the Selenka expedition of 1910, which was the only one since the work of Doctor Dubois in 1891–1893. The lower deposits along the river are full of the fossil bones of Tertiary and Quaternary mammals, but among them at any time may be remains of greater value. Many of the fossils fall out of exposed strata every year and lie in the mud, where the natives occasionally gather them and take them to their homes.

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The data obtained in Australia, supplemented by those on the Tasmanian material in the College of Surgeons, London, throw a very interesting and, to some extent, new light on the moot questions of both the Australian and the Tasmanian aborigines. According to these observations, the Australian aborigines deserve truly to be classed as one of the more fundamental races of mankind, and yet it is a race which shows close connections with our own ancestral stock—not with the negroes or Melanesians (except through admixture), but with the old white people of postglacial times. They carry, however, some admixtures of the Melanesian blacks, which is more pronounced in some places than in others.

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The two main objects of the visit to South Africa were the investigation on the spot of the important find of the Rhodesian skull and of the recent discovery of the skull of a fossil anthropoid ape at Taungs, which had been reported as being possibly a direct link in the line of man's ascent.

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The discovery in 1921 at Broken Hill in southern Rhodesia of the skull of the so-called "Rhodesian man" was an event of much scientific importance. The find, moreover, is still enigmatic. The skull shows a man so primitive in many of its features that nothing like it has been seen before. The visit to the Broken Hill mine, in which the skull was discovered, proved a good demonstration of the necessity of a prompt following up by scientific men of each such accidental discovery. The impracticability of such a following up in this case has resulted in a number of errors and uncertainties on important aspects of the case, some of which have already misled students of the finds. It was possible to clear up some of the mooted points, but others remain obscure and can be definitely decided only by further discoveries.

As one of the results of the present visit, it was possible to save and bring for study a collection of bones of animals from the cave, the lower recesses of which gave the Rhodesian skull, and also two additional mineralized human bones belonging to two individuals, all of which, to facilitate the study of the whole subject, were deposited with the earlier relics in the British Museum. The mine is by no means exhausted; and since the interest of everybody on the spot is now fully aroused to these matters, there is hope that more of value may yet be given to science from this locality.

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Doctor Hrdlička has returned deeply impressed with the opportunities for and the need of anthropological research offered by all these distant parts of the world and the openings everywhere for American cooperation. The story of man's origin, differentiation, spread, and struggle for survival is evidently greater, far greater, than ordinarily conceived, and a vast amount of work remains for its satisfactory solution.

ARCHEOLOGICAL STUDIES IN MISSISSIPPI

Mr. Henry B. Collins, jr., assistant curator of ethnology in the National Museum, was detailed during the summer of 1925 to the Bureau of American Ethnology to conduct an archeological exploration of the region in Mississippi formerly occupied by the Choctaw Indians. In describing the scope of the work, Mr. Collins says:

> The region selected for investigation was the eastern part of the State, the former center of the Choctaw Tribe. Here are found not only the village sites known to have been occupied by the Choctaw within historic times, but also a number of prehistoric mounds similar to those found throughout the Mississippi Valley and in other parts of the South and East, denoting a still earlier occupancy of this region by either the Choctaw themselves or by related tribes.
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> At the time of first contact with Europeans, the Choctaw were the most numerous of all the southern Indians. They are also generally regarded as a basic type, culturally and physically, of the great Muskhogean linguistic stock. In any consideration of the ethnic problems of the South, therefore, the Choctaw must assume a place of importance, but as yet very little work has been done among them. It was decided, therefore, that operations for the summer should be confined to definitely known Choctaw territory, devoting part of the time to exploration of historic village sites and part to the excavation of prehistoric mounds in an attempt to establish as far as possible the relation of the two.

From Jackson, Miss., Mr. Collins made a thorough reconnaissance of the ancient mounds in some nine counties of the State. The most important mound examined was the famous Nanih Waiya, which is regarded by the Choctaw as the place of their origin. This large, well-preserved earthwork plays an important part in the legendary history of the Choctaw.

The first mounds to be excavated by Mr. Collins were a group of eight near Crandall, in Clarke County. These proved to be burial mounds, and numerous skeletons were found in them, some of them showing evidences of cremation. The next mound opened, near the town of Increase, was of a different type and much larger. Although containing no skeletons and but a few artifacts, the mound proved of unusual interest because of a peculiar stratification encountered. Regarding this stratification and the relationships of the mound, Mr. Collins writes:

> This stratification consisted of a series of brilliantly colored sand layers, yellow, brown, orange, blue-gray, and pure white, from which, at the center of the mound, there suddenly arose a dome-shaped structure of compact yellow clay. This clay dome and the succession of colored sand strata probably had a ceremonial significance, having been placed on the floor of what had very likely been a temple, the site of which was later covered over with a mound of earth, on the top of which, still later, there probably stood a temple or council house. Colored sand strata in much the same arrangement have also been found in the effigy mounds of Wisconsin.
>
> Within this small inner mound or clay dome was found a rectangular ornament of sheet copper and silver inclosing a core of wood. Both copper

and silver are shown by analysis to be native American, probably from the Lake Superior region. Silver and copper ornaments practically identical to this have been found in small numbers in Florida, Tennessee, Ohio, and Michigan.

Thin, flaked knives, struck with a single blow from flint cores, were found both in the mound and in the adjoining field. These are identical in every respect with the flaked knives from Flint Ridge in Ohio which, while abundant in the Ohio mounds, are rarely found in other localities.

With the most significant features of the McRae mound so strongly suggesting northern influence, we must conclude that the builders of this Mississippi mound maintained at least a close trade relationship with the northern tribes. While undoubtedly the many mounds and various other earthworks of North America were built by Indian tribes of diverse stocks, there are certain resemblances between even the most distant of them which suggest a contact something more than sporadic.

Another group of seven small mounds near Hiwannee, Wayne County, proved to be similar in contents and construction to the burial mounds near Crandall. Upon completing their study, Mr. Collins examined the cemetery of the historic Choctaw village of Coosha. near Lockhart, Lauderdale County. This was found to be comparatively recent, dating probably from the first 30 years of the nineteenth century, and the burials indicated that the Choctaw had by then lost most of their native culture and adopted the ways of the whites.

Mr. Collins concluded his season's work with a series of measurements and observations on 58 adult Choctaw living at Philadelphia, Miss.

SMITHSONIAN RADIO TALKS

The Institution continued to make use of radio broadcasting as an effective means of carrying out its purpose—the increase and diffusion of knowledge. The Smithsonian talks on scientific subjects continued to increase in popularity as indicated by the interest shown in them by magazine editors, news writers, and others. The talks were given on a regular weekly schedule from Station WRC, of the Radio Corporation of America, Washington, D. C., beginning October 1, 1925, and continuing until May 20, 1926. Thirty-two talks were given in all, of which 14 were presented by members of the staff of the Institution and its branches, and the other 18 by representatives of the Department of the Interior, the Department of Agriculture, the Department of Commerce, and Harvard College Observatory, speaking under the auspices of the Institution. Through the cooperation of Prof. J. McKeen Cattell, many of the talks have been published with illustrations in the Scientific Monthly.

Through a system of exchanges, seven of the Smithsonian talks were sent to Station WBZ, of Springfield, Mass., for rebroadcasting there under the auspices of a series similar to that of the Smithsonian, and certain of the talks from the New England series, which is under the direction of Dr. Edward Wigglesworth, were rebroadcast in Washington. A number of talks on astronomy, given from Station WEEI, Boston, under the auspices of the Harvard College Observatory, were also rebroadcast from Washington as part of the Smithsonian series, through the courtesy of Prof. Harlow Shapley and Station WEEI.

A second series of talks of a somewhat different nature, entitled "Radio Nature Talks from the National Zoological Park," was inaugurated during the year. This series is described in detail in the report on the National Zoological Park, which forms Appendix 6 of this report. The direction of both of these series under the auspices of the Institution was in the hands of Mr. Austin H. Clark, curator of echinoderms in the National Museum.

A list of the talks in the regular Smithsonian series follows:

August 5, 1925: Butterflies. Mr. Austin H. Clark, National Museum (given from Station WBZ).

October 1, 1925: Flies. Dr. J. M. Aldrich, National Museum.

October 8, 1925. Our Lighthouse Service. Hon. George R. Putnam, Director of Lighthouses.

October 15, 1925: Plant Lice and Scale Insects. Mr. Harold Morrison, Bureau of Entomology.

October 22, 1925: Earthquakes, Commander N. H. Heck, Coast and Geodetic Survey.

October 29, 1925: Our Alaskan Fisheries. Hon. Henry O'Malley, Commissioner of Fisheries.

November 5. 1925: The Work of the Bureau of Standards. Dr. George K. Burgess, director, Bureau of Standards.

November 12, 1925: Turtles. Miss Doris M. Cochran, National Museum.

November 19, 1925: Studying the Sun in Chile. Mr. L. B. Aldrich, Astrophysical Observatory.

November 26, 1925: Comets. Prof. Edward S. King, Harvard College Observatory (read by Mr. Austin H. Clark).

December 3, 1925: The Ups and Downs of the Earth. Maj. William Bowie, Coast and Geodetic Survey.

December 10, 1925: The Story of Time Keeping. Mr. Carl W. Mitman, National Museum.

December 17, 1925: The Numbers, Motions, and Sizes of the Stars. Dr. William J. Luyten, Harvard College Observatory (read by Mr. Austin H. Clark).

December 24, 1925: How the Insects Spend the Winter. Mr. S. A. Rohwer, Bureau of Entomology.

January 7, 1926: How Men Learned to Fly. Mr. Paul E. Garber, National Museum.

January 14, 1926: New Stars and Variables. Dr. Annie J. Cannon, Harvard College Observatory (read by Mr. Austin H. Clark).

January 21, 1926: The American Sword. Mr. T. T. Belote, National Museum.

January 28, 1926: Measuring the Universe. Prof. Harlow Shapley, director, Harvard College Observatory (read by Mr. William M. Sweets).

February 11, 1926: Archeology in the Southern States. Mr. Henry B. Collins, jr., National Museum.

February 18, 1926: Our Ancient Seas. Dr. Charles E. Resser, National Museum.

February 25, 1926: Some Aspects of the Development of Printing. Mr. R. P. Tolman, National Museum.

March 4, 1926: Birds from the Rocks. Mr. Charles W. Gilmore, National Museum.

March 11, 1926: Household Pests. Dr. E. A. Back, Bureau of Entomology.

March 25, 1926: Some Aspects of Northwest Coast Indian Art. Mr. Herbert W. Krieger, National Museum.

April 1, 1926: Bug versus Bug. Mr. R. A. Cushman, Bureau of Entomology.

April 8, 1926: Eclipses. Mr. Leon Campbell, Harvard College Observatory (read by Mr. Austin H. Clark).

April 15, 1926: Spring Flowers. Dr. Edgar T. Wherry, Bureau of Chemistry.

April 22, 1926: What Are the Stars? Prof. Harlow Shapley, director, Harvard College Observatory (read by Mr. Austin H. Clark).

April 29, 1926: How Fossils got into the Rocks. Dr. Wendell P. Woodring, Geological Survey.

May 6, 1926: Spiders. Mr. Clarence R. Shoemaker, National Museum.

May 13, 1926: Crabs, Lobsters, and Their Relatives. Dr. Waldo L. Schmitt, National Museum.

May 20, 1926: Bright Stars and Constellations. Dr. William J. Luyten, Harvard College Observatory (read by Mr. Austin H. Clark).

SMITHSONIAN EXHIBIT AT THE SESQUICENTENNIAL

Since 1855 the Smithsonian Institution has taken advantage of nearly every prominent exposition to be held in this country and many abroad to advance, through its carefully planned exhibits, the increase and diffusion of knowledge. The Institution has taken part in 33 expositions, and in addition to thus reaching millions of people through its scientific exhibits, there has resulted the further advantage of bringing to the National Museum a large amount of exhibition material at the close of certain of these expositions. In fact, the Museum received its greatest stimulus when it was still in the formative stage, as a result of the Centennial Exposition in 1876, from which over 40 carloads of valuable material were received as gifts from foreign governments and other exhibitors.

With the funds available for the purpose, the Institution has endeavored at the Sesquicentennial Exposition in Philadelphia to represent in its exhibit as many as possible of the varied scientific activities under its direction. In anthropology, biology, geology, and arts and industries, the exhibits are taken from the National Museum. Anthropology exhibits include nine models in miniature of Indian village groups—Iroquois, Sioux, Pawnee, Wichita, Chippewa, Seminole, Navaho, and Pujunan. A particularly educational exhibit portrays the evolution from simple beginnings to modern form of objects of household use, such as the lamp, the cup, knife, fork and spoon, the hammer, saw, and drill, and the ax.

The arts and crafts of the American Indian are represented by life-size models of Zuñi potters, Navaho silversmiths, and Navaho blanket weavers at work at their tasks. The work in biology is typified by a mounted group of the interesting Bighorn, or Rocky Mountain sheep, shown in lifelike poses, which has proved to be a most attractive exhibit. Both educational and interesting are the geological exhibits, which include a series illustrating how rock is weathered to form soil; the gems and precious stones which occur in America and the minerals in which they are found; a number of interesting fossil forms such as fossil turtles, a giant fossil fish which had swallowed another fish, both being preserved in the rock, fossil plants from the coal measures of Pennsylvania, and fossil algae or seaweed, among the earliest known forms of life on the earth.

The vast collection of American historical material in the National Museum is represented in the Institution's Sesquicentennial exhibit by a selected series of arms, insignia, uniforms, medals, and decorations, and by models of Columbus' ships, of the *Mayflower*, and of the *Constitution*. Mechanical technology is represented by a very complete exhibit showing the development of the steam engine and of the steamboat. The progress in photography is illustrated by examples of this art from the days of the first daguerreotype to the finest modern work, and this graphic arts exhibit also includes examples of etching, intaglio engraving, the halftone process, and other methods of artistic expression and reproduction.

The Institution's work in astrophysics, especially on the study of the variation of the sun's heat, is represented by the instruments used in this investigation—the bolometer, an instrument so sensitive that it will measure a change in temperature of one-millionth of a degree centigrade; the pyrheliometer, which measures the heat received on the earth from the sun; and the pyranometer and the melikeron, devices which permit the determination of the heat lost in passing through the earth's atmosphere.

The Smithsonian exhibit contains also a complete set of its publications and those of the bureaus under its direction, numbering in all nearly 900 volumes, which illustrate one of the Institution's principal means of diffusing knowledge. The entire exhibit was brought together and arranged in Philadelphia under the direction to Mr. W. de C. Ravenel, administrative assistant to the secretary.

PUBLICATIONS

The 11 series of publications issued under the direction of the Institution form its chief means of accomplishing "the diffusion of knowledge among men," one of its primary functions. These publications, all on scientific subjects with the exception of the catalogues of the National Gallery of Art, are distributed for the most part free to libraries, learned societies and institutions, and specialists throughout the world. For the general reader interested in keeping up with the march of scientific progress, the Institution presents in the Smithsonian Annual Reports a series of carefully selected articles, some specially prepared, some reprinted, covering as far as possible recent advances and interesting developments in all branches of science.

During the past year 88 volumes and pamphlets have been published by the Institution and the Government bureaus unders its administrative charge. There were distributed 168,932 publications, which included 96,804 volumes and separates of the National Museum series, 35,671 volumes and separates of the Smithsonian Annual Reports, 20,222 volumes and separates of the Smithsonian Miscellaneous Collections, 12,993 publications of the Bureau of American Ethnology, and smaller numbers of the various other series.

Among the eight papers to appear in the Smithsonian Miscellaneous Collections there may be mentioned as of special interest one entitled " An introduction to the morphology and classification of the foraminifera," by Joseph A. Cushman, which has proved of great value to petroleum geologists; " Fossil footprints from the Grand Canyon," by Charles W. Gilmore, describing a large and valuable series of fossil tracks of extinct creatures collected for the National Museum by Mr. Gilmore; and " Music of the Tule Indians of Panama," by Frances Densmore, a paper which describes for the first time the songs and instrumental music of the so-called " white Indians " of the Isthmus of Darien, Panama.

Allotments for printing.—The congressional allotments for the printing of the Smithsonian report to Congress and the various publications of the Government bureaus under the administration of the Institution were practically used up at the close of the year. The appropriation for the coming year ending June 30, 1927, totals $90,000, allotted as follows:

Annual Report to the Congress of the Board of Regents of the Smithsonian Institution	$12,500
National Museum	42,500
Bureau of American Ethnology	25,600
National Gallery of Art	1,200
International Exchanges	300
International Catalogue of Scientific Literature	100
National Zoological Park	300
Astrophysical Observatory	500
Annual Report of the American Historical Association	7,000

Committee on printing and publication.—All manuscripts submitted to the Institution for publication, both papers by members of the staff and those by outside authors, are referred for consideration and recommendation to the Smithsonian advisory committee on printing and publication. The committee also considers matters of publication policy. During the past year seven meetings were held and 96 manuscripts were considered and acted upon. The membership of the committee is as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. George P. Merrill, head curator of geology, National Museum; Dr. J. Walter Fewkes, chief, Bureau of American Ethnology; Dr. William M. Mann, director, National Zoological Park; Mr. W. P. True, editor of the Institution, secretary; Dr. Marcus Benjamin, editor of the National Museum; and Mr. Stanley Searles, editor of the Bureau of American Ethnology.

LIBRARY

The most important change in personnel was the appointment of Miss Isabel L. Towner to the position of assistant librarian in the National Museum to fill the vacancy caused by the retirement and subsequent death of Mr. Newton P. Scudder. Mr. R. Webb Noyes succeeded Miss Sara Young as junior librarian. The death is regretfully recorded of Mr. Francis H. Parsons, for 25 years assistant in charge of the Smithsonian Division of the Library of Congress.

The growth of the Smithsonian library is due almost entirely to the exchange of publications of the Institution for those of learned societies and institutions throughout the world. During the year, 30,541 packages of publications came to the library direct by mail, and 7,352 through the International Exchange Service of the Institution. The accessions of all publications totaled 10,125, which brings the estimate of the number of volumes, pamphlets, and charts in the Smithsonian library to 677,483, to say nothing of the many thousands of parts of volumes awaiting completion of the volumes.

The sets of publications of learned societies in the Museum library were gone over and the missing numbers listed. It was found that many of these could be supplied from the duplicates in the Library of Congress, and an effort is being made to obtain the rest from other sources. The shelves of the main collection in the Museum library were arranged, a task that had not been done for years. An intensive effort was made to bring the filing of the Concilium bibliographicum cards up to date, and much progress was made. Nearly 1,800 volumes were prepared for binding during the year.

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NATIONAL MUSEUM

During the past year the total appropriations received for the maintenance of the National Museum were $598,392, an increase of $13,600 over the previous year. This additional amount was applied to the increase of salaries, mostly through reallocation of positions by the Personnel Classification Board, for the employment of special watchmen to allow the opening of the Arts and Industries Building on Sundays, and to the fund for printing and binding. The Museum was benefited by these increases, but they are only a small part of those needed. As pointed out in last year's report, much more generous appropriations are needed to enable the Museum to properly reward efficient service by its employees and to maintain the collections at their greatest usefulness to the ever-increasing public that they serve. It is also most important that representation of many natural forms that are rapidly disappearing under the spread of civilization should be secured for the benefit of future generations.

In the series of Smithsonian radio talks, now an established feature of the winter program of Station WRC, the Museum contributed 12 speakers. Many of the talks have been published in the Scientific Monthly through the interest of its editor, Dr. J. McKeen Cattell.

The total number of specimens added to the Museum collections during the year was 254,032, and more than 1,000 lots of material were received for examination and report. Three thousand eight hundred and fifty-seven objects were given to schools and other educational agencies and 37,682 specimens exchanged for other material, while many thousands of specimens were loaned to specialists for study.

A detailed account of the accessions in all departments of the Museum is given in the Report of Assistant Secretary Wetmore, Appendix 1, but a few of the more noteworthy may be mentioned here.

In the department of anthropology, the division of ethnology received an excellent series of ethnological and cult material from the Rev. D. C. Graham as a result of his explorations for the Smithsonian Institution in western China and eastern Tibet, and a collection of 105 artifacts obtained in Young's Canyon, Ariz., by J. C. Clarke, transferred by the Bureau of American Ethnology. The division of physical anthropology received valuable skeletal material of Australian aboriginals by exchange with the Adelaide Museum and through personal collection by Doctor Hrdlička.

In the department of biology, the division of insects was greatly enriched by the purchase, with private funds raised by Dr. William

Schaus, of the Dognin collection of lepidoptera, which adds about 82,000 specimens, including 3,000 types, to the collection. The division of marine invertebrates received large additions through the collections of Dr. W. L. Schmitt in South America, and also benefited through the transfer from the Bureau of Fisheries of further material taken on the *Albatross* expedition of 1911 to Lower California, which included many new crustaceans as well as birds and fishes. The division of birds was presented, through Dr. W. L. Abbott, with a valuable collection of birds made in Siam and the Mentawi Islands west of Sumatra by C. Boden Kloss, and through Mr. B. H. Swales and Dr. Casey A. Wood with 65 bird skins of genera and forms not previously represented in the collections.

In the department of geology, the accessions have included very choice and much-needed materials. The outstanding contribution to the division of geology was a collection of approximately 5,000 specimens of ores of rarer metals, assembled by Mr. Frank L. Hess and received by transfer from the United States Geological Survey. The late Col. W. A. Roebling continued his generous contributions to the mineral collections, and other important additions were presented by the United States Mint at Philadelphia, Mr. Jack Hyland, and the Government of British Guiana through Sir John Harrison. Of greatest interest for exhibition purposes was a large group of fluorite crystals presented by the Benson Fluorspar Co., of Cave-in-Rock, Ill., and thought to be the most unusual yet brought to public attention in America. The division of stratigraphic paleontology was enriched through the field explorations of its staff, which added invertebrate fossils from England, Canada, and Europe, as well as the United States. In continuation of his work of last year, Mr. C. W. Gilmore added a new series of shale and sandstone slabs containing the tracks of extinct animals to the collections of vertebrate fossils. Fossil mammal material of unusual value was collected in Florida by Dr. J. W. Gidley.

The accessions in the department of arts and industries showed an increase over last year. In the section of mineral and mechanical technology, the outstanding accession was the airplane *Chicago*, the flagplane of the world flight of 1924, which was transferred to the Museum by the War Department. The textile collections were enriched by the addition of many new fabrics. Several models were installed illustrating the production of certain industrial articles, such as methyl alcohol, coke, casein, and condensed milk. Examples of etching, wood-engraving, lithograph, and other forms of graphic expression have been received by the division of graphic arts. The section of photography has received a valuable set of machines and material illustrative of the growth of the motion-picture industry.

The Loeb collection of chemical types was increased by 165 specimens, and the historical collection by 17,256 specimens.

A number of field expeditions were participated in during the year by members of the Museum staff cooperating with private organizations or with other governmental agencies. The bulk of the accessions to the collections was derived from these activities, which are described in Appendix 1. The lecture rooms and auditorium of the National Museum were used for 110 meetings covering a wide range of activities. Visitors to the Smithsonian Building totaled 110,975; to the Arts and Industries Building, 355,762; to the Natural History Building, 581,563; and to the Aircraft Building, 58,005. The Museum published 8 volumes and 49 separate papers during the year and distributed 96,804 copies of its publications.

NATIONAL GALLERY OF ART

Attention is again called in the director's report to the urgent need of a separate building for the National Gallery, the estimated cost of which would be $8,000,000. Without such a building, and with the art works now belonging to the gallery crowded into temporary quarters in the National Museum, there has been a marked decrease in gifts and bequests to the gallery in recent years. With a suitable building, not only would the people of America again begin to add their art treasures to the national collection in Washington, but the collections of graphic arts, ceramics, textiles, and American history, now exhibited in scattered places in the National Museum, could be shown in association with the paintings and sculpture, thereby releasing many thousand feet of floor space needed for the natural sciences.

The National Gallery Commission held its fifth annual meeting on December 8, 1925. The various affairs of the gallery were considered, and attention was given to the year's accessions, to the purchases made through the Ranger fund, to the proposed National Portrait Gallery, and to the method to be followed in considering the acceptance of art works given or bequeathed to the gallery. The present officers and members of committees were reelected for the ensuing year. The marble statue, the "Libyan Sibyl," by William Wetmore Story, and a marine painting, "The Sea," by Edward Moran, were accepted by the commission as permanent additions to the gallery collections.

A very generous offer was made to Congress by Mrs. John B. Henderson during the year, of a large tract of land on Sixteenth Street for a national gallery building site.

Special exhibitions held in the gallery included a loan exhibition of early American portraits, miniatures, and silver; an exhibition of portrait busts in marble and bronze, by Moses Wainer Dykaar; and an important assemblage of modern Italian art collected and exhibited under the patronage of His Majesty, the King of Italy.

Eight paintings were purchased and assigned to various institutions during the year from the fund provided by the Henry Ward Ranger bequest. It will be recalled that any of these paintings may be reclaimed by the National Gallery of Art during the five-year period beginning 10 years after the death of the artist represented.

Accessions of art works during the year, subject to the approval of the advisory committee of the gallery commission, were 10 paintings to be known as the George Buchanan Coale Collection, 1819–1887; a portrait of Rear Admiral Robley D. Evans, United States Navy; two portrait busts by Moses W. Dykaar; and three paintings by Edward Moran. A number of art works were accepted as loans during the year, and several previously accepted were withdrawn. Nineteen paintings belonging to the gallery were loaned for exhibition by other institutions.

The gallery's library has increased to over 1,400 volumes and pamphlets. A second number of the gallery's catalogues of collections was issued during the year.

FREER GALLERY OF ART

The year's work in the preservation of the collection included work on 10 American oil paintings and the reconditioning of the ceiling of the Peacock Room, half of the latter work being completed at the close of the year. The study of a considerable number of Japanese paintings, including classification and the translation of signatures, seals, and inscriptions upon them, was accomplished during the year. The collection of Near Eastern pottery also was intensively studied and considerably revised.

The library was increased by 500 volumes, of which 462 are in the Chinese and Japanese languages, 72 periodicals, and 142 pamphlets. There has been an increasing demand for photographs of objects in the collection, and 518 subjects are now available for purchase at cost. Over 1,400 photographs were sold during the year. Several hundred copies each of the three publications issued by the gallery—the descriptive pamphlet, gallery books, and the Synopsis of History—were also sold.

The total attendance at the gallery for the year was 108,310. Of this number, several hundred came for special purposes such as to examine objects not on exhibition, and to make copies or photographs of objects in the collections, and six groups varying in number from 20 to 148 made appointments for special study or instruction regarding the collections.

The work of the gallery's archeological expedition in China was practically at a standstill during the year because of the disturbed conditions in that country.

BUREAU OF AMERICAN ETHNOLOGY

The bureau has continued to conduct ethnological researches among the American Indians and to excavate and preserve ruins of prehistoric Indian structures, in accordance with the act of Congress authorizing the work. Dr. J. Walter Fewkes, chief of the bureau, selected as a promising region for study that part of Arizona west of the Little Colorado River, an area practically unknown archeologically. After a brief reconnaissance of the region, Doctor Fewkes chose for excavation a large mound near Flagstaff, Ariz., which revealed an ancient rectangular building 145 by 125 feet in size, containing nearly 40 rooms and a large kiva, or ceremonial chamber. Besides clearing and repairing the walls in order to make this interesting ruin available to tourists and to students of archeology, Doctor Fewkes unearthed and brought back to Washington a large collection of characteristic pottery of diversified form and color, and a number of skeletons of the former inhabitants. As a result of this work, it will be possible to draw conclusions regarding the culture and relationships of the ancient dwellers in this little-known region.

Mr. J. N. B. Hewitt was occupied during the first part of the year in transliterating, amending, and translating the Chippewa text of "The Myth of the Daymaker." Later he undertook the task of reclassifying and recataloguing the valuable collection of linguistic and historical ethnological manuscripts in the bureau archives.

Dr. John R. Swanton completed his papers on the "Social Organization and Social Usages of the Indians of the Creek Confederacy," "Religious Beliefs and Medical Practices of the Creek Indians," and "The Culture of the Southeast," and these works are now in course of publication. He completed the editing of a paper on the "Trails of the Southeast," by the late William E. Myer. Doctor Swanton continued his work in compiling a card catalogue of the words of the Timucua language, and also his investigations on the aboriginal trail system of North America.

Dr. Truman Michelson conducted researches among the Algonquian Indians of Iowa, studying especially the festivals of the Thunder and Bear gentes of the Fox Indians. He later carried on linguistic investigations among the Ojibwa, Ottawa, and Potawatomi. In Washington, Doctor Michelson prepared for publication two papers on sacred packs of the Fox Indians.

Mr. J. P. Harrington was occupied during the year in rescuing all that could be learned of the vanishing culture of the Mission

Indians of California. Extensive excavations were made at several ruined village sites which revealed two distinct coast Indian cultures—an earlier and a later. Under the direction of one of the few survivors who still knows how to make the Mission Indian houses, or jacals, Mr. Harrington succeeded in building one of these structures and excellent photographs were obtained showing each step in the construction. A large amount of valuable information regarding the Mission Indians was brought together by Mr. Harrington, and this material will later be published by the bureau.

Dr. Francis La Flesche was engaged during the year in classifying the personal names of the full-blood members of the Osage Tribe according to their places in the gentes of the tribe. Each name refers cryptically to the origin story of the gens to which it belongs. Nearly 2,000 names were recorded, but their translation has not been completed. Doctor La Flesche, in collaboration with Doctor Swanton, began a vocabulary of the Osage Tribe, some 3,000 words having been recorded with translations thus far.

Miss Frances Densmore continued her studies of Indian music, collecting during the year extensive material among the Menominee of Wisconsin, and completing her manuscript on Papago music, which is now in shape for publication. Mr. Gerard Fowke conducted for the bureau during the period February to April, 1926, a survey and exploration of a group of aboriginal remains near Marksville, La. The mounds excavated and the methods of burial disclosed differentiate this group of remains from any other known to the bureau. Mr. Fowke submitted to the chief a full report, with illustrations and map, on the work.

During the last three months of the year, Mr. H. W. Krieger of the National Museum was detailed to the bureau for the purpose of studying the archeology of the Upper Columbia River Valley, and to undertake the restoration of the old Haida Indian village, Old Kasaan, a national monument in southeastern Alaska. A reconnaissance trip along the upper Columbia River in Oregon and Washington resulted in the selection of an old Indian camp site at Wahluke Ferry as the most promising station for excavation. Several hundred objects were unearthed, most of which had been ceremonial offerings accompanying the cremation form of burial. At Kasaan, it was found that most of the fine totem poles and all of the houses of the old village had either decayed beyond recall or had been burned in a recent fire. A few poles were scraped and the rotted wood removed. On the return trip, Mr. Krieger completed a map of archeological sites on the upper Columbia River, and undertook excavation at eight stations along the river.

Mr. Henry B. Collins, jr., of the National Museum, was detailed to the bureau to carry on archeological work in Louisiana and Mississippi, particular attention being given to 21 mounds on Pecan Island in Vermilion Parish, from which considerable cultural material and a number of skulls were obtained. Mr. Collins then located the sites of several historic Choctaw villages in eastern Mississippi, and secured physical measurements on 72 living Choctaw.

Dr. J. W. Gidley conducted for the bureau an exploration of the fossil beds near Melbourne and Vero, Fla. Many fossil bones were collected, including some new forms, and a number of Indian mounds were visited and examined.

Dr. Aleš Hrdlička was sent to Alaska for the purpose of studying the archeology of Seward Peninsula, in the vicinity of Nome, but this part of his work did not begin until the close of the fiscal year and the results will be reported on next year.

The bureau issued one publication during the year—the Fortieth Annual Report, containing a number of papers on the Fox Indians by Dr. Truman Michelson—and a number of publications were in press or in preparation at the close of the year. There were distributed 12,993 copies of bureau publications.

INTERNATIONAL EXCHANGES

The number of packages of governmental, scientific, and literary publications handled by the International Exchange Service during the fiscal year 1926 was 480,776, an increase of more than 12,000 over the preceding year. These packages reached a total weight of 558,493 pounds, representing more than 10 per cent increase in weight over last year. Over 2,500 boxes were required for the shipment of publications to foreign exchange agencies for distribution abroad.

The depository of United States governmental documents in China has been changed from the American-Chinese Publication Exchange Department in Shanghai to the Metropolitan Library in Peking. Iceland and the Dominican Republic have been added during the year to the list of depositories of partial sets of our governmental documents. Steps were taken by the exchange service, at the request of several depositories, to have the regular series of governmental documents delivered more promptly than has been customary, and several letters of appreciation of this action were received from abroad by the Smithsonian Institution. Sets of United States official documents are now sent to 101 foreign depositories, and 75 copies of the Congressional Record are exchanged for similar proceedings of foreign parliaments.

In the report on the exchange service, appended hereto, is reproduced a circular describing the service and presenting the rules under which packages are received for distribution.

NATIONAL ZOOLOGICAL PARK

Although the number of animals in the park remains practically the same as in the previous year, the value of the collection has decreased somewhat through the loss of a number of the larger mammals which are expensive and therefore difficult to replace. Among the 150 animals presented to the park may be mentioned six specimens of the rhea, the ostrich of South America; a very interesting collection of birds and snakes from Sumatra; a three-toed sloth; an ocelot; a fine pair of Canada lynx; a Tasmanian wallaby; and four giant salamanders. One hundred and one mammals, birds and reptiles were born or hatched in the park during the year. The mammals included Rocky Mountain sheep, mouflon, Alpine ibex, American bison, Indian buffalo, yak, guanaco, various deer, Javan and Japanese monkeys, raccoon, rock kangaroo, and beaver. The animals lost by death included a number that had been in the park for long periods, the longest record being that of a sloth bear, which had lived in the park for 21 years and 6 months. The total number of animals at the close of the year was 1,619, including 461 mammals, 1,042 birds, and 116 reptiles and batrachians.

The number of visitors for the year was 2,512,900, slightly less than the year before, but more than in any previous year. Schools and classes visiting the park numbered 309, comprising 24,309 individuals. General improvements included grading along the new western boundary of the park near Cathedral Avenue, a large amount of needed repairing to roofs, rebuilding the roadway to and around the administration building, and putting in a new drainage system for the cages and walks on the south side of the lion house.

It is gratifying to report that provision is made in the appropriation for the coming year for a bird house, for which there has been urgent need for several years. It is planned to begin construction in the spring of 1927. This structure will enable the officials of the park to assemble a collection of birds worthy of the National Zoological Park. Funds were made available during the past year for furnishing uniforms to the park policemen, making possible the maintenance of a better standard of personal appearance. Similar provision should also be made for the keepers, who are brought to a considerable extent into contact with the public.

In connection with the Smithsonian series of radio talks, a new series was begun during the year entitled "Radio Nature Talks from the National Zoological Park." In this series, thirty-one 15-minute talks were given through station WRC, each preceded by a brief statement of current news of the park.

Through the interest and financial support of Mr. Walter P. Chrysler, automobile manufacturer, an expedition was sent to Tanganyika Territory, East Africa, to secure for the park certain large and important African animals needed for the collection. This Smithsonian-Chrysler expedition left New York March 20, headed by Dr. W. M. Mann, director of the park, and at the close of the year a report was received of the capture of the first animals in the field by the expedition.

ASTROPHYSICAL OBSERVATORY

A grant of $55,000 to Doctor Abbot was made during the year by the National Geographic Society for the purposes of selecting the best site in the Eastern Hemisphere and of establishing and maintaining for about four years a third solar-observing station to cooperate with the two now operated by the Astrophysical Observatory for the measurement of solar variation. To select the best site for the new station, Doctor Abbot visited and examined promising localities in Algeria, Egypt, Baluchistan, and South West Africa, finally giving preference to Brukkaros Mountain in South West Africa. Although extremely isolated, this mountain is otherwise most promising for the investigation. Two-thirds of the 3½-inch average annual rainfall occurs in February and March, when better conditions prevail at the two American stations, and good months may be expected at Brukkaros Mountain when observing weather is poorest in America. Work was begun in April on the construction of the observing tunnel, dwelling, shop, reservoir, and garage, and the expedition is expected to leave this country in the autumn. The station will be manned by Mr. W. H. Hoover, director, and Mr. F. A. Greeley, assistant.

Through the continued generosity of Mr. John A. Roebling, the station maintained for five years on Mount Harqua Hala, Ariz., was transferred to Table Mountain, Calif., in order to obtain better sky conditions. Mr. A. F. Moore, director of the Harqua Hala station, designed and superintended all of the construction of the new station, and regular observations were begun from Table Mountain in October, 1925. The high quality of the observing conditions has amply justified making the change.

Mr. Roebling felt in 1924 that his part in supporting the solar radiation work should end with June 30, 1925. Letters were addressed to the National Academy of Sciences, the Chief of the Weather Bureau, and the director of the meteorological office of the Air Ministry of Great Britain, asking whether in their opinion the importance of the solar observations warranted asking for increased Government appropriations to cover the support of the Montezuma station. The replies were emphatic in stating that the work was of the highest value and importance, and Congress granted the necessary increase to continue the Chilean station.

The daily solar constant values have been cabled to Washington from the Montezuma station as heretofore, and since January 1, 1926, the solar constant data have been published on the daily weather map at the request of the Chief of the Weather Bureau. On that date, the Institution made public announcement that it would furnish "through the United States Weather Bureau, through either of the telegraph companies, or through the Associated Press, or Science Service, if any or all of these organizations shall request it for the use of their clients, daily or 10-day mean values of the solar constant of radiation as early and as frequently as results are available from its field stations in Chile and California."

The staff of the observatory at Washington have been largely occupied during the year with a complete revision of all of the Mount Montezuma data. As a result of this extensive work, the newly derived solar constant values show a new and higher order of accuracy than ever reached before.

A new proof of solar variability was devised by Doctor Abbot, on the basis that if the atmosphere had uniform temperature, transparency, and humidity, and if the pyrheliometer observations were made always at the same altitude above the horizon, the readings of the pyrheliometer would be directly proportional to the intensity of the solar rays. Testing this idea on all observations made in the months of July at Mount Wilson, from 1910 to 1920, excluding the years 1912 and 1913 as well as many individual days of unusual atmospheric conditions, Doctor Abbot plotted a full curve from the remaining observations. Then using the identical days, the mean solar constant values as heretofore published were plotted as a dotted curve. Both curves agree very closely except in 1914, when they differ by about 1 per cent. Both curves indicate a range of solar variation in July of 1910 to 1920 of over 2 per cent. With them was plotted in a double line the variation of sun-spot numbers. Even in details the agreement is quite remarkable.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Attention is again called to the urgent need of financial support to enable the organization to resume publication. The United States is the only country sufficiently prosperous to furnish this support, and no bibliographic enterprise more worthy of assistance could be found than this great international cooperative undertaking which for so many years was the only complete bibliographic aid to students and investigators in all branches of science. More than ever before, commercial enterprises depend on scientific work, and as it is through the literature of science that all such work is announced and recorded, every effort should be made to have these records exact, complete, and available. It was this field that was covered by the International Catalogue.

NECROLOGY

GEORGE GRAY

Judge George Gray, member of the Board of Regents of the Institution for over 30 years and chairman of its executive committee for the past 10 years, died on August 7, 1925. Judge Gray was born at New Castle, Del., on May 4, 1840, and graduated from Princeton University in 1859. He studied law at Harvard and was admitted to the bar in 1863. After practicing for 16 years, he was appointed attorney general of Delaware in 1876. This office he held for six years, when he was elected United States Senator for the unexpired term (1885–1887) of Thomas F. Bayard, who had been appointed Secretary of State. Judge Gray was twice reelected to the Senate, and at the end of these two terms, he was made United States circuit judge, third judicial circuit, which office he held from 1899 to 1914. From this time until his death, Judge Gray was a member of a number of important peace commissions and international arbitration commissions. For several years preceding his death he had served as a trustee and vice president of the Carnegie Endowment for International Peace.

Through his long period of service on the Board of Regents and as chairman of the executive committee, Judge Gray had a real interest in the activities of the Institution and a thorough knowledge of its affairs, and his wise counsel will be greatly missed in the meetings of the board.

FRANCIS HENRY PARSONS

Francis Henry Parsons, assistant in charge of the Smithsonian Division of the Library of Congress for 25 years, died July 25, 1925. Although Mr. Parsons was an employee of the Library of Congress, his close association with the Smithsonian makes it fitting that his career be briefly reviewed here.

Born January 23, 1855, in Cleveland, Ohio, Mr. Parsons was the son of Charles Henry and Sarah Rice Parsons, both of New England ancestry. In September, 1862, he came with his parents to Washington, where the remainder of his life was spent. Due to delicate health, his education was acquired from private instruction, supplemented by extensive reading.

In January, 1872, he was appointed by Commander James H. Gillis, United States Navy, as his clerk, and sailed with him on the store ship *Supply* from New York to Rio de Janeiro: he was mustered out of the Navy August 8, 1872. From 1873 to 1894 he served with the United States Coast and Geodetic Survey; on one of its expeditions he discovered some rare Indian pottery, which is now in the United States National Museum. While connected with the survey he was selected to assume the duties of chief of library and archives, and reorganized that branch of the service. From 1894 to 1900 he was a computer in the United States Naval Observatory.

In April, 1900, Mr. Parsons was appointed assistant in charge of the Smithsonian Division of the Library of Congress, and it was here that his major life work was accomplished. The division had been established in the same year to care for the valuable collection of the publications of institutions and societies comprising the Smithsonian deposit (dating from 1866) and the Library of Congress accessions.

In the 25 years of his incumbency he saw the collection grow into a great library, perhaps unequalled anywhere for purposes of scientific research. Mr. Parsons brought to his task infinite care and patience, and a wide knowledge of learned societies and their methods of publication, and his colleagues in the Library of Congress learned to depend upon the fullness and accuracy of his records. His contribution to the care and upbuilding of the collection, which he carried on with the constant cooperation of the Smithsonian Institution, will be a lasting memorial.

Respectfully submitted.

Charles D. Walcott, *Secretary*.

APPENDIX I

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operations of the United States National Museum for the fiscal year ended June 30, 1926.

The total appropriations for the National Museum for the fiscal year amounted to $598,392, an increase of $13,600 over the previous year. The additional sums available include $7,600 for increases in salaries, of which $5,100 came through reallocations of positions by the Personnel Classification Board; $1,000 for increase in salaries of employees in the shops, and $1,500 for employment of special watchmen to allow the opening on Sunday of the Arts and Industries Building. The sum of $6,500 was added to the funds for printing and binding. The appropriation for the purchase of books for the Museum library was decreased by $500, leaving only $1,500 available, an amount insufficient for the purpose in view of the present output of scientific publications.

Though the increases noted have afforded a certain measure of relief, particularly in the important matter of publications, the funds available for administration above the total of the pay roll are inadequate for the needs of the Museum. The amounts now in hand for operation are barely sufficient for routine expenditure for needed supplies when handled with the greatest possible economy, leaving only small sums available for the purchase of specimens and little or nothing for explorations.

The collections of the National Museum grow steadily in size and importance through transfers from other governmental agencies, from collections or single specimens presented by outside agencies, or through participation by members of the staff in expeditions financed from outside sources. This support is fully appreciated but it should be supplemented by appropriations that will permit the development of the many opportunities that come to us to obtain new information and material through direct field investigation. Further, the Smithsonian Institution, through the National Museum, should be in a position to develop useful researches of its own in many lines. Augmented funds for the purchase of specimens are also necessary since many gaps exist in our series. Though occasionally a gap is filled by gift, there should be funds for making purchases when desirable specimens are offered at reasonable prices, as there can be no question but that every opportunity should be utilized to complete the collections of the Museum. Civilized man is occupying increasing areas of the surface of the earth, and with his occupation come such vast changes from the original condition that natural conformations are destroyed and hundreds and thousands of species of animals and plants must disappear. Only those remain that are sufficiently adaptable to fit into the modified scheme brought about by man's presence, and those at all sensitive to change or that require special conditions for their existence inevitably disappear. The next 50 years will offer the last opportunities to secure many forms of nature for preservation for the information and study of future generations, so that yearly it becomes more and more important, in fact a duty, to secure such material. Opportunities now neglected may never offer again. Certainly the National Museum of one of the greatest countries in the world should not fall behind in such matters.

Another matter deserving most serious consideration is that of the status of pay of the members of the staff. When the general reclassification act went into effect on July 1, 1924, it included provision for increase in pay at regular rates in the various grades. During the present year the third survey of the efficiency of the entire staff has been made with the result that it has been found that the majority have attained an efficiency rating sufficient to warrant promotion. The majority still stand at the entrance salaries in their respective grades. The financial assistance already accorded the staff has been greatly appreciated but it should be supplemented now, after a lapse of three years, as indicated. It is important that provision be made to make the promotions indicated to maintain the morale of the personnel. Such promotion is required especially in the many low salaried positions since these do not afford a proper living wage.

Modern developments in transportation, particularly the automobile, have brought to the National Museum a greatly increased attendance, one drawn from a broader area of our country than ever before. Parking spaces near the Museum are crowded daily, except during the colder months, with cars bearing license tags from every State in the Union. The educational function of the collections has thus been broadened and extended and personal contact has been established with a larger body of the public. Interest in matters that pertain properly to the sphere of a museum has also increased, with a resultant growth in number of inquiries by mail and in amount of material forwarded for identification or for information regarding it.

The radio program of the Smithsonian Institution organized two years ago has continued as a regular winter feature of the program of Station WRC, and has attained marked popularity as indicated by growing interest in the subject matter of the various talks. Thirty-two talks were given during the year from August 5, 1925, to May 29, 1926, through the medium of 30 speakers, 14 of whom were members of the Smithsonian staff, including 12 from the National Museum. Seven of these talks reached a broader audience than usual as they were broadcast also from station WBZ in Springfield, Mass. The subjects covered a wide range of topics from butterflies to earthquakes, and turtles to comets. The subject matter of a number has been given permanent preservation by means of publication in the pages of the Scientific Monthly through the interest of its editor, Prof. J. McKeen Cattell. As an educational factor for the spread of authentic scientific information the radio has a steadily increasing importance, and is a means for the diffusion of knowledge among men wholly in accord with the aim and ideals of the Smithsonian Institution.

COLLECTIONS

The growth in collections housed in the National Museum, while not so extraordinary as last year, has brought rich additions to our material. The total number of specimens received amounted to 254,032, while there came to hand in addition more than 1,000 lots of material for examination and report. These included approximately 28,000 individual specimens in the department of biology alone. Gifts to schools and other educational agencies included 3,857 objects, while 37,682 specimens were sent out to institutions or to private individuals in exchange for other materials. Loans of many thousands of specimens were made to specialists for study.

Following is a résumé of the more important accessions for the year in the various departments and divisions of the Museum:

Anthropology.—Among noteworthy accessions there may be mentioned an excellent series of ethnological and cult material acquired by the Rev. D. C. Graham in western China and eastern Tibet, during his explorations in that region for the Smithsonian Institution. The specimens obtained are especially valuable in completing collections previously at hand of the Miao aborigines, a native race whose culture will be lost as they are replaced by Chinese. Maj. Edward D. W. Dworak, formerly governor of the island of Mindanao, loaned a fine collection of Moro brass work for exhibition.

The Bureau of American Ethnology transferred a collection of 105 artifacts obtained in Young's Canyon, Ariz., by J. C. Clarke, a welcome addition to the collections in American archeology. An ancient maskette from Mexico, beautifully carved from hard stone, was presented by Dr. W. H. Holmes. Considerable additions to the collections of ancient stone implements from France, collected by members of the American School of Archæology in France, were deposited through the Archæological Society of Washington.

In the Division of Physical Anthropology, valuable human skeletal material of Australian aboriginals was obtained by exchange with the Adelaide Museum and through personal collection by Doctor Hrdlička. There came also miscellaneous Indian skeletons from Mississippi collected by H. B. Collins, jr., and a cast of a Neanderthaloid skull presented by the Instytut Nauk Anthropologicznych of Warsaw.

The fine collection of laces gathered by the late Mrs. H. K. Porter remained on exhibition in the section devoted to art textiles through the kindness of Miss Annie May Hegeman.

Biology.—Though the total of accessions in this department was smaller than last year, much of the material was of such high quality as to offset its lessened amount. The greatest single contribution was that of the Dognin collection of lepidoptera purchased by a special fund of $50,000 assembled from friends of the Institution by Dr. W. Schaus, honorary assistant curator of insects. This collection, mainly of New World forms, adds about 82,000 specimens, including 3,000 types, to the collection. The addition of this material gives the National Museum what is undoubtedly the best representation of American species in this group to be found in any museum in the world. Doctor Schaus, accompanied by Mr. J. T. Barnes as assistant, went personally to France to pack the collection for transfer to Washington.

The Hamfelt collection of microlepidoptera, secured through the United States Department of Agriculture, is another contribution of great importance to this group.

Collections obtained by Dr. W. L. Schmitt from South America form large and important additions to the division of marine invertebrates. Through the Bureau of Fisheries, further series of specimens taken on the *Albatross* expedition of 1911 to Lower California have been transferred to the National Museum. The material recently received includes birds, fishes, and crustaceans, with a number of type specimens.

Considerable contributions have come from China and southeastern Asia, excellently supplementing earlier collections from this general region received mainly through the generosity and interest of Dr. W. L. Abbott. A valuable collection of birds collected by C. Boden Kloss in Siam and on the Mentawi Islands west of Sumatra, presented by Doctor Abbott, adds material from a new field. Important collections of mammals, birds, reptiles, amphibians, crustaceans, and mollusks, have come from Dr. H. M. Smith, fisheries advisor to the Government of Siam, while Dr. H. C. Kellers, United States Navy, detailed by the Navy Department to accompany the United States Navy eclipse expedition of 1925 to Sumatra, has returned with valuable series of mammals, birds, reptiles, amphibians, fishes, marine invertebrates, and other material; from Rev. D. C. Graham in western China have come additional collections of mammals, birds, bird skeletons, reptiles, amphibians, fishes, mollusks, crustaceans, and insects, including particularly important series from the Wa and Omei Mountains in western Szechwan.

Mr. B. H. Swales, honorary assistant curator of birds, presented 45 skins to the bird collections, a donation of importance, since all represent genera or forms not previously represented in the Museum. Among birds of especial interest may be mentioned a peculiar roller from Madagascar, *Uratelornis chimaera*, a flamingo *Phoeniconaias minor*, the only form of the family lacking in the collection, a starling *Leucopsar rothschildi* from the island of Bali, the streaked breasted tinamou *Rhynchotus maculicollis* and a dipper *Cinclus schulzi* from Argentina, together with a rare finch *Idiopsar brachyurus*, long known only from the type specimen, which came to the National Museum in 1864. Mr. Swales' donations include also a specimen in alcohol of *Mesoenas variegatus*, a highly peculiar form, and seven skeletons of North and South American birds.

Dr. Casey A. Wood, collaborator in the division of birds, presented 20 bird skins from the Fiji Islands and 2 skins and 32 alcoholic specimens from Ceylon.

Geology.—The records in the department of geology show a decided increase in the number of accessions; and although the sum total of specimens received is less than last year, very choice and much-needed materials are included.

In the division of geology the bulk of material received was by transfer from the United States Geological Survey, of particular note being a valuable reference collection consisting of approximately 5,000 specimens of ores of the rarer metals. This collection, which was assembled by Mr. Frank L. Hess during many years of field work, comprises unquestionably the most complete series of such ores in existence. Many other suites of described material are included in these transfers. Additions to the meteorite collection were acquired chiefly through exchanges, with examples of 13 falls registered as new to the collection.

The late Col. W. A. Roebling, by his generous donation of money for the purchase of minerals, was the chief contributor to the mineral collections, 11 accessions, comprising choice exhibition and study specimens, being recorded in his name. Other important additions are nuggets of gold formerly in the numismatic collection of the United States Mint at Philadelphia; a collection of Bolivian tin minerals, in part presented and in part deposited by Mr. Jack Hyland; and a rare palladium amalgam from British Guiana presented by the government of that country through Sir John Harrison. Of outstanding importance for exhibition is a large group of fluorite crystals thought to be the most unusual yet brought to public attention in America. This was presented by the Benzon Fluorspar Co. of Cave-in-Rock, Ill. Rare minerals from foreign countries were acquired by exchange, and 37 cut stones were added to the Isaac Lea collection of gems through the Chamberlain fund.

Material of inestimable value to the study series in stratigraphic paleontology was added chiefly through field explorations by members of the staff. Invertebrate fossils from the Cambrian and Ozarkian rocks of British Columbia, from the Lower Paleozoic of Great Britain and the continent of Europe, from the Middle and Upper Paleozoic of the Central States, and from the Devonian of New York, all selected with the museum's special needs in mind, are among the collections thus secured. Gifts and transfers added important type specimens, as well as vast collections of Cenozoic fossils. Although purchases were necessarily few in number, a few excellent exhibition specimens were thus procured; exchanges added valuable foreign material.

Notable among the accessions of vertebrate fossils is a series of shale and sandstone slabs containing tracks of extinct animals, obtained from the Hermit and Yaki trails in Grand Canyon National Park by Mr. C. W. Gilmore in continuation of his work of last year. The present collection considerably exceeds in number of specimens the one obtained last year, and is of unique interest in containing faunas from three distinct levels, through a geological thickness of 950 feet, and from three distinct formations. Their great age, variety, and excellent preservation, as well as unusual occurrence, are features endowing these tracks with particular value in throwing light upon the character of the animal life of the Permian period. Fossil mammal material collected in Florida by Dr. J. W. Gidley is of unusual value as evidence for consideration in working out the problem of early man in that State.

Arts and industries.—The aggregate collections in this department indicate a fair increase over the previous fiscal year.

In the division of mineral and mechanical technology the most important accession has been the airplane *Chicago*, the flag plane during the round-the-world flight of 1924, which was transferred to the Museum by the War Department. The Collier trophy of the National Aeronautic Association, awarded annually for some outstanding development in aeronautics, which was presented this year to Dr. S. Albert Reed for his development of a high-speed metal propeller, has been placed on exhibition by Doctor Reed with the aeronautical exhibit.

An exhibit to illustrate the modern watch industry was installed by the Elgin National Watch Co.

In the textile collections 150 specimens of cotton fabrics of various types were presented by the Pacific Mills through Lawrence & Co. An interesting series of casement material of different weaves illustrating forms of curtains was presented by the Quaker Lace Co., and the North American Lace Co. presented a set of cotton and rayon laces made by machines in imitation of types of hand-made laces.

The Ford Motor Co. installed a model illustrating the process of production of methyl alcohol with specimens of the main products derived from the distillation of wood, including charcoal, briquets, tars, oils, acetate of lime, methanol and many others. Another model loaned by the same company illustrates part of a battery of by-product coke ovens.

The Karolith Corporation contributed 262 specimens of articles manufactured from casein according to a basic process developed by chemists at the Mellon Institute in Pittsburgh.

In the food exhibits there was installed a large model of a milk condensary, gift of the Borden Sales Co. (Inc.), designed to illustrate the production of milk and its manufacture into a condensed product. The Kroydon Co. presented a series of 10 specimens showing the manufacture of golf clubs from hickory and persimmon wood. The latter wood has been found especially suitable for the heads of clubs because of its unusual density and toughness.

In the division of graphic arts the most important accession for the year was a work by John Evelyn entitled "Sculptura," published in England in 1662, in which is given the first account of the art of mezzotint engraving. Mr. J. Frank Wilson supplied a series of etchings, wood engravings, lithographs, and paintings, many of them especially fine examples that had been on exhibition in the division many years ago, and that now come as a permanent accession. Another important accession of specimens of engravings, proofs, tools, and materials has come from Mrs. G. F. C. Smillie, whose husband was long chief portrait engraver at the Bureau of Engraving and Printing.

Through the cooperation of Mr. Will Hays, president of the Motion Picture Producers and Distributors of America (Inc.), there has been presented to the Museum a valuable set of machines and material to illustrate the growth of the motion-picture industry. The exhibits in this industry are assuming increased importance and it is planned to make them as complete as possible. There have also come to the exhibits in photography many additions in pictorial photographs from some of the foremost workers in the world in this field, including a bromide print entitled "Damp and Cold," by Floyd Vail, and prints by many others.

The Loeb collection of chemical types, established to preserve samples of the rarer chemical compounds, has been increased by 165 specimens. The collection is broadening its usefulness through contacts with a steadily increasing circle of chemists.

History.—During the year 17,256 specimens were added to the historical collections, a considerable increase over last year. Additions to the military and naval collections were of especial interest and value. Mrs. Beulah Hepburn Emmet presented a collection of 131 American and foreign military and naval swords dating back to 1750, forming the collection of Dr. Alfred J. Hopkins and known by his name. There are included many fine and ornate examples of the sword-makers art. In addition to swords of the Continental Army during the Revolution, there are many showing the development of the sword in the American Army through the nineteenth century to the close of the Civil War. The set of naval swords covers a like period of naval history. A large and interesting series of relics of Gen. Philip H. Sheridan was donated by Mrs. Philip H. Sheridan.

In the numismatic collections, 65 modern coins and tokens were received as a bequest from the late Col. Thomas L. Casey through Mrs. Laura Welsh Casey; 112 Chinese coins, many of them very old, were received from Rev. D. C. Graham; and 68 French coins, tokens, and paper currency of the period of the World War were presented by Capt. Charles Carey.

The philatelic collections received large additions from the Post Office Department including a set of 12,314 varieties of precanceled stamps from 1895 to the present date. Transfers from the Post Office Department to this collection have included all of the new stamps, both regular and commemorative issued by the 278 governments in the Universal Postal Union. Commemorative stamps of our own government have included three issues, the centenary of the arrival of Norwegians in Minnesota, the Sesquicentennial of the signing of the Declaration of Independence, and the erection of a memorial to John Ericsson, inventor and engineer, builder of the Monitor.

EXPLORATIONS AND FIELD WORK

The bulk of the accessions to the collections during the year came from expeditions and explorations organized under private auspices or by other governmental agencies.

In biology, important field work was carried on by Dr. Waldo L. Schmitt, curator of marine invertebrates under an award of the

Walter Rathbone Bacon Scholarship of the Smithsonian Institution. Doctor Schmitt collected from August, 1925, to February, 1926, at various stations on the coast of eastern South America from Brazil south to Buenos Aires, devoting his attention especially to the crustacean fauna, but collecting specimens in many other groups. The material secured is highly valuable and includes many species not previously in the National Museum, as well as many new to science.

Rev. David C. Graham continued his zoological explorations in Szechwan, western China, and though his travel in this region was hindered to some extent by civil warfare and the activities of brigands, he secured highly valuable collections in various branches of natural history. During the summer he visited Mount Omei and Washan where a number of new forms were procured and extensions made in the known ranges of others. The new material procured speaks well for Mr. Graham's skill as a collector, since the region had been visited by other naturalists who had collected there extensively.

During April and May, 1926, Dr. J. M. Aldrich visited Guatemala for the purpose of collecting important diptera needed in the study of the Museum collections. His work was financed from personal funds and by a small contribution from the Museum. He crossed from Puerto Barrios to Guatemala City, and at the request of the Guatemalan Government went also to Coban as advisory member of a party to study locust infestations and possible means for their control. His specimens have included many important additions to the collections. Mr. C. T. Greene, honorary assistant custodian of diptera, visited Panama from March to May in the interests of the Federal Horticultural Board mainly in connection with studies of the fruit flies of the genus *Anastropha*. Mr. Greene made extensive collections of diptera which have added extensively to the Museum series.

Through the cooperation of the Navy Department, Dr. H. C. Kellers, United States Navy, was detailed to the United States Naval Observatory Eclipse Expedition to Sumatra that he might, while serving as surgeon to the members of the party, have opportunity to collect zoological material. The expedition was established in the village of Kepahiang, inland from the seaport of Benkoelen, Sumatra. During the period from October to January, Doctor Kellers procured a rich collection of marine invertebrates, fresh-water crustacea, insects, fishes, reptiles, amphibians, birds, mammals, and plants. Considering the time available for the work the collections made are extensive and contain many interesting forms new to the Museum. They are marked by careful preparation. The cooperation of the Navy Department in this matter has been greatly appreciated.

Dr. Hugh M. Smith, honorary associate curator in zoology, at present fisheries adviser to the Siamese Government, through arrangement with the National Museum and with some outside assistance, has secured valuable collections from Siam that have added especially to the series of fishes, reptiles, amphibians, birds, and mammals. The material received is especially important since there has been little previously in the Museum from this region. Preliminary examination has shown several previously unknown species, some of which have been already described. The region is one of considerable importance since it connects the Malayan region with China, from both of which we have great series of specimens.

Prof. M. M. Metcalf, of Johns Hopkins University, presented to the Museum extensive series of batrachians collected during work on opalinid parasites in that group in South America.

The National Geographic Society has transferred to the National Museum specimens collected by Dr. Walter Koelz during the expedition of 1925 to Greenland under Capt. Donald B. MacMillan. Capt. R. A. Bartlett forwarded an interesting series of marine invertebrates collected during a visit to the coast of Labrador, and Mr. J. Morgan Clements sent collections of marine invertebrates and fishes secured during travels in Polynesia.

Mr. Paul C. Standley, associate curator of plants, through cooperation with Mr. Oakes Ames and the United Fruit Co., visited the Canal Zone and Costa Rica, making extensive collections of plants. A week was spent at the Barro Colorado Island Biological Station gathering data for a list of the plants of the island. In Costa Rica Mr. Standley visited the Canton de Dota, where are found the first paramos north of Colombia. A month in the mountains of Guanacaste and work in other upland sections as well as in the Atlantic lowlands gave important data to be utilized ultimately for a report on the flora of Central America.

Dr. W. L. Abbott, through his continued interest in the National Museum, financed an expedition by Mr. Emery C. Leonard, aid in the division of plants, to northern Haiti for a period extending from November to March. The 9,000 specimens procured will supplement material previously in hand for a report on the botany of the island.

Dr. Aleš Hrdlička, curator of physical anthropology, in the department of anthropology, under the joint auspices of the Buffalo Society of Natural Sciences and the Smithsonian Institution, made an extensive journey that included areas where remains of fossil or ancient man had been discovered in southern Asia, Australia, and Africa, and returned with series of photographs, specimens, and first-hand information of great value. Mr. H. W. Krieger carried on field work among the Indians of the State of Washington, and on the coast of southeastern Alaska, through a cooperative arrangement with the Bureau of American Ethnology. Mr. H. B. Collins, jr., under the same auspices, visited a number of Indian village sites in Mississippi and Louisiana to study ancient Choctaw, Attacapa, and Muskhogean cultures.

Investigations at Pueblo Bonito under the auspices of the National Geographic Society by Mr. Neil M. Judd, curator of American archeology, were continued for another season since it had not been practicable to complete the work in five years as originally contemplated. Mr. Judd left for the site of the excavations in May and will continue his work through the summer. Mr. Judd, as chairman of the Research Committee of the Archaeological Society of Washington, guided researches carried on by Dr. Manuel Gamio, for the society at pre-Columbian village sites in the highlands of Guatemala.

Under grants from the O. C. Marsh and Joseph Henry endowment funds of the National Academy of Sciences, Secretary Walcott, assisted by Mrs. Walcott, continued field work in the early geological strata of Canada during the season of 1925, beginning at Lake Louise Station in Alberta on July 9. Work this year included discovery of new fossil deposits in the great lower Paleozoic section north of Bow Valley, and in the lower Ordovician rocks of the Johnston-Wild Flower Canyon Pass section. Results from this work have been considerable though the season was unfavorable because of forest fires, whose smoke hindered photographic work, and frequent snow falls that interfered with field investigations.

Dr. Charles E. Resser and Dr. E. O. Ulrich were members of the Smithsonian-Princeton expedition to Europe during the summer of 1925 to study important outcrops of the lower Paleozoic beds. The route included more than 7,500 miles by automobile through England, Wales, Scotland, the Scandinavian countries, Germany, Czechoslovakia, Austria, Switzerland, and France. As a result of this work many important fossils were secured and arrangements were perfected for valuable exchanges.

During August and a part of September, 1925, Dr. R. S. Bassler, in cooperation with the Tennessee Geological Survey, continued his geological studies in the central basin and highland rim areas of Tennessee. His work this season covered stratigraphic surveys of approximately 250 square miles divided among four areas. Mr. E. R. Pohl was occupied for several weeks in 1925 in critical studies of the Devonian formations in the State of New York. This work was continued in May and June, 1926, in western New York and in Ontario with resultant information that enables a more correct idea to be formed as to the proper stratigraphic horizons for many series of fossils whose previous position had been unsatisfactorily known.

Under an allotment from the Marsh fund of the National Academy of Sciences, Mr. Charles W. Gilmore visited the Grand Canyon in Arizona and in cooperation with the National Park Service continued work on beds containing fossil footprints. As an outcome of this season's investigation there are now known three distinct series of these tracks that serve to indicate the animal life of the Permian world. The beds in which the tracks are found are especially notable for the graphic picture that they give, through their exposure in the canyon walls, of the enormous reach of time during which vertebrated animals have had their evolution.

Dr. James W. Gidley, under the auspices of the Bureau of American Ethnology, continued work in the vicinity of Melbourne, Fla., in investigating evidence as to early man in Florida and in study of the Pleistocene deposits in that region. In October, 1925, Doctor Gidley was detailed to examine a spring deposit in southwestern Oklahoma, where he secured a number of specimens of ethnological and geological importance.

BUILDINGS AND EQUIPMENT

Minor repairs to the various buildings housing the Museum have kept them in good condition during the year.

It was necessary to replace a space of worn-out concrete roadway, slightly more than 87 feet in length, leading from B Street to the east entrance to permit the entry of trucks with coal and other supplies. Other repair work on the Natural History Building consisted of the usual painting required on window frames, repairs to the concrete water table, and pointing of joints in the stone steps at the south entrance.

In the Arts and Industries Building the wooden floor on the south end of the gallery of the south hall was replaced by terrazzo, a great improvement that lessens fire risk. Much paint and repair work was required for the exterior of the building. In the Smithsonian Building the public portion of the disbursing office was remodeled to give greater security during the handling of funds on pay days.

Minor repairs were required in the Freer Gallery and the aircraft building.

In the heating plant the consumption of coal amounted to 3,465 tons, the excess over last year being due to the longer period of continuance of cold weather. Considerable repairs were made to the plant and more will be required annually since it has now been in operation for 17 years. The boilers were inspected by the Steamboat Inspection Service of the United States and found to be in good condition. The elevators have been regularly inspected by the building inspector of the District of Columbia and certain additional safeguards installed to protect passengers as fully as possible. The total electric current produced amounted to 493,295 kilowatt-hours, manufactured at a cost of 2.32 cents per kilowatt including labor, material, interest, and depreciation on the plant.

The ice plant produced 344.1 tons of ice at a cost of $3.51 per ton. The increased cost is due to a new compressor installed during the year and some other changes in the plant that will lead to increased efficiency and will reduce the expense of operation for succeeding periods.

In the shops there were made during the year 11 exhibition cases and 117 storage cases and other pieces of laboratory furniture. In addition, 40 pieces of storage, laboratory, and office furniture were acquired by purchase.

MEETINGS AND RECEPTIONS

The lecture rooms and auditorium of the National Museum were used for 110 meetings covering a wide range of activities.

Governmental agencies using the lecture and meeting rooms included the United States Tariff Commission for an exhibition of motion pictures depicting methods employed in shipping living birds, the Extension Service of the United States Department of Agriculture for an exhibition of motion pictures, and the Federal Horticultural Board for various hearings, particularly with regard to quarantine regulations for certain bulbs. Members of the Forest Service held a series of meetings during the year dealing with various phases of their work.

Scientific societies that met regularly in the meeting room included the Entomological Society of Washington, the Society for Philosophical Inquiry, the Anthropological Society of Washington, and the American Horticultural Society. Meetings were held also by the National Parks Association, the Federation of Music Clubs of the District of Columbia, the Vivarium Society, the Wild Flower Preservation Society, the Audubon Society of the District of Columbia, the Art and Archaeology League of Washington, the Washington Society of Engineers, the National Soy-bean Growers' Association, and by the Biological Society in cooperation with the Audubon Society.

The School of Foreign Service of Georgetown University conducted a series of 15 lectures on the American Constitution and ideals as compared with the Communist ideals manifested in Bolshevism. The second national spelling bee, organized by the Courier-Journal, of Louisville, Ky., held June 17, was won by Miss Pauline Bell, of Clarkson, Ky.

The second Industrial Conference of Women under the auspices of the United States Department of Labor, held from January 18 to 21, included at its initial session on January 18, the reading of a letter from President Coolidge and addresses by Hon. James J. Davis, Secretary of Labor; Mrs. John Jacob Rogers, Member of Congress from Massachusetts; and Mrs. Julius Kahn, Member of Congress from California.

An illustrated address on the collections in the National Gallery of Art was delivered by Dr. Gertrude R. Brigham on December 5. On January 25 under the auspices of the Twentieth Century Club there was an illustrated lecture on the National Gallery of Art by Mrs. Porter R. Chandler.

Educational and other organizations holding meetings in the building included the Associate Alumnae of Vassar College, the department of superintendents of the National Educational Association, the Smithsonian Relief Association, the National League of Girls Clubs, the Veterans of Foreign Wars of the United States, Federal Post No. 824, the Girl Scouts, the Nature Study Corps of the public schools of the District of Columbia, a class in bird study from George Washington University, and a class in parasitology from Howard University.

On October 21 Dr. Aleš Hrdlička gave to the staff an account of his studies of ancient man during his journey in southern Asia, Australia, and Africa. There were also several exhibits of pictures and talks for members of the staff, including one by Mr. Rollin R. Winslow, United States Consul at Surabaya, Java.

On November 5 there was a lecture by M. Georges Plasse on the making of aquatints in color, illustrated by motion pictures taken in the studio of the speaker in Paris.

On February 20, under the auspices of the Smithsonian Institution, M. Henri Correvon of Geneva, Switzerland, gave an address on Alpine plants and their use in rock gardens.

On June 4 Dr. Johannes Schmidt, Director of the Physiological Division, Carlsberg Laboratorium, Copenhagen, Denmark, delivered an illustrated address on Danish Oceanographic Expeditions—Eel Investigations, before a meeting held under the auspices of the Carnegie Institution of Washington, the Washington Academy of Sciences, the Biological Society of Washington, and the Smithsonian Institution.

EXHIBIT AT THE SESQUICENTENNIAL

Considerable time was devoted during the year by members of the Museum staff to the preparation of material to form part of the

Smithsonian exhibit at the Sesquicentennial Exposition in Philadelphia. The anthropological exhibits include miniature models of Indian village groups, life-size models of Indian potters, silversmiths, and weavers at work, and a series to illustrate the evolution of the lamp, cup, knife, fork, spoon, hammer, saw, drill, and ax. The chief exhibit in biology is a mounted group of the Bighorn, or Rocky Mountain sheep. Geology is represented by a series illustrating the weathering of rock to form soil, a collection of gems and precious stones found in America with the minerals in which they occur, and a number of interesting fossil forms including fossil fish, turtles, plants, and algae. The Museum's historical exhibit comprises a series of arms, insignia, uniforms, and medals, and models of Columbus' ships, of the *Mayflower*, and of the *Constitution*. Mechanical technology is represented by an extensive exhibit illustrating the development of the steam engine and of the steamboat. In graphic arts are shown examples illustrating the progress in photography from the days of the daguerreotype to the present, and other forms of graphic expression. The entire Smithsonian exhibit was prepared and installed in Philadelphia under the direction of Mr. W. de C. Ravenel, administrative assistant to the Secretary.

MISCELLANEOUS

Visitors to the buildings under the National Museum show a steady annual increase, in the present year registering a total of 1,106,305. The attendance in the several buildings was recorded as follows: Smithsonian, 110,975; Arts and Industries, 355,762; Natural History, 581,563; Aircraft, 58,005. The average daily attendance, including Sunday, was approximately 2,500. The exhibition halls were closed on Christmas Day and New Year's.

The Museum published 8 volumes and 49 separate papers during the year, while its distribution of literature amounted to 96,804 copies of its books and pamphlets.

Additions to the Museum library have included 1,660 volumes and 1,466 pamphlets, obtained mainly by exchange or donation. In the considerable progress made in library matters during the year, mention may be made of binding and of the checking of sets of periodicals and of the attempt to fill existing gaps in these series.

Dr. Casey A. Wood, well known as an ornithologist, was given honorary appointment as collaborator in the division of birds on January 9, 1926. Doctor Wood has shown deep interest in the collections of that division for a number of years.

Dr. H. H. Bartlett, director of the botanical garden of the University of Michigan, who will collect specimens in Formosa and Sumatra on behalf of the National Museum and the University of

Michigan, was appointed collaborator in the division of plants for two years beginning March 17, 1926. Dr. William H. Longley, of Goucher College, who is working in cooperation with the Museum, was made collaborator in the division of marine invertebrates on March 20, 1926. The honorary appointment of Dr. George Grant MacCurdy as collaborator in the department of anthropology was extended for one year beginning February 14, 1926.

Earl D. Reid was promoted from clerk to aid in the division of fishes on August 1, 1926. Miss Isabel L. Towner was appointed assistant librarian of the Museum in January, 1926, succeeding the late Mr. N. P. Scudder, in charge of the Museum library. Miss Hortense Hoad, aid in the division of history, resigned on January 31, 1926. Mr. Paul G. Van Natta left the service by resignation on May 6, 1926. It may be noted that turnover in the watch force has become so great that in the last year the 61 positions of guard were held by 80 persons.

Dr. Brayton H. Ransom, assistant custodian of the helminthological collections of the Museum since January 5, 1905, died September 17, 1925, after a brief illness. Other deaths among members of the Museum force were those of Mr. J. H. Williams, laborer, on September 4, 1925; Mr. Henry Gibson, laborer, November 21; Mr. Sylvester W. Baldwin, laborer, December 24; Mr. John E. Johnson, watchman, March 26, 1926; and Mr. Marston R. Carey, mail carrier, April 1.

Respectfully submitted.

Alexander Wetmore,
Assistant Secretary.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

Sir: I have the honor to submit the following report on the affairs of the National Gallery of Art for the year ending June 30, 1926.

In the annual report of the director of the gallery for the fiscal year 1924–25 a list of the personnel of the staff was given, and the nature of their activities was briefly indicated. No noteworthy changes have been made during the present year. Reference was made to a decided falling-off in the acquirement of art works in recent years, a result attributed to the lack of available space for the accommodation of additions save of the most limited kind. The dire need of a gallery building was there explained, and the sketch plans for such a building, prepared under the direction of the Regents of the Institution, by Mr. Charles A. Platt, architect of the Freer Gallery, were discussed in some detail. The estimated cost of the structure, which when completed, would be worthy of a people who aspire to bring together in Washington a representative collection of the art treasures of the world, is $8,000,000, although there appears no reason why this large expenditure, if approved by Congress, should not extend over a number of years. Such a building would not only make additions by gift and bequest possible, but would permit the assemblage, in association with the paintings and sculptures, of the collections of graphic arts, ceramics, textiles, etc., now installed for lack of gallery space, in several separate branches of the Museum. It would accommodate the National Portrait Gallery and the extensive collections of American history which now occupy nearly 80,000 feet of floor space belonging to and much needed by the natural sciences.

THE GALLERY COMMISSION

The fifth annual meeting of the National Gallery Commission was held in the Regents' room of the Smithsonian Institution, December 8, 1925. The members present were: Gari Melchers, chairman; W. H. Holmes, secretary; Herbert Adams, Joseph H. Gest, John E. Lodge, Charles L. Moore, James E. Parmelee, Edward W. Redfield, Edmund C. Tarbell, and C. D. Walcott. The varied activities of the gallery were considered, and attention was given to the accessions for the year, to the Ranger fund purchases and their disposition, to the problems of the proposed national portrait gallery, and to the procedure to be adopted in considering acceptance of gifts and bequests of art works. After discussion of the latter topic the following resolution was adopted:

Resolved, That the advisory committee of the National Gallery of Art Commission shall consist of the full membership of the commission; that in carrying out the functions of the advisory committee a quorum shall consist of seven members, four of whom shall be artists or museum directors.

The commission considered at some length the agencies now enlisted in the promotion of the prospective gallery building, without developing any plan of procedure. The activities of the American Federation of Arts and the Federation of Women's Clubs in appealing to the American people for support of the gallery building project were brought to the attention of the commission and encouragement was found in the assurance that appreciation of art is growing rapidly in all sections of the country.

The expiration of the terms as members of the commission of W. K. Bixby, W. H. Holmes, and Herbert L. Pratt was announced. The secretary was directed to cast the ballot of the commission recommending to the Board of Regents the reappointment of these members for the ensuing term of four years. It was stated that Mr. A. Kingsley Porter, elected to the commission in 1921, had thus far not attended any meeting of the commission and that, in accordance with section 3 of Article V of the plan of organization of the commission, his membership automatically terminated, December 8, 1925. To fill the vacancy thus created, the commission passed a resolution recommending to the Board of Regents, the appointment of Mr. John Russell Pope, architect. The appointment was declined by Mr. Pope in a letter dated January 5, 1926.

The Regents' plan provides for the election of officers and members of committees at the annual meeting, and the secretary of the commission was directed to cast the ballot of the commission for the reelection of the present incumbents.

At 12 o'clock the commission adjourned and at 2 o'clock met in the National Gallery as the advisory committee to consider the offerings of art works for the year. The Libyan Sibyl, a statue in Carrara marble, heroic in size, by William Wetmore Story, and a marine painting, The Sea, by Edward Moran, were accepted by the committee as additions to the National Gallery collections.

CATALOGUE

Early in the year a second and enlarged edition of the catalogue of the gallery collections was submitted to the Public Printer. Page proofs were read in November and the volume appeared in May.

It contains 118 pages and 104 plates. The permanent accessions number 93 and the artists represented 228.

MRS. HENDERSON'S OFFER

Decided impetus has been given recently to the gallery's building project by the very generous offer to Congress by Mrs. John B. Henderson of a valuable tract of land containing between 4 and 5 acres, on Meridian Hill, facing Sixteenth Street, as a gallery building site.

ACTIVITIES OF THE AMERICAN FEDERATION OF ARTS AND THE FEDERATION OF WOMEN'S CLUBS

The American Federation of Arts and the Federation of Women's Clubs continued their work on behalf of the gallery, furthering its interests with propaganda and lectures, with the use of lantern slides and photographic prints.

SPECIAL EXHIBITIONS HELD IN THE GALLERY

Loan exhibition of early American portraits, miniatures, and silver.—The loan exhibition season was opened by a noteworthy display of early American art treasures comprising portrait paintings, miniatures, and silver, on view from December 5, 1925, to January 31, 1926. The exhibition, which was drawn from all available sources, was conceived and assembled by the Washington loan exhibition committee, the members of which are as follows:

Mrs. William C. Eustis, chairman.
Mr. Frederick H. Brooke, vice chairman.
Mrs. Porter R. Chandler, secretary.
Mr. James Parmelee, treasurer.
Mrs. William Penn Cresson.
Mr. Frederic A. Delano.
Mrs. Peter Goelet Gerry.
Dr. William H. Holmes.
Mrs. McCook Knox.
Miss Leila Mechlin.
Mr. C. Powell Minnigerode.
Mr. Duncan Phillips.
Mrs. Duncan Phillips.
Mrs. Corcoran Thom.

The very excellent illustrated catalogue of the exhibit was prepared by Miss Leila Mechlin and is introduced by a short historical sketch of the National Gallery.

The portrait exhibit, representing nearly every portrait painter of distinction previous to the year 1840, was organized and assembled at the cost of much exacting effort on the part of the subcommittee on portraits, the membership of which follows:

Miss Leila Mechlin, chairman.
Mrs. Porter R. Chandler, vice chairman.
Mrs. William Penn Cresson.
Mrs. W. M. Grinnell.
Mrs. McCook Knox.
Miss Sarah R. Lee.
Mr. Lynch Luquer.
Mrs. David A. Reed.

The portraits, 103 in number, were shown to excellent advantage, occupying the walls of the central rooms of the gallery, and surrounding the exhibits of silver and miniatures, which occupied the floor spaces. A four-page résumé of the portrait art of America is given, with brief mention of the masters, and much valuable biographical data regarding the painters is given in the catalogue.

The collection of miniatures was of surpassing interest and was in charge of the subcommittee on miniatures, the membership of which is as follows:

Miss Helen Amory Ernst, chairman.
Miss Elizabeth Allen White.
Mrs. John Hill Morgan.
Mrs. Minnigerode Andrews.
Mrs. Rose Gouverneur Hoes.
Mrs. Henry Leonard.
Mrs. Orme Wilson, jr.
Mrs. William Cabell Bruce.
Miss Lilian Giffen.
Mrs. J. Madison Taylor.
Mrs. William F. Wharton.

The installation, a most exacting task, was made by Miss Ernst, and was unusually attractive and of very wide interest. The catalogue of 208 numbers was introduced by a few interesting paragraphs on early American miniatures, by Mr. Albert Rosenthal.

The collection of silver was shown to excellent advantage in six large gem cases in the central room of the gallery. Maj. Gist Blair, chairman of the subcommittee, being unable to take part in the installation, the work was taken up by Mrs. John Henry Gibbons, aided by other members of the committee, which was constituted as follows:

Maj. Gist Blair, chairman.
Mrs. John Henry Gibbons.
Mrs. Breckinridge Long.
Mr. Hollis French.
Mrs. Miles White, jr.
Mr. Luke Vincent Lockwood.
Mr. R. T. H. Halsey.

The collection, numbering 255 examples of the art of early American silversmiths, was generally regarded as one of the most interesting and valuable ever brought together. The catalogue was introduced by a four-page story of the development of the art by Miss Elizabeth B. Benton.

The Dykaar exhibition.—An exhibition of portrait busts in marble and bronze, with certain other pieces, by Moses Wainer Dykaar was installed in the middle room of the gallery March 5 to March 20. The exhibit made a very favorable impression and included the following subjects.

Calvin Coolidge.
Mrs. Calvin Coolidge.
Warren Gamaliel Harding.
Dr. Alexander Graham Bell.
Abraham Cahan.
Eugene V. Debs.
Samuel Gompers.
Hudson Maxim.
Gen. George Owen Squier.
Justice Wendell P. Stafford.
Carolyn Harding Votaw
Dr. Charles D. Walcott
Rabbi Stephen S. Wise
A Young Teacher.
The Modern Woman.
Nude Girl: Primavera
Once Upon a Time.
Satyric Mask.
An American Student.
W. H. Holmes.

A bust in marble of Abraham Cahan, well-known author and editor, and one of W. H. Holmes, director of the gallery, were presented to the Smithsonian Institution by the sculptor.

The Italian exhibit of paintings, sculpture, etc.—The third exhibit of the season was an important assemblage of modern Italian art, collected and exhibited under the patronage of His Majesty the King of Italy. It was assembled on the invitation of the Italy-America Society of New York City by the Italian Minister of Public Instruction, the works being chosen largely under the personal supervision of Arduino Colasanti, director general of fine arts, Italy. The collection, installed under the competent direction of Dr. Lauro de Bosis, occupied the entire central series of rooms and connecting spaces in the gallery, with a running wall space of 430 feet. This display attracted more than ordinary attention. The excellent catalogue was prepared by the Italy-America Society and comprises 24 pages of text and 34 plates representing selections from the 290 items of the exhibit. The exhibit was opened to the public on the afternoon of March 25, with a reception given by the Secretary and Regents of the Smithsonian Institution, and was closed on April 24, 1926. An especially noteworthy feature of the catalogue is the four-page "Foreword" by Christian Brinton. His admirable characterization of the exhibit follows:

The aim of the present exhibition is to offer a balanced and comprehensive picture of current Italian artistic activity. The picture opens with the work of the great protagonists, Boldini, Mancini, and Medardo Rosso, and closes with a courageous presentation of Futurist painting and decorative art. Every movement of consequence finds place on these walls, with special emphasis upon the work of certain painters and sculptors who have risen to prominence as the result of postwar influences. You will hence be able to adjudge the merits of what may be termed the living art of Italy. You will be able to trace in line, color, and form the artistic physiognomy of a country recently fired to new effort yet ever mindful of its heroic heritage.

Very appropriately the frontispiece of the catalogue is a three-quarter photographic portrait of Vittorio Emanuele, King of Italy.

THE HENRY WARD RANGER FUND

Since the paintings purchased during the year by the council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest are, under certain conditions, prospective additions to the gallery collections, the list, including the names of the institutions to which they have been assigned, may be given in this place.

Since it is a provision of the Ranger bequest that paintings purchased from the fund and assigned to favored American art institutions may be reclaimed by the National Gallery during the 5-year period beginning 10 years after the death of the artist represented, it is appropriate that the death of Ben Foster, N. A., which occurred on January 28, 1926, should be noted.

Title	Artist	Date of purchase	Assignment
52. The Enchanted Pool	William Ritschel, N. A.	Mar. 28, 1926	The Minneapolis Society of Fine Arts, Minneapolis, Minn.
53. From a Window	Carl W. Peters	do	Witte Memorial Museum, San Antonio, Tex.
54. Spring	H. Bolton Jones, N. A.	do	Mills College, Oakland, Calif.
55. Passing By	E. Martin Hennings	do	Museum of Fine Arts of Houston, Tex.
56 Southaven Mill	W. Granville-Smith, N. A.	do	Toledo Museum of Art, Toledo, Ohio.
57. Circe and Anatol	Robert Reid, N. A.	do	The Akron Institute, Akron, Ohio.
58. Cliffs of the Upper Colorado River, Wyoming Territory.	Thomas Moran, N. A.		Louisville Free Public Library, Louisville, Ky.
59. Days of Sunshine	William Wendt, A. N. A.		Malden Public Library, Malden, Mass.

The paintings purchased from the Ranger fund during the past fiscal year and unassigned at its close (1924–25) have subsequently been assigned as follows:

45. The Wood-Cart, by Louis Paul Dessar, N. A.; to the museum of the school of fine arts of Yale University, New Haven, Conn.
46. A Reading, by Thomas W. Dewing, N. A.; to the Cincinnati Museum Association, Cincinnati, Ohio.

47. Dawn, by Dwight W. Tryon, N. A.; to the Carnegie Institution, Pittsburgh, Pa.
48. The Prodigal Son, by Horatio N. Walker, N. A.; to the Buffalo Fine Arts Academy, Albright Art Gallery, Buffalo, N. Y.
49. Storm Birds, by Armin Hansen; to the Norfolk Society of Arts, Norfolk, Va.
50. Helen, by Jerry Farnsworth; to the Isaac Delgado Museum of Art, New Orleans, La.
51. Across the Valley, by Hobart Nichols, N. A.; the Des Moines Association of Fine Arts, Des Moines, Iowa.

ART WORKS ADDED DURING THE YEAR

Accessions of art works by the Smithsonian Institution, subject to transfer to the National Gallery on approval of the advisory committee of the Gallery Commission, are as follows:

Ten paintings, to be known as the George Buchanan Coale collection, 1819-1887:

Portrait of Thomas Hopkinson (1709-1751), attributed to Robert Feke.

Portrait of Mary Hopkinson (wife of Dr. John Morgan), by Benjamin West, 1764.

Portrait of Thomas McKean, Signer from Delaware, by Charles Willson Peale.

Portrait of Abigail Willing Coale (Philadelphia, 1809), by Thomas Sully.

Portrait of Jan Uytenbogaert, by Jan Van Nes (or Nees (1635)).

Self Portrait, by Thomas Vivien (1657-1735).

The Vintage, by A. R. Veron (1858).

The Continentals, by Frank B. Mayer (1875).

Sheep, by Balthasar Pauwel Ommeganck, Antwerp (1755-1826).

Flora, attributed to Beechy or Verbruggen.

Presented by Mrs. Mary Buchanan Redwood (Mrs. Francis T. Redwood), of Baltimore, Md.

Portrait of Rear Admiral Robley D. Evans, United States Navy, by August Franzen, N. A.; presented by Horatio S. Rubens, New York City.

Two portrait busts in marble by Moses W. Dykaar: Abraham Cahan, author and editor; and William H. Holmes, scientist and art director; presented by the sculptor.

Three paintings by Edward Moran (1829-1901): Riding Out a Gale, The Sea, and Life Saving Patrol; bequeathed to the United States National Museum by the late Mrs. Clara L. Tuckerman. Deposit.

LOANS ACCEPTED BY THE GALLERY

Noon, an oil painting, by Luigi Chialivi; lent by Mrs. Marietta Minnigerode Andrews, of Washington, D. C. Withdrawn before the close of the year.

Portraits of Dr. William Shippen, jr., and of Thomas Lee Shippen, by Gilbert Stuart; lent by Dr. L. P. Shippen, of Washington, D. C.

Six pieces of sculpture, by Moses Wainer Dykaar; lent by the sculptor. They are as follows:

Calvin Coolidge, President of the United States.
Mrs. Calvin Coolidge.
Dr. Alexander Graham Bell.
Justice W. P. Stafford.
Dr. Charles D. Walcott.
"The Modern Woman."

Portrait of Mrs. Sherman Flint, by Philip A. de Laszlo; lent by Mrs. Sherman Flint, of Washington, D. C.

Sixteen examples of the works of old masters:

Portrait of a boy, Sir Henry Raeburn.
Portrait of Irish gentleman, John Hopner.
Portrait of Viscountess Hatton, Sir Peter Lely.
Portrait of a gentleman, Sir Godfrey Kneller.
Portrait of Judith von Volbergen, P. Moreelse.
Landscape (31 by 26), Richard Wilson.
Landscape (21 by 16), Gainsborough.
Small landscape (11 by 13) Gainsborough.
Landscape (12 by 21), Constable.
The Doctor's Visit, Jan Steen.
Scene in Venice (8 by 13), Guardi.
Portrait of Sir Wm. Boothby, Sir Joshua Reynolds.
Portrait of Mrs. Price, Sir Joshua Reynolds.
Portrait of woman, Drost or Vermeer.
Turkish scene, Diaz.
Grand Canal Venice, Canaletto.

Lent by Mrs. Marshall Langhorne, of Washington, D. C.

Five paintings by Old World masters and four by American painters:

Portrait of Admiral Vernon, Thomas Gainsborough.
The Ford, J. B. C. Corot.
Garden at Giverny, Claude Monet.
Saskia as "Minerva," Rembrandt Van Rijn.
Children on the Beach, T. Sorolla.
Sunset, George Inness.
Olive Trees at Corfu, John Singer Sargent.
Portrait of Mrs. Samuel Miller, John Wesley Jarvis.
Portrait of Sarah Cresson, Thomas Sully.

Lent by Mrs. Breckinridge Long, of Washington, D. C.

Portrait bust in marble of Mrs. William C. Preston, by Hiram Powers; lent by Mr. James Quentin Davis, of Durham, N. C., through Mrs. Anne Davis Thorn (Mrs. J. C. Thorn), of New York City.

Portrait of Mrs. Charles Eames, by Gambadella; lent by Mrs. Alistair Gordon-Cumming.

Six oil paintings and a bas-relief in bronze lent by Miss Sarah Redwood Lee, of Washington, D. C., as follows:

Madonna and Child, Francesco Bissolo.

Portrait of Mrs. Richard Eaton, Charles Willson Peale.

Spanish Interior, Juan Galves, 1598.

Holy Family, attributed to Francesco Francia.

Portrait, Man in a Red Coat, attributed to Thomas Hudson, master of Sir Joshua Reynolds.

Portrait, Man Holding a Lily, artist unknown.

Portrait, Sarah Redwood Lee (bronze bas-relief), Augustus Saint-Gaudens.

Portrait bust in plaster of the Hon. Frederick H. Gillett, Speaker of the House of Representatives, by Joseph Anthony Atchison; lent by the sculptor.

LOANS BY THE GALLERY

Two paintings, The Georgian Chair, by Childe Hassam, and Musa Regina, by Henry Oliver Walker, were lent to the American Federation of Arts, to be sent out with paintings from other sources on an educational circuit under the auspices of the federation.

Twelve paintings, mostly from the William T. Evans collection, were lent to the American Federation of Arts for exhibition in Chattanooga, Tenn., February 15, 1926:

June (the Rose), John W. Alexander.

At Nature's Mirror, Ralph Albert Blakelock.

Birch Clad Hills, Ben Foster.

Portrait of Walter Shirlaw, Frank Duveneck.

An Interlude, Wm. Sergeant Kendall.

Moonrise at Ogunquit, Hobart Nichols.

Landscape, Chauncey Ryder.

November, Dwight W. Tryon.

The Cup of Death, Elihu Vedder.

Autumn at Arkville, Alexander Wyant.

Conway Hills, F. Ballard Williams.

The Island, Edward W. Redfield.

Five paintings (by members of the National Academy of Design) were lent to the academy for its centennial exhibition held at the Corcoran Gallery of Art, Washington, D. C., October 17 to November 15, 1925, and at the Grand Central Art Galleries, New York City, December 1, 1925, to January 3, 1926. These were:

The Lesson, Hugo Ballin.

Sunset, San Giorgio, W. Gedney Bunce.

The Siren, Louis Loeb.

Illusions, Henry B. Fuller.

The Monarch of the Farm, Wm. Henry Howe.

Three paintings, portraits of Field Marshal Haig and Marshal Joffre, by John C. Johansen, and portrait of Her Majesty Elizabeth, Queen of the Belgians, by M. Jean McLane (Mrs. J. C. Johansen), from the National Art Committee's collection of war portraits, were lent to the Corcoran Gallery of Art to form part of a joint exhibition of the works of these artists held in that gallery during the month of January.

DISTRIBUTIONS

Paintings lent to the gallery have been withdrawn by their owners during the year as follows:

Portrait of François Paul de Grasse de Rouville, Amiral Comte de Grasse, by Largilliere; portrait of Theodosius O. Fowler, by G. P. A. Healy; portrait of St. Bernard dog "Hero," by Benjamin West; withdrawn by Miss Silvie de Grasse Fowler.

Series of 13 historical marine paintings by Edward Moran, lent by Theodore Sutro, of New York City, were withdrawn by the trustees of Mr. Sutro, Frederick C. Sutro, Basking Ridge, N. J., Victor Sutro, New York City, and Paul E. Sutro, Philadelphia, Pa., for shipment to Los Angeles, Calif., as follows: The Ocean—The Highway of All Nations; Landing of Lief Ericson; the *Santa Maria, Nina*, and *Pinta;* the Debarkation of Columbus; Midnight Mass on the Mississippi; Henry Hudson Entering New York Bay; Embarkation of the Pilgrims from Southampton; First Recognition of the American Flag; Burning of the Frigate *Philadelphia;* the Brig *Armstrong* Engaging the British Fleet; Iron versus Wood; the White Squadron's Farewell Salute to the Body of Capt. John Ericsson; Return of the Conquerors.

Noon, by Luigi Chialiva; withdrawn by Mrs. Marietta Minnigerode Andrews.

Mrs. Siddons in The Tragic Muse, copy by Rembrandt Peale of Sir Joshua Reynolds's celebrated painting, and Milton Dictating to His Daughter, by Rembrandt Peale; withdrawn by Mrs. John Biddle Porter.

Portrait of Franklin Pierce, by A. G. Powers; withdrawn by Mr Joseph Stewart.

Portrait of Admiral Thomas Holding Stevens, by Robert Hinckley; portrait of Mrs. Thomas Holding Stevens, by an unknown artist; portrait of Hon. Eben Sage, by Chester Harding; A Madonna, by Honario Marinari; and A Madonna, by Carlo Mahratta; withdrawn by Mrs. Pierre C. Stevens.

LIBRARY

The gallery library is steadily growing from a modest beginning in 1920 to upwards of 1,400 volumes and pamphlets, acquired by gift, exchange, and purchase. Notable accessions for the year were the gift of a large number of volumes from the library of the director, and of 11 bound and 29 unbound catalogues of notable art collections, by Dr. William Schaus.

PUBLICATIONS

Holmes, W. H. Catalogue of Collections, II, National Gallery of Art. Government Printing Office, 1926. 8vo, pp. i–vi, 1–118, 42 plates and 3 ground plans.

This is the second number of the catalogue series of the gallery which is to be issued from time to time as conditions warrant. It follows in general the form of Catalogue of Collections I, N. G. A., 1922, with additions of works received to date of printing. It contains an introduction by the director, giving a brief account of the development of the art interests of the Institution and an outline of the organization of the gallery. This is followed by a list of the art works acquired previous to November, 1925, with brief biographies of the artists.

——— Report on the National Gallery of Art for the year ending June 30, 1925. Appendix 2, Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1925, pp. 48–56.

Catalogue of an exhibition of early American paintings, miniatures, and silver, assembled by the Washington Loan Exhibition Committee, December 5, 1925–January 31, 1926, National Gallery of Art, Washington, D. C. Washington, 1925, pp. 1–107, plates 15, with introductions on early American portraits by Miss Leila Mechlin, Washington; early American miniatures by Mr. Albert Rosenthal, Philadelphia; and early American silver by Miss Elizabeth B. Benton, Boston.

Catalogue of a collection of busts of prominent personages in marble and bronze by Moses W. Dykaar, exhibited in the central room of the National Gallery, Natural History Building, United States National Museum, March 5 to 20, 1926. Washington, D. C., 1926, pp. 1–4.

Catalogue: Exhibition of modern Italian art under the patronage of His Majesty the King of Italy, organized by the Italian Ministry of Public Instruction. Introduction by Arduino Colasanti, director general of fine arts, Italy; foreword by Christian Brinton. Auspices of the Italy-America Society, Grand Central Art Galleries, New York, 1926. New York, 1926, 24 pp.; 34 illustrations.

Respectfully submitted.

W. H. Holmes, *Director.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE FREER GALLERY OF ART

Sir: I have the honor to submit the sixth annual report on the Freer Gallery of Art for the year ending June 30, 1926:

THE COLLECTION

The work continued during the year in the preservation of the collection includes the work upon 10 American oil paintings and the work of reconditioning the ceiling of the Peacock Room. Half of the latter work has been successfully completed at the date of this report. In the oriental section 2 Chinese panels, 3 Japanese screens, and 1 Chinese scroll have been remounted and restored.

Work within the collection has included the study of a considerable number of Japanese paintings, involving their proper classification and the translations of signatures, seals, and inscriptions found upon them. All this matter has been recorded in the folder sheets. Every object in the collection is represented by such a dossier, and the work of compilation goes forward from year to year. The collection of Near Eastern pottery has also undergone an intensive study and considerable revision.

Changes in exhibition during the year involved 9 Japanese screens, 7 Chinese panels, 2 Chinese scrolls, and 10 Persian potteries.

An addition to the collection of Chinese paintings is as follows:

26.1. Illustration to a Buddhist *sūtra:* The Buddha addressing Yamarāja at Kuśinagara. Ink, color and gold on paper. Sung Dynasty.

Additions to the library by gift and purchase include 500 volumes, of which 462 are in the Chinese and Japanese languages, 72 periodicals, and 142 pamphlets. A list of these accompanies this report as Appendix A (not printed).

The work of photographing objects for registration continues. In the meantime an increasing demand for photographs of objects in the collection has caused a rapid development of that part of the work. Five hundred and eighteen subjects are now available for purchase in sizes 5 by 7, 8 by 10, or 11 by 14, at cost price; 5 subjects are issued in post-card form to be sold at 10 cents each. During the past year 1,467 photographs, 28 lantern slides, and 115 post cards have been sold. Of the publications issued by the gallery, there have been sold during the year 698 copies of the descriptive pamphlet, 391 copies of gallery books, 449 copies of the Synopsis of History, and 3 floor plans of the building.

During the past year 76 objects have been submitted for examination and identification, and several Chinese and Japanese texts have been submitted for translation.

Repairs to the building during the year include work on the roof, the repointing of stonework at the entrance, the resetting of a stone architrave, and many minor repairs. A full report of shopwork accompanies this report as Appendix C (not printed).

ATTENDANCE

The gallery has been open every day, with the exception of Mondays, Christmas Day, and New Year's Day, from 9 until 4.30. The total attendance for the year was 108,310. The aggregate Sunday attendance was 30,372, making an average of 584; the week-day attendance amounted to 77,938, with an average of 249. Of these visitors, 342 came to the study rooms to see objects not on exhibition or to consult books in the library, 15 to make copies or photographs, 52 to examine the building or equipment, 32 to submit objects for information concerning them, 33 for general information, and 261 to examine photographs. Six groups varying in number from 20 to 148 made appointments for special study or instruction regarding the collections.

PERSONNEL

Miss Katharine N. Rhoades, associate, was granted leave of absence for a year, dating from October, 1925.

Mr. Herbert E. Thompson, Boston, worked on the preservation of oil paintings and the Peacock Room.

Mr. Y. Kinoshita of the Museum of Fine Arts, Boston, worked at the gallery during the winter months on the preservation of oriental paintings.

Mr. A. G. Wenley, field assistant, returned to the gallery in the spring of 1926 for a four months' stay before resuming field work.

FIELD WORK

Owing to disturbed conditions in China, archeological work in the field has been practically impossible. A detailed account of the activities of the field staff is contained in Appendix B submitted herewith (not printed).

Respectfully submitted.

J. E. LODGE, *Curator.*

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the researches, office work, and other activities of the Bureau of American Ethnology during the fiscal year ended June 30, 1926, conducted in accordance with the act of Congress approved April 22, 1925. The act referred to contains the following item:

American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains, under the direction of the Smithsonian Institution, including the necessary employees and the purchase of necessary books and periodicals, $57,160.

In pursuance of the requirements for the excavation and preservation of ruins contained in the above item, considerable work has been done in the region near Flagstaff, Ariz. Arizona shows many evidences of a prehistoric aboriginal population and is a State particularly favorable to the study of prehistoric ruins. Thus far very few ruins have been excavated in northern Arizona and very scanty material has been obtained for a study of the objects illustrating the former culture of this region.

Research in this line was inaugurated by the bureau in 1907 at Casa Grande and has been continued in successive years at the Mesa Verde National Park, Colo. Formerly walls of ruins were destroyed in the search for small specimens, such as pottery, and thus work of great archeological value was lost. The method adopted by some institutions of burying the walls after objects have been extracted from the rooms, while intended as a means of preservation, is not satisfactory. The Bureau of American Ethnology, however, when the walls are not so mutilated that they can not be repaired, has endeavored to preserve them for future students.

SYSTEMATIC RESEARCHES

The chief of the bureau has headed an expedition to determine the western extension of the pueblo area in Arizona, where comparatively little attention had been given to the character of the sedentary life of the Indians in prehistoric times. This includes the region west of the Little Colorado River which is archeologically a terra incognita. The site chosen by the chief to be excavated is situated about 6 miles from Flagstaff on the National Old Trails Highway. The work was begun on May 27 and was unfinished at the close of the fiscal year.

As a result of this excavation there has emerged from the ground near Elden Mountain a rectangular building measuring 145 by 125 feet, containing nearly 40 rooms and a large kiva, from a study of which a good idea can be obtained of the aboriginal architecture of this neighborhood. The building was a compact community house in places two stories high, whose upper walls, judging from the amount of stones found in the rooms, were formerly 4 or 5 feet higher than at present. No walls were visible when the work began, but since the earth has been removed, they rise to a height of 4 to 10 feet.

The rooms are comparatively large and compactly united without any visible outside entrances, being formerly entered by ladders and a hatchway in the roof. No windows or lateral doorways are visible in the walls now standing. In order to protect this large building from the elements its walls have been repaired where necessary and their tops covered with Portland cement to prevent erosion.

The most striking result of the work has been the accumulation of a large collection of characteristic pottery from the two cemeteries which were discovered a short distance from the northern and eastern walls and which extended over a considerable area, but never very distant from the pueblo itself. A number of skeletons were found, some of which were nearly perfect, others more or less fragmentary. Several of these skeletons have been brought back for the study of specialists. They appear to have artificially deformed skulls. There was no common orientation, although a majority were interred with heads to the east.

The distinction of the kinds of pottery would naturally be reserved for a more complete report which will appear later. As a rule, however, the number of varieties was rather limited and there were very few intrusions from outside, all of which goes to show the ancient character of the ruin and the isolation of its people from others in the Southwest. The typical specimens of pottery may be grouped under a few characteristic types. Perhaps the most abundant is colored dull red on the exterior with glossy black interior. The exterior surface is corrugated or smooth. From its abundance this type may be known as the Flagstaff ware. It is never decorated with painted designs. A more striking type is white with black decorations, mainly geometrical figures, which is widely distributed in Arizona. There occur also a few specimens of red ware with black interiors, which bear indubitable evidence of having been derived from the settlements on the banks of the Little Colorado or near Tuba City.

The forms of the Elden Pueblo pottery are food bowls, ladles, dippers, vases, mugs, and ollas. Several very characteristic pieces of the black and white ware are effigy forms. There occur remarkable bracelets made of clamshell (*Pectunculus*), with incised ornamentation, from the Pacific coast, and there are ornamented bone objects which may be mentioned among the rare specimens. Turquoise beads and shells, which when strung formed strands of a necklace several feet in length, were sifted out of the soil found near the necks of skeletons. There were undoubted examples of shells set with turquoise mosaics, but they were more or less damaged by long presence in the ground. Stone implements were excavated more commonly in the rooms of the building, and there were several different forms of paint grinders, which enrich the collection. There is nowhere a larger or better collection from Arizona than that excavated from Elden Pueblo.

One of the most significant discoveries at Elden Pueblo was a room called the kiva or ceremonial chamber about midway in the length of the ruin on its east side. The kiva has thus far not been described from the Flagstaff area and its existence has been denied in the ruins of this area.

The kiva of Elden Pueblo is very large and rectangular in form with round corners. It is partly subterranean and has a banquette extending wholly around the wall of the room, but no pilasters; it also has a ventilator opening externally in the east wall, peculiarities which occur in the ruins at Marsh Pass and elsewhere in northern Arizona. It thus appears that the legend of the modern Hopi that certain of the Hopi clans formerly lived on the San Juan and its tributaries is not fanciful, but that what they recount of the southern migration of these clans before they settled on their present mesas is supported by archeological evidences in architecture as well as ceramics.

Several Hopi visitors retold their legends, published by the chief many years ago, that the ruins under Mount Elden were settlements of the Hopi in their ancient migrations, and as far as it goes the archeology of Elden Pueblo supports these legends which are sometimes very vague, differing somewhat in minor particulars. These legends differ in the names of the Hopi clans that lived at Elden Pueblo, but the Snake, Badger, and Patki are all mentioned as former inhabitants.

The particular claim of this pueblo for popular consideration is that it is easily accessible and not far from the city of Flagstaff. It bids fair to be visited in the future by many tourists who now pass through northern Arizona to visit its attractions, such as the Grand Canyon and the great bridges, and to attend the ceremonial survivals of the ancient religious rites of the Hopi. The number of visitors to Elden Pueblo during its excavation was very large and consisted not only of a large number of residents of Flagstaff but also of tourists from distant States.

Before commencing the archeological work, the chief assisted by Mr. John P. Harrington, ethnologist, cooperated with Mr. J. O. Prescott, of the Starr Piano Co., Richmond, Ind., in the recording of some of the Hopi songs. Through the kindness of the Office of Indian Affairs, four of the older Hopi were brought from Walpi to the Grand Canyon, where 11 katcina songs were recorded. It was particularly fitting that the records were made at the Grand Canyon, as it holds such a prominent position in Hopi mythology.

The chief was also assisted in the archeological work by Mr. Harrington and by Mr. Anthony W. Wilding, stenographer. Their assistance was invaluable and did much to make the field work a success.

During the past year, the bureau has had in the field a larger number of investigators than in any previous year during the last decade. Field-work has been done in various parts of our country, from Alaska to Florida, and although the line of research has in some instances been more or less limited in its nature, the total results have brought into the office much new data regarding the Indian life and a larger number of specimens illustrative of it than has resulted from field-work in comparatively recent years.

It is recognized by the chief that the time that can be devoted to rescuing data regarding the life and habits of the American Indians is more or less restricted; that is, Indian culture is rapidly fading away and is doomed in a short time to utter extinction. While this is true of ethnological data it is not necessarily true of archeological material. In fact the antiquities of our country belonging to the past of the Indian are yearly attracting more and more attention, and in order to keep pace with this interest the bureau has chosen to represent it in the field a considerable proportion of archeological problems.

At the beginning of the fiscal year, Mr. J. N. B. Hewitt, ethnologist, took up anew the work of transliterating, amending, and translating the Chippewa text of The Myth of the Daymaker, by Mr. George Gabaoosa, and also that of an Ottawa version of a portion of the Nanabozho cycle of myths by John L. Miscogeon.

In October Mr. Hewitt began the work of reclassifying and recataloguing the linguistic, historical, and other ethnological manuscripts in the archives of the bureau. In this work he was assisted by Miss Mae W. Tucker. The card index consists of 2,924 items, with approximately 6,150 cross-reference cards.

During the fiscal year Dr. John R. Swanton, ethnologist, made final additions to his papers on the Social Organization and Social

Usages of the Indians of the Creek Confederacy, Religious Beliefs and Medical Practices of the Creek Indians, and The Culture of the Southeast. These papers are now going through the press. He has also finished the scientific editing of a paper on the Trails of the Southeast, by the late William E. Myer, which, with those just mentioned, is to appear in the Forty-second Annual Report.

With the help of Miss Mae W. Tucker, stenographer, Doctor Swanton made a considerable advance in compiling a card catalogue of the words of the Timucua language previously extracted from missionary publications of the Spanish fathers Pareja and Movilla.

Doctor Swanton also continued his investigations bearing on the aboriginal trail system of North America.

Dr. Truman Michelson, ethnologist, continued his researches among the Algonquian Indians of Iowa, concentrating on the gens festivals of the Fox Indians, especially those of the Thunder and Bear gentes. He also revised in the field the list of Fox stems incorporated in the Fortieth Annual Report of the bureau. In August he went to Odanah, Wis., to gain further first-hand information on the Ojibwa Indians and enough material was secured to show decided dialectic differences from the western Ojibwa dialects. The social organization of the Ojibwa is relatively simple as compared with that of the Foxes, and the various gentes lack rituals peculiar to themselves, in sharp contrast with Fox customs. At Baraga and L'Anse, Mich., Doctor Michelson located one Stockbridge (Mahican) family in the vicinity, but unfortunately none spoke their native language. The Ojibwa dialect, though not identical with that spoken at Odanah, is closely allied to it. He also made a preliminary survey of the Ojibwa, Ottawa, and Potawatomi, finding that the various languages still persist and that their ethnology is better preserved than might be expected.

Doctor Michelson returned to Washington on September 19, when he prepared for publication by the bureau two papers on sacred packs of the Fox Indians and their appurtenant gens festivals, one called A'penäwänä'ᴀ' belonging to the Thunder gens; the other Sāgimā'kwäwᴀ belonging to the Bear gens. Doctor Michelson also completed typewriting the English translation and Indian text of a Fox sacred pack belonging to the Thunder gens formerly in possession of Pyätwäyā. A fuller text than this on Pyätwäyā's pack, written in the current syllabary, was restored phonetically, as was an Indian text on the Thunder Dance of the Bear gens, a complete version having been worked out previously, and a fuller redaction was obtained.

Mr. J. P. Harrington, ethnologist, was engaged during the fiscal year in the important work of rescuing what can still be learned of the vanishing culture of the Mission Indians of California. Work was continued at ruined village sites of the Santa Ines, Ojai, and Simi Valleys and at several of these sites extensive excavations were made revealing an earlier and later coast Indian culture. Pictographs were discovered and photographed; also rocks which were "first people" petrified, and which figure in Indian legends still extant. Spirit footprints on the rocks, both of moccasined and bare feet, made by these "first people" when the earth was still soft and muddy, were found at several places and photographed. At San Marcos the bowlders on a hillside represent the warriors of a mythic battle; some are standing with the blood from wounds running down their sides, seen as stains on the rock. A curious medicine rock was also visited, the size of a man and standing erect and surrounded at least at the present time by a bunch of opuntia cactus which keeps the curious at a respectful distance. At Rincon were photographed a couple of tall bowlders which stand six feet apart. To have good luck in hunting, so that one would be able to jump successfully among the rocks in the mountains, it was the custom for Indian boys to spring from one to the other of these bowlders. They also were called "medicine."

Mr. Harrington also discovered at Rincon the ruins of a medicine house formerly used by the island wizards for secret ceremonies. An enormous bowlder is supported on several rocks forming a natural cave, still smudged on the interior by the smoke of ancient fires. In front of this chamber on the east is a circular corral or parapet 18 feet in diameter and rising to a height of 3 feet. From the top of this stone wall rafters had formerly extended to the roof of the cave chamber, and on these thatch had been placed. It is believed by the Indians that if a person comes upon this place by mistake, thunder, lightning, and rain will immediately result.

The construction of a Mission Indian house by one of the few survivors who still know how to make them was next attempted under the direction of Mr. Harrington, and an excellent series of photographs was obtained, showing the house in all the successive stages of building. The jacal is slightly elliptical in shape, with the door, less than 4 feet high, at one end. Door leaves, both of woven tules and of jarilla, were constructed. The diameter of the structure is 13 feet, and it is only 7 feet high, with an unduly ample smokehole at the top.

Post holes a step apart and the same distance in depth were dug with a short bar of willow, the earth being scooped out with the hand. Tall and slender willow poles were selected with the greatest care from a place where the growth was thick. These poles were burnt down. Eight of them were first erected in the post holes, forming a Greek cross. Opposite pairs of poles were then arched and lashed together with yucca tyings. Only after the complete framework of uprights had been constructed were the "latas" or horizontals lashed on at intervals of a foot apart. On these a thick thatching of deerbrush was sewed, the bottom layer being stem down but all the higher layers tip down, the inverted leaves better shedding the water. The sewing was done with yucca shreds, using a great needle of wood called "raton" in Spanish, which is poked through the thatch; the sewing was performed by two Indian workers, one outside and one inside.

An expedition to the Cañada de las Uvas proved rich in discovery along several different lines. At several of the sites the old hut circles could still be traced on the surface of the ground and proved that our recently constructed house was about normal size. The old fireplaces in the center were also discovered.

Special attention was given by Mr. Harrington to the site of the old rancheria of Misyahu. This place resembles a giant citadel when viewed from down canyon. A great rocky hill was completely covered with wigwams, 12 to even 20 feet in diameter. At the base of the cliff a strong flowing spring bursts forth from an otherwise dry arroyo, 75 feet below the Indian city. It was discovered that the Misyahu cemetery has unfortunately been washed away by the freshets of the arroyo. Choriy village was located, also Sikutip, a mile distant. Four large springs with pictographs traced on their rocky walls were located in the vicinity of Choriy. At Sikutip the Indian huts were formerly clustered at the southwest border of the cienega.

In May Mr. Harrington proceeded to Flagstaff, Ariz., where he assisted in bringing four Hopi singers to the Grand Canyon for the purpose of recording their songs. At Flagstaff Mr. Harrington also assisted the chief in the excavation of the Elden Pueblo ruin.

During the fiscal year Dr. Francis La Flesche, ethnologist, was engaged in classifying the personal names of the full-blood members of the Osage Tribe according to their places in the various gentes that comprise the tribe. Each name refers, cryptically, to the origin story of the gens to which it belongs. Thus the name Star-radiant is itself meaningless until some one who is versed in the tribal rites explains that it refers to the story of the people who, when they came from the blue sky to earth, came suddenly upon a stranger whose dignified appearance and bearing immediately struck them with awe and reverence. When the people asked "Who art thou?" the stranger replied, "I am Star-radiant, who has brought for you from the starry regions peace and brotherly love." This and other star names belong to the Wa-tse-tzi (people of the stars) gens, in whose keeping are the House of Refuge and the Fireplace of Peace. The meaning of the name Pi-si (Acorn) is also obscure until it is explained that it points to the story of the people of the Tsi-zhu gens and subgentes, who when they came from the sky to the earth, alighted upon seven red oak trees. The alighting of the people on the tops of the trees sent down showers of acorns, and a voice spoke, saying, "Your little ones shall be as numerous as the acorns that fall from these trees." About 1,991 gentile names have been recorded, covering 83 pages. The translations of the names are yet to be made.

Doctor La Flesche also spent three weeks assisting Mr. De Lancey Gill, illustrator, in classifying negatives of photographs of Ponca; Omaha, and Osage Indians.

A vocabulary of the Osage language has also been started by Doctor La Flesche and Dr. John R. Swanton. So far some 3,000 or more words have been recorded with translations.

SPECIAL RESEARCHES

The research in Indian music by Miss Frances Densmore during this fiscal year has been marked by the collecting and developing of extensive material among the Menominee of Wisconsin, and the completion of the book on Papago music which is now ready for publication. The proof of the book on The Music of the Tule Indians of Panama was read, and the text of Pawnee Music (apart from analyses) was retyped, putting it in final form.

The titles of the manuscripts furnished to the bureau during the fiscal year are as follows: "Songs connected with ceremonial games and adoption dances of the Menominee Indians," "Menominee songs connected with hunting bundles, war bundles and the moccasin game," "Menominee songs connected with a boy's fast, also dream songs, love songs, and flute melodies," "Dream dance songs of the Menominee Indians," "Songs used in the treatment of the sick by Menominee Indians," and "Menominee war songs and other songs."

The Menominee Indians have been in contact with civilization for many years but retain their old customs to a remarkable degree. Miss Densmore attended a meeting of their Medicine Lodge (corresponding to the Chippewa Grand Medicine), at which two persons were initiated. She witnessed the ceremony for about four hours, listening to the songs, and presented tobacco which was received in a ceremonial manner. She was also present at a gathering where a lacrosse game was played "in fulfilment of a dream," and witnessed the similar playing of a "dice and bowl" game by a woman who had dreamed of the "four spirit women in the east" and been instructed by them to play the game once each year.

The songs of the Dream Dance received extended consideration, the dance having been witnessed in 1910.

Among the interesting war songs were those connected with the enlistment and service of Menominee in the Civil War, with the songs of the charms ("fetiches") by which they believed that they were protected. Songs of the warfare against Black Hawk were obtained, and one very old war song with the words "The Queen (of England) wants us to fight against her enemies."

Mr. Gerard Fowke, special archeologist, was engaged for three months, February to April, in making a survey and explorations of a group of aboriginal remains near Marksville, La. The works consisted of 3 enclosures, 20 mounds, 8 lodge sites, and several village sites, extending a distance of 2 miles along the bluff overlooking Old River and in the bottom land bordering that watercourse. Eight of the mounds are of the flat-topped, domiciliary type; the others are conical or dome-shaped, usually classed as burial mounds. Six of the last were fully excavated. Two of them contained evidence of many interments; two were house sites indicating at least three periods of construction; the remaining two yielded nothing that would show the reason for their building. All were singularly barren of contents. Only traces of bones were found in the graves. The manner of construction of these mounds and the methods of burial were of a character which differentiates them from any others that have so far been reported to the bureau. They do not seem to belong with those to the east of the Mississippi, or with those which are so numerous to the westward.

A full report, with map and illustrations, has been prepared.

During the months of April, May, and June, Mr. H. W. Krieger, curator of ethnology of the National Museum, was detailed to engage in field work for the Bureau of American Ethnology. He was authorized by the chief of the bureau to proceed to Walla Walla, Wash., and vicinity for the purpose of studying the archeology of the upper Columbia River Valley, thence to proceed to southeastern Alaska to undertake the restoration of Old Kasaan, a national monument on Prince of Wales Island.

A careful inspection was made of the various collections of archeological material gathered by members of the Columbia River Archeological Society at Walla Walla, Wenatchee, Quincy, and other points in the State of Washington.

Accompanied by Mr. H. T. Harding, a local archeologist, who had spent over 20 years in archeological investigations along the upper Columbia, a reconnaissance was undertaken from The Dalles, in Oregon, to Wenatchee, Wash., for the purpose of plotting a map of the known archeological sites and selecting likely stations for excavation. The old Indian camp site at Wahluke Ferry, located at the extreme southern extent of the big bend of the Columbia, was selected as the most promising. There were no traces of previous disturbance by curio hunters. The ruins of the old Indian camp site and the cemetery near by yielded several hundred objects, most of which had been placed in the group burials as ceremonial offerings accompanying the cremation form of burial. No objects were found in the more deeply-placed graves where no cremation practices had been observed.

The restoration of the national monument of Old Kasaan, southeast Alaska, has long been the ambition of the chief of the bureau, but conditions at this unique old Haida village were found to be very discouraging. Rainfall reaches a total of 235 days annually at the town of Ketchikan on Revillagigedo Island near by, and the process of rotting and disintegration is practically continuous throughout the year. Many of the fine old carvings on the totem poles and memorial columns still standing are either partially or entirely obliterated, and every house in the village has either fallen into decay or was burned in the recent fire which destroyed the major portion of the village. The house ("big doings") and the totem pole erected by the former Haida chief Skay-al were among the objects consumed in this fire.

Several of the house sites at Old Kasaan, Tongass, Village Island, and Cape Fox village were excavated in an attempt to determine the relative age of the settlements of extreme southeastern Alaska. But few objects were obtained which might indicate a culture older than the Hudson Bay Co. post at Fort Simpson, British Columbia, or the Russian settlement at Sitka, Alaska, on the north. The few poles worthy of restoration at Old Kasaan were scraped and rotted wood was removed. The tall alder brush was cut from the immediate vicinity of the poles. Information relative to house, totem, and place names was obtained from a few survivors of the old village still living either at Wrangell, Ketchikan, or at the recently established Indian village of New Kasaan, about 40 miles from the old abandoned village.

Upon returning to the United States, the task of completing the map of archeological sites on the upper Columbia River to the Canadian border was completed. Excavation was undertaken at eight different stations along the river between Wenatchee, Wash., and the mouth of the Okanagan River.

Mr. Henry B. Collins, jr., assistant curator of ethnology of the National Museum, was detailed by the bureau to carry on archeological work in southern Louisiana and Mississippi, a region in which scarcely any work of this nature had previously been done. A reconnaissance of the field was begun in April, first in southern Mississippi, where a number of mounds were examined, and then along the low-lying Gulf coast of Louisiana. Many earth mounds and shell heaps were found throughout this latter region, indicating the existence there in prehistoric times of an advanced culture of fairly uniform type. Particular attention was given to the 21 mounds on Pecan Island in the lower part of Vermillion Parish. This part of Louisiana was occupied in historic times by the Attacapa, a cannibalistic tribe of comparatively low culture. The builders of the Pecan Island mounds, however, were apparently not Attacapa but an earlier and more advanced people who made an excellent type of pottery and who were skilled workers in stone, shell, and bone. The presence in these Pecan Island mounds of native copper and galena, as well as slate and other kinds of stone not native to the section, indicates that at a very early date the Indians of lower Louisiana had trade relations with other tribes to the north and east. In addition to the cultural material collected, a number of undeformed skulls were obtained from Pecan Island, and these will be of particular value since skeletal material from Louisiana is scarce.

Upon completion of the work in Louisiana in the latter part of June Mr. Collins proceeded to eastern Mississippi and located the sites of several of the historic Choctaw villages and secured physical measurements on 72 living Choctaw in the vicinity of Philadelphia, Miss. The latter phase of the work was in continuation of similar studies on the Choctaw begun in the summer of 1925, and was made possible by an appropriation from the American Association for the Advancement of Science.

Dr. J. W. Gidley, assistant curator of vertebrate paleontology in the National Museum, was detailed to the bureau for a continuation of work begun in the summer in conjunction with Amherst College, in exploring the fossil beds in the vicinity of Melbourne and Vero, Fla., for fossil bones and possible human remains. Mr. C. Wythe Cook, of the United States Geological Survey, aided Doctor Gidley in a determination of the geologic formation of the bed. Most of the work of this expedition was to verify the geological observations of the previous expedition and to obtain if possible more evidence on the subject. More than 100 specimens of fossil bones were added to the collection and some new forms were represented, the most important of which were fossil remains of a large extinct jaguar and teeth of an extinct species of Termarctos, a genus of bear living now in South America and having never been found before in North America. Several Indian mounds were visited and examined, a survey was taken of the Grant Mound 14 miles south of Melbourne, and a plot made of the general structure of the shell heap, burial mound, and connecting ridges. Doctor Gidley also visited some mounds near Sarasota that had been reported to the bureau, but found that they had been dug into by curio hunters. He also examined the region at Lake Thonotosassa, 14 miles northeast of Tampa. Here he secured a few Indian artifacts that had been picked up by Mr. Samuel Conant. Mr. Conant also guided Doctor Gidley to an ancient work-shop which covers several acres and seemed to be a very favorable location for future investigation.

Dr. Aleš Hrdlička, curator of physical anthropology in the National Museum, was detailed to the bureau and sent to Alaska in May for the purpose of studying the archeology of Seward Peninsula in the vicinity of Nome. As he did not reach the site of his work until the close of the fiscal year, a consideration of the results of his expedition is reserved until next year.

EDITORIAL WORK AND PUBLICATIONS

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, editor, assisted by Mrs. Frances S. Nichols, editorial assistant. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED

Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society Known as "Those Who Worship the Little Spotted Buffalo"; The Traditional Origin of the Fox Society Known as "The Singing Around Rite," by Truman Michelson. 664 pp., 1 pl., 1 fig.

PUBLICATIONS IN PRESS OR IN PREPARATION

Forty-first Annual Report. Accompanying papers: Coiled Basketry in British Columbia and Surrounding Region (Boas, assisted by Haeberlin, Roberts, and Teit); Two Prehistoric Villages in Middle Tennessee (Myer).

Forty-second Annual Report. Accompanying papers: Social Organization and Social Usages of the Indians of the Creek Confederacy; Religious Beliefs and Medical Practices of the Creek Indians; The Culture of the Southeast (Swanton); Indian Trails of the Southeast (Myer).

Bulletin 82. Archeological Observations North of the Rio Colorado (Judd).

Bulletin 83. Burials of the Algonquian, Siouan, and Caddoan Tribes West of the Mississippi (Bushnell).

Bulletin 84. The Language of the Kiowa Indians (Harrington).

DISTRIBUTION OF PUBLICATIONS

The distribution of the publications of the bureau has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma B. Powers. Publications were distributed as follows:

Report volumes and separates	5, 729
Bulletins and separates	6, 582
Contributions to North American ethnology	33
Introductions	12
Miscellaneous publications	637
	12, 993

As compared with the fiscal year ended June 30, 1925, there was an increase of 5,639 publications distributed. This was due partly to the fact that more publications were issued by the bureau than in the previous year, and partly to an increase in demand for the works.

Five addresses were added to the mailing list during the year and 37 taken from the list, making a net decrease of 32. The list now stands at 1,738.

ILLUSTRATIONS

Mr. DeLancey Gill, illustrator, continued the preparation of the illustrations of the bureau. A summary of the work follows:

Negatives of ethnologic and archeologic subjects	34
Negative films from field exposures	15
Portrait negatives of Indians	5
Photographic prints	466
Drawings prepared for book illustrations	41
Illustrations prepared for engraving (Bureau American Ethnology)	567
Illustrations prepared for engraving (other Smithsonian Institution bureaus)	681
Engravers' proof read	635
Edition prints of colored plates examined at Government Printing Office	17,000

On the 1st of February, 1926, the services of a photographer were discontinued and the work was taken over by the photographer of the National Museum in cooperation with the Bureau of American Ethnology.

LIBRARY

The reference library has continued under the immediate care of Miss Ella Leary, librarian, assisted by Mr. Thomas Blackwell. During the year 560 volumes were accessioned, and 200 pamphlets were received and catalogued; also 2,992 serials, chiefly the publications of learned societies, were received and recorded. Of these 155 were acquired by purchase, 207 by binding of periodicals, and the remainder through gift and exchange. The library now contains 26,661 volumes, 15,712 pamphlets, and several thousand unbound periodicals. During the year there were sent to the bindery 207 volumes. In addition to the use of its own library, which is becoming more and more valuable through exchange and by limited purchase, it was found necessary to draw on the Library of Congress for the loan of about 200 volumes. The purchase of books and periodicals has been restricted to such as relate to the bureau's researches. Although maintained primarily as a reference library for the bureau staff its value is becoming better known to students not connected with the Smithsonian Institution who make frequent use of it.

During the year the library was used also by officers of the executive departments and the Library of Congress. The library is greatly indebted to many private individuals for numerous donations of publications. Mention may be made of a collection given by Mrs. Safford, consisting of 50 books and one manuscript belonging to her husband, the late Dr. W. E. Safford.

During the year the cataloguing has been carried on as new accessions were acquired and good progress was made in cataloguing ethnologic and related articles in the earlier serials.

The library, among other representative libraries, is cooperating with the Library of Congress in checking up the Union List of Serials of the United States and Canada, compiled by the H. W. Wilson Co. This necessitates the checking up of the entire collection of periodicals.

COLLECTIONS

88232. Two plaster casts made by Mr. Egberts of an amulet sent to the bureau for identification by W. W. C. Dunlop, Codrington College, Barbados, British West Indies.

90380. Two chert rejects, four potsherds, and one small arrow point found in a gravel pit about one-half mile west of the Grand River, near Prior, Okla., and presented to the bureau by Grant Foreman.

90604. Archeological and skeletal material collected by H. B. Collins, jr., at various localities in Mississippi during 1925. (78 specimens.)

90652. Collection of 44 archeological specimens from graves at Vantage Ferry, Wash., purchased by the bureau from Earle O. Roberts.

90813. Collection of eight stone and shell implements found by Charles T. Earle on the beach at Shaws Point, Fla., and presented by him to the bureau.

91825. Collection of about 19 lots of human skeletal material collected in Florida by Dr. J. W. Gidley.

92317. Archeological specimens collected in Louisiana by Gerard Fowke. (108 specimens.)

PROPERTY

Furniture and office equipment were purchased to the amount of $750.

MISCELLANEOUS

Clerical.—The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief, assisted by Mr. Anthony W. Wilding, stenographer. On May 15, Mr. Wilding accompanied the chief to the field, acting as general assistant. Miss Mae W. Tucker, stenographer, was engaged in assisting Dr. John R. Swanton in compiling a Timucua dictionary and in assisting Mr. Hewitt in reclassifying and recataloguing the manuscripts in the bureau archives. Mrs. Frances S. Nichols assisted the editor.

Personnel.—Mr. James E. Connor, who received a temporary appointment as minor clerk February 4 to assist in the cataloguing of the archives of the bureau, was dropped from the rolls June 15, there being no further need for his services.

Mr. Gerard Fowke was given a temporary appointment as special archeologist in the bureau from February 9 to June 30.

Mr. Albert E. Sweeney, photographer, resigned January 31.

Respectfully submitted.

J. Walter Fewkes, *Chief.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE INTERNATIONAL EXCHANGES

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1926:

The appropriation granted by Congress for the support of the service during the year was $46,260. While this amount is $3,290 less than the appropriation for the fiscal year 1925, the actual money available for the running of the service for 1926 was the same as that for 1925, the salaries of two of the personnel that were carried on the exchange roll during 1925 having been transferred to other appropriations. In addition to the above appropriation, an allotment of $300 for printing and binding was allowed. The repayments from departmental and other establishments aggregated $4,883.75, making the total resources available for carrying on the system of exchanges during the year, $51,443.75

The total number of packages handled in 1926 was 480,776, an increase over the number for the preceding year of 12,045. The weight of these packages was 558,493 pounds, a gain of 52,329 pounds. For statistical purposes the packages handled by the exchange service are divided into several classes. The number and weight of the packages in these classes are given in the following table:

	Packages		Weight	
	Sent	Received	Sent	Received
			Pounds	*Pounds*
United States parliamentary documents sent abroad	193,598		99,601	
Publications received in return for parliamentary documents		5,169		20,626
United States departmental documents sent abroad	145,912		156,836	
Publications received in return for departmental documents		6,280		26,703
Miscellaneous scientific and literary publications sent abroad	97,483		185,170	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		32,334		69,557
Total	436,993	43,783	441,607	116,886
Grand total	480,776		558,493	

A comparison of the figures given in the above table with those in the report for last year will show a substantial gain in the number of packages received from abroad. This is gratifying, because the packages received from abroad have always been fewer in number than those sent; although, as referred to in previous reports, this disparity is not so great as would appear, for many foreign publications reach correspondents in this country direct by mail and not through exchange channels.

On account of many complaints of delay in the distribution of packages sent to China through the American-Chinese publication exchange department of the Shanghai Bureau of Foreign Affairs, shipments to that country were suspended May 18, 1925. In December, 1925, all packages on hand for China were forwarded to the Zi-ka-wei Observatory near Shanghai, the director of that observatory, Rev. Father L. Froc, S. J., having kindly signified his willingness to undertake their distribution. The Zi-ka-wei Observatory, it might be added, acted as the Smithsonian exchange agency in China before the work was taken over by the Shanghai Bureau of Foreign Affairs. The Government of the Chinese Republic recently adhered to the Brussels Exchange Conventions of 1886 and organized a Bureau of International Exchange of Publications as a department of the Ministry of Education in Peking. The first consignment of exchanges to this newly established bureau was forwarded May 4, 1926.

During the year 2,521 boxes were used in forwarding exchanges to foreign agencies for distribution—an increase of 196 over the number for the preceding 12 months. Of the total number of boxes shipped abroad, 389 were for the foreign depositories of full sets of United States governmental documents and the remainder (2,132) included departmental and other publications for depositories of partial sets and for miscellaneous correspondents.

As was stated in the report for 1925, the Smithsonian exchange service, as a rule, forwards its consignments to other countries in boxes, but sometimes the packages that accumulate for a particular country are not of sufficient bulk to warrant their transmission by freight, this latter material being mailed directly to its destination. In addition, a number of packages are forwarded by mail to remote places which can not be reached through existing exchange channels. During the year the number of packages sent abroad in this manner was 49,087.

The number of boxes sent to each country is given in the table following.

Country	Number of boxes	Country	Number of boxes
Argentine Republic	55	Java	1
Austria	73	Latvia	6
Belgium	60	Mexico	7
Brazil	41	Netherlands	80
British Colonies	16	New South Wales	35
British Guiana	2	New Zealand	27
Bulgaria	4	Norway	43
Canada	28	Palestine	60
Chile	26	Peru	15
China	54	Poland	34
Colombia	16	Portugal	14
Costa Rica	11	Queensland	16
Cuba	7	Rumania	10
Czechoslovakia	57	Russia	67
Danzig	5	South Australia	18
Denmark	45	Spain	29
Ecuador	2	Sweden	91
Egypt	2	Switzerland	67
Esthonia	25	Syria	4
Finland	20	Tasmania	17
France	190	Turkey	44
Germany	372	Union of South Africa	35
Great Britain and Ireland	314	Uruguay	14
Greece	12	Venezuela	9
Haiti	2	Victoria	42
Hungary	46	Western Australia	18
India	48	Yugoslavia	14
Italy	92		
Japan	79	Total	2,521

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS

In last year's report the statement was made that 18 countries had joined the exchange conventions of 1886. Notification was received through diplomatic channels that China had adhered to both conventions in December, 1925. It should be added that China is the first country to take this action since the question of having a larger number of countries join those conventions was taken up at Geneva in the summer of 1924 by the committee on intellectual cooperation of the League of Nations.

The depository in China has been changed from the American Chinese Publication Exchange Department in Shanghai to the Metropolitan Library in Peking. During the year depositories of partial sets have been established in Iceland and the Dominican Republic. In the former the name of the depository is National Library, Reykjavik, and in the latter, Biblioteca del Senado, Santo Domingo.

Several of the depositories have asked that steps be taken to have the publications forming the regular series of governmental documents delivered more promptly in order that the information contained therein may be available for use as soon after publication as practicable.

The publications forming the full series, therefore, instead of being held three months until a sufficient number accumulates to fill a large packing box, will be shipped in small boxes at monthly intervals. Furthermore, arrangements have been made with the Public Printer to have the publications supplied either in paper covers or departmental binding instead of withholding them to be bound as a part of the special congressional series, this latter practice often delaying the delivery of the documents to the Institution for many months. Several letters of appreciation of this action on the part of the Institution have been received. As an example of the tone of these letters there is quoted below a portion of one received from the Library of the League of Nations at Geneva:

> I am very glad indeed that steps have been taken to expedite the delivery of these documents. They are of the greatest value to us, and it is important for us to get them as soon as possible after issue.

The following references to certain resolutions and acts of Congress concerning the International Exchange Service are made here as a matter of record:

Resolution approved March 2, 1867 (Stat. XIV, 573), setting aside 50 copies of each United States official document for exchange with foreign governments through the agency of the Smithsonian Institution.

Printing act approved March 2, 1901 (Stat. XXXI, 1464), increasing to 100 the number of copies of documents for the use of the Library of Congress and for international exchanges, this number being increased to 125 by act of March 3, 1925 (Stat. XLIII, 1106).

Resolution approved March 4, 1909 (Stat. XXXV, 1169), setting aside 100 copies of the daily issue of the Congressional Record for exchange, through the Smithsonian Institution, to the legislative chambers of such foreign governments as may agree to send to the United States current copies of their Parliamentary Record or like publication. The act of March 3, 1925, increased to 125 the number of Congressional Records provided for this purpose.

In accordance with the terms of the first Brussels convention, sets of United States official documents are forwarded through the Exchange Service to 101 foreign depositories. The governments receiving these documents send to the United States, in return, copies of their own publications, which are deposited in the Library of Congress. By the terms of the second convention, copies of the daily Congressional Record are forwarded by the Institution directly by mail to foreign parliaments, those bodies sending in return copies of their own proceedings. In accordance with the latter convention, 75 copies of the Congressional Record are now being transmitted abroad, a statement concerning which will be found on a subsequent page of this report.

A list of the foreign depositories is given below:

DEPOSITORIES OF FULL SETS

ARGENTINE REPUBLIC: Ministerio de Relaciones Exteriores, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
BAVARIA: Staats-Bibliothek, Munich.
BELGIUM: Bibliothèque Royale, Brussels.
BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)
CANADA: Library of Parliament, Ottawa.
CHILE: Biblioteca del Congreso Nacional, Santiago.
CHINA: Metropolitan Library, Pei Hai, Peking.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Secretaría de Estado (Asuntos Generales y Canje Internacional), Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Kongelige Bibliotheket, Copenhagen.
ENGLAND: British Museum, London.
ESTONIA: Riigiraamatukogu (State Library), Reval.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
GLASGOW: City Librarian, Mitchell Library, Glasgow.
GREECE: Bibliothèque Nationale, Athens.
HUNGARY: Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRISH FREE STATE: National Library of Ireland, Dublin.
ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
MANITOBA: Provincial Library, Winnipeg.
MEXICO: Biblioteca Nacional, Mexico.
NETHERLANDS: Bibliotheek van de Tweede Kamer der Staten-Generaal, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NORTHERN IRELAND: Ministry of Finance, Belfast.
NORWAY: Universitets-Bibliotek, Oslo. (Depository of the Government of Norway.)
ONTARIO: Legislative Library, Toronto.
PARIS: Préfecture de la Seine.
PERU: Biblioteca Nacional, Lima.
POLAND: Bibliothèque du Ministère des Affaires Étrangères, Warsaw.
PORTUGAL: Bibliotheca Nacional, Lisbon.
PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
QUEENSLAND: Parliamentary Library, Brisbane.
RUSSIA: Shipments temporarily suspended.
SAXONY: Sächsische Landesbibliothek, Dresden—N. 6.

South Australia: Parliamentary Library, Adelaide.

Spain: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.

Sweden: Kungliga Biblioteket, Stockholm.

Switzerland: Bibliothèque Centrale Fédérale, Berne.

Switzerland: Library of the League of Nations, Geneva.

Tasmania: Parliamentary Library, Hobart.

Turkey: Shipments temporarily suspended.

Union of South Africa: State Library, Pretoria, Transvaal.

Uruguay: Oficina de Canje Internacional de Publicaciones, Montevideo.

Venezuela: Biblioteca Nacional, Caracas.

Victoria: Public Library of Victoria, Melbourne.

Western Australia: Public Library of Western Australia, Perth.

Wurttemberg: Landesbibliothek, Stuttgart.

Yugoslavia: Ministère des Affaires Étrangères, Belgrade.

DEPOSITORIES OF PARTIAL SETS

Alberta: Provincial Library, Edmonton.

Alsace-Lorraine: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.

Bolivia: Ministerio de Colonización y Agricultura, La Paz.

Bremen: Senatskommission für Reichs- und Auswärtige Angelegenheiten.

British Columbia: Legislative Library, Victoria.

British Guiana: Government Secretary's Office, Georgetown, Demerara.

Bulgaria: Ministère des Affaires Étrangères, Sofia.

Ceylon: Colonial Secretary's Office (Record Department of the Library). Colombo.

Danzig: Stadtbibliothek, Free City of Danzig.

Dominican Republic: Biblioteca del Senado, Santo Domingo.

Ecuador: Biblioteca Nacional, Quito.

Egypt: Bibliothèque Royale, Cairo.

Finland: Parliamentary Library, Helsingfors.

Guatemala: Secretary of the Government, Guatemala.

Haiti: Secrétaire d'Etat des Relations Extérieures, Port-au-Prince.

Hamburg: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.

Hesse: Landesbibliothek, Darmstadt.

Honduras: Secretary of the Government, Tegucigalpa.

Iceland: National Library, Reykjavik.

Jamaica: Colonial Secretary, Kingston.

Latvia: Bibliothèque d'Etat, Riga.

Liberia: Department of State, Monrovia.

Lourenço Marquez: Government Library, Lourenço Marquez.

Lübeck: President of the Senate.

Madras, Province of: Chief Secretary to the Government of Madras, Public Department, Madras.

Malta: Minister for the Treasury, Valetta.

New Brunswick: Legislative Library, Fredericton.

Newfoundland: Colonial Secretary, St. John's.

New Zealand: General Assembly Library, Wellington.

Nicaragua: Superintendente de Archivos Nacionales, Managua.

Nova Scotia: Provincial Secretary of Nova Scotia, Halifax.

Panama: Secretaría de Relaciones Exteriores, Panama.

PARAGUAY: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores, Estrella 563, Asunción.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
RIO DE JANEIRO: Bibliotheca da Assemblea Legislativa do Estado, Nictheroy.
RUMANIA: Academia Romana, Bucharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SASKATCHEWAN: Government Library, Regina.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
THURINGIA: Rothenberg-Bibliothek, Landesuniversität, Jena.
UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.
VIENNA: Bürgermeister-Amt der Stadt, Wien.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNAL

During the year the governments of 25 foreign states have entered into the immediate exchange of the Official Journal with the United States Government. The names of these states are: Aguascalientes, Anhalt, Argentine Republic, Braunschweig, Chihuahua, China, Coahuila, Colima, Dominican Republic, Durango, Dutch East Indies, Germany, Guerrero, Jalisco, Lower California Territory, Mexico, Nuevo León, Oldenburg, San Luis Potosi, Sinaloa, Sonora, Tabasco, Tamaulipas, Vera Cruz, Yucatán.

To the above statement I may add that the Ministère des Affaires Étrangères, Bucharest, has been listed to receive a copy of the daily issue of the Congressional Record. The interparliamentary exchange of the Official Journal was entered into with the Government of Rumania in 1909, and since that time one copy of the Record has been transmitted to the Bibliothèque de la Chambre des Députés.

The total number of copies of the daily issue of the Congressional Record now forwarded abroad through the Institution is 75. A complete list of the states taking part in this immediate exchange is given below, together with the names of the establishments to which the record is mailed:

AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.
ANHALT: Anhaltische Landesbücherei, Dessau.
ARGENTINE REPUBLIC:
  Biblioteca del Congreso Nacional, Buenos Aires.
  Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bibliothek des Nationalrates, Wien I.
BADEN: Universitäts-Bibliothek, Heidelberg.
BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.
BOLIVIA: Cámara de Diputados, Congreso Nacional, La Paz.
BRAUNSCHWEIG: Bibliothek des Braunschweigischen Staatsministeriums, Braunschweig.
BRAZIL: Bibliotheca do Congresso Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

CHIHUAHUA: Gobernador del Estado de Chihuahua.

CHINA: Metropolitan Library, Pei Hai, Peking.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA:

Biblioteca de la Cámara de Representantes, Habana.

Biblioteca del Senado, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DANZIG: Stadtbibliothek, Danzig.

DENMARK: Rigsdagens Bureau, Copenhagen.

DOMINICAN REPUBLIC: Biblioteca del Senado, Santo Domingo.

DURANGO: Gobernador Constitucional del Estado de Durango, Durango.

DUTCH EAST INDIES: Volksraad van Nederlandsch-Indië, Batavia, Java.

ESTONIA: Riigiraamatukogu (State Library), Reval.

FRANCE:

Bibliothèque de la Chambre des Députés, au Palais Bourbon, Paris.

Bibliothèque du Sénat, au Palais du Luxembourg, Paris.

GERMANY: Deutsche Reichstags-Bibliothek, Berlin, N. W. 7.

GREAT BRITAIN: Library of the Foreign Office, Downing Street, London, S. W. 1.

GREECE: Library of Parliament, Athens.

GUATEMALA: Biblioteca de la Oficina Internacional Centro-Americana, 8a Calle Poniente No. 1, Guatemala.

GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.

HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

HUNGARY: Bibliothek des Abgeordnetenhauses, Budapest.

INDIA: Legislative Library, Simla.

ITALY:

Biblioteca della Camera dei Deputati, Palazzo di Monte Citorio, Rome.

Biblioteca del Senato del Regno, Palazzo Madama, Rome.

JALISCO: Biblioteca del Estado, Guadalajara.

LATVIA: Library of the Saeima, Riga.

LIBERIA: Department of State, Monrovia.

LOWER CALIFORNIA TERRITORY: Gobernador del Distrito Norte, Mexicali, B.C.

MEXICO: Secretaria de la Cámara de Diputados, Mexico, D. F.

NEW SOUTH WALES: Library of Parliament, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Stortingets Bibliotek, Oslo.

NUEVO LEÓN: Biblioteca del Estado, Monterey.

OLDENBURG: Oldenburgisches Staatsministerium, Oldenburg i. B.

PERU: Cámara de Diputados, Congreso Nacional, Lima.

POLAND: Ministère des Affaires Étrangères, Warsaw.

PORTUGAL: Bibliotheca do Congresso da Republica, Lisbon.

PRUSSIA: Bibliothek des Abgeordnetenhauses, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.

QUEENSLAND: Chief Secretary's Department, Brisbane.

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RUMANIA:
Bibliothèque de la Chambre des Députés, Bucharest.
Ministère des Affaires Étrangères, Bucharest.

SAN LUIS POTOSI: Congreso del Estado, San Luis Potosi.

SINALOA: Gobernador del Estado de Sinaloa, Culiacan.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

SPAIN:
Biblioteca del Congreso de los Diputados, Madrid.
Biblioteca del Senado, Madrid.

SWITZERLAND:
Bibliothèque de l'Assemblée Fédérale Suisse, Berne.
Library of the League of Nations, Geneva.

TABASCO: Secretaría General de Gobierno, Sección 3a Ramo de Prenso, Villahermosa.

TAMAULIPAS: Secretaria General de Gobierno, Victoria.

TRANSVAAL: State Library, Pretoria.

UNION OF SOUTH AFRICA: Library of Parliament, Cape Town.

URUGUAY: Biblioteca de la Cámara de Representantes, Montevideo.

VENEZUELA: Cámara de Diputados, Congreso Nacional, Caracas.

VERA CRUZ: Gobernador del Estado de Vera Cruz, Departamento de Gobernación y Justicia, Jalapa.

WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida, Yucatán.

YUGOSLAVIA: Library of the Skupshtina, Belgrade.

A complete list of the foreign exchange agencies or bureaus is given below. Those in the larger countries and many of those in the smaller countries forward to the Smithsonian Institution reciprocal contributions for distribution in the United States. Correspondents desiring to make use of any of the exchange agencies in the forwarding of consignments to the United States should make application directly to the respective bureau.

ALGERIA, via France.

ANGOLA, via Portugal.

ARGENTINE REPUBLIC: Comisión Protectora de Bibliotecas Populares, Calle Córdoba 931, Buenos Aires.

AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.

AZORES, via Portugal.

BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Chariots 46, Brussels.

BOLIVIA: Oficina Nacional de Estadística, La Paz.

BRAZIL: Servicio de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.

BRITISH COLONIES: Crown Agents for the Colonies, London.

BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.

BRITISH HONDURAS: Colonial Secretary, Belize.

BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.

CANARY ISLANDS, via Spain.

CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.

CHINA: Bureau of International Exchange of Publications, Ministry of Education, Peking.

COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CZECHOSLOVAKIA: Service Tchécoslovaque des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-79.

DANZIG: Amt für den Internationalen Schriftenaustausch der Freien Stadt Danzig, Stadtbibliothek, Danzig.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.

ECUADOR: Ministerio de Relaciones Exteriores, Quito.

EGYPT: Sent by mail.

ESTONIA: Riigiraamatukogu (State Library), Reval.

FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.

FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.

GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.

GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 2, 3, and 4 Arthur St., New Oxford St., London, W. C. 2.

GREECE: Bibliothèque Nationale, Athens.

GREENLAND, via Denmark.

GUATEMALA: Instituto Nacional de Varones, Guatemala.

HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.

HONDURAS: Biblioteca Nacional, Tegucigalpa.

HUNGARY: Service Hongrois des Échanges Internationaux, Musée National Budapest, VIII.

ICELAND, via Denmark.

INDIA: Superintendent of Stationery, Bombay.

ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.

JAMAICA: Institute of Jamaica, Kingston.

JAPAN: Imperial Library of Japan, Tokyo.

JAVA, via Netherlands.

KOREA: Government General, Seoul.

LATVIA: Service des Échanges Internationaux, Bibliothèque d'État de Lettonie, Riga.

LIBERIA: Bureau of Exchanges, Department of State, Monrovia.

LITHUANIA: Sent by mail.

LOURENÇO MARQUEZ, via Portugal.

LUXEMBURG, via Belgium.

MADAGASCAR, via France.

MADEIRA, via Portugal.

MOZAMBIQUE, via Portugal.

NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Académie Technique, Delft.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: Dominion Museum, Wellington.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

NORWAY: Universitets-Bibliotek, Oslo.

PALESTINE: Hebrew University Library, Jerusalem.

PANAMA: Secretaría de Relaciones Exteriores, Panama.

PARAGUAY: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores. Estrella 563, Asuncion.

PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque du Ministère des Affaires Ètrangères, Warsaw.

Portugal: Secção de Trocas Internacionaes, Bibliotheca Nacional, Lisbon.
Queensland: Bureau of Exchanges of International Publications, Chief Secretary's Department, Brisbane.
Rumania: Bureau des Échanges Internationaux, Institut Météorologique Central, Bucharest.
Russia: Academy of Sciences, Leningrad.
Salvador: Ministerio de Relaciones Exteriores, San Salvador.
Siam: Department of Foreign Affairs, Bangkok.
South Australia: Public Library of South Australia, Adelaide.
Spain: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
Sumatra, via Netherlands.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.
Syria: American University of Beirut.
Tasmania: Secretary to the Premier, Hobart.
Trinidad: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
Tunis, via France.
Turkey: Robert College, Constantinople.
Union of South Africa: Government Printing Works, Pretoria, Transvaal.
Uruguay: Oficina de Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library of Victoria, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Yugoslavia: Académie Royale Serbe des Sciences et des Arts, Belgrade.

RULES GOVERNING THE TRANSMISSION OF EXCHANGES

For the information of any who may desire to make use of the Smithsonian system of exchanges in the forwarding of publications to foreign correspondents, there is reproduced below a revised edition of a circular containing a brief description of the service and the rules under which packages are received for distribution.

In effecting the world-wide distribution of its first publications, the Smithsonian Institution established foreign agencies by means of which it was enabled to materially assist institutions and individuals of this country in the transmission of their publications abroad, and also foreign societies and individuals in distributing their publications in the United States.

In more recent years the Smithsonian Institution has been charged with the duty of conducting the official Exchange Bureau of the United States Government, through which the publications authorized by Congress are exchanged for those of other governments; and by a formal treaty it acts as intermediary between the learned bodies and scientific and literary societies of this and other countries for the reception and transmission of their publications.

Attention is called to the fact that this is an international and not a domestic exchange service, and that it is designed to facilitate exchanges between the United States and other countries only. As publications from domestic sources for addresses in Hawaii, the Philippine Islands, Porto Rico, and other territory subject to the jurisdiction of the United States do not come within the designation "international," they are not accepted by the Institution for transmission through the service.

Packages prepared in accordance with the rules enumerated below will be received by the Smithsonian Institution from individuals or institutions of learning in the United States and forwarded to their destinations abroad through the various exchange bureaus or agencies in other countries. Many of those bureaus and agencies will likewise receive packages of publications from correspondents in their countries for distribution as gifts or exchanges to correspondents in the United States and its dependencies and will forward them to Washington, after which the Institution will transmit them to their destinations by mail free of cost to the recipients.

On receipt of a consignment from a domestic source it is assigned a "record number," which number is, for identification purposes, placed on each package contained therein. After the packages have been recorded they are packed in boxes with publications from other senders and are forwarded by freight to the bureaus or agencies abroad which have undertaken to distribute exchanges in those countries. To Great Britain and Germany shipments are made weekly; to France and Italy, semimonthly; and to all other countries consignments are forwarded at intervals not exceeding a month.

The Institution assumes no responsibility in the transmission of packages intrusted to its care, but at all times endeavors to forward exchanges safely and as promptly as possible. Especial attention should be called in this connection to the time ordinarily required for the delivery of packages sent through the exchange service. To Great Britain and Germany, for example, where weekly shipments are made, the average time for a package to reach its destination is about six weeks. To those countries to which shipments are made at semimonthly and monthly intervals, the time of delivery is, of course, somewhat longer, depending on the distance and also whether packages are received at the Institution immediately before or after a shipment. If, therefore, advance notices are mailed by senders, mention should be made of the above facts in order that consignees may expect some delay between the receipt of notices and the arrival of packages. In cases where greater dispatch is desired, publications should be forwarded by the senders to their foreign destinations direct by mail.

RULES

The rules governing the Smithsonian International Exchange Service are as follows:

1. Consignments from correspondents in the United States containing packages for transmission abroad should be addressed—

SMITHSONIAN INSTITUTION,
International Exchanges,
Washington, D. C.

and forwarded with carriage charges to Washington prepaid.

2. In forwarding a consignment the sender should mail a letter to the Institution stating by what route it is being shipped, and the number of boxes or parcels comprising the shipment. A list giving the name and address of each consignee should also be furnished. It is important that this request be complied with in order that a detailed record of the contents of consignments may be kept in the files of the exchange office for use in answering inquiries concerning the forwarding of packages.

3. Packages should be legibly and fully addressed, using, when practicable, the language of the country to which they are to be forwarded. In order to avoid any possible dispute as to ownership, names of individuals should be omitted from packages intended for societies and other establishments.

4. Packages should be securely wrapped, using cardboard, if necessary, to protect plates from crumpling.

5. Letters are not permitted in exchange packages.

6. If donors desire acknowledgments, packages may contain receipt-forms to be signed and returned by the establishment or individual addressed. Should publications be desired in exchange, a request to that effect may be printed on the receipt-form or on the package.

7. The work carried on by the International Exchange Service is not in any sense of a commercial nature, but is restricted to the transmission of publications sent as exchanges or donations. Books sold or ordered through the trade are, therefore, necessarily excluded.

8. Specimens are not accepted for distribution, except when permission has been obtained from the Institution.

Respectfully submitted.

C. G. Abbot,

Assistant Secretary, in charge of Library and Exchanges.

Dr. Charles D. Walcott,

Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit herewith the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1926.

The appropriation made by Congress under the bill for the District of Columbia for the regular maintenance of the park was $157,000, and there was the usual allotment of $300 for printing and binding. Virtually the entire appropriation was required for maintenance, so that very little could be done in the way of permanent improvement, and some much-needed repairs had to be deferred.

While the collection of animals on exhibition has not decreased in numbers it has lost somewhat in value, as several serious gaps have occurred during the year which it has not been possible to fill. There is especial lack among the larger kinds of mammals which are expensive and, therefore, difficult to include in the present budget.

ACCESSIONS

Gifts.—There were added to the collection by gift a total of 150 animals. The Canadian Government, through Hon. J. B. Harkin, commissioner of Dominion parks, presented a splendid male Rocky Mountain sheep as a new head to the little herd that has bred here so successfully for nine years past.

Six fine specimens of rhea, the ostrich of South America, were received as a gift from Dr. Daníel Garcia Accevedo, of Montevideo, Uruguay; and a fine collection of South American snakes, including specimens of bushmaster and fer-de-lance, was presented by Dr. Vital Brazil, of Sao Paulo, Brazil. All these came from South America under the special care of Dr. W. L. Schmitt of the National Museum.

Dr. H. C. Kellers, United States Navy, who accompanied the department's solar eclipse expedition to Sumatra, brought back for the park a very interesting collection of birds and snakes, including hornbills, fruit pigeons, various other birds, and two Philippine green snakes. These reached the park in excellent condition and make valuable additions to the exhibits.

Mr. Samuel Kress, of Port Limon, Costa Rica, presented a three-toed sloth and a paca; Miss Elizabeth Clayton, Pedro Miguel, Canal Zone, an ocelot; Mr. P. W. Shufeldt, Belize, British Honduras, a margay; and Mrs. G. J. Schirch, Washington, D. C., a Guatemalan deer.

A nice pair of Canada lynx was received from Mr. A. L. Jones, of Juneau, Alaska.

Mr. M. K. Brady, of Washington, D. C., presented four giant salamanders, a Loochoo terrapin and a leprous terrapin.

A Tasmanian wallaby, a bay lynx and an alligator, that had been presented to the President, were placed in the park.

Among the miscellaneous donations also were several species new to the collection.

The complete list of donors and gifts is as follows:

Dr. Daniel Garcia Accevedo, Montevideo, Uruguay, through Dr. W. L. Schmitt, United States National Museum, 6 rheas.

Mr. S. M. Alvis, Fisherville, Va., gray spider monkey.

Dr. W. E. Balderson, Washington, D. C., water snake.

Mr. Herbert Barber, Washington, D. C., little blue heron.

Mr. Oscar E. Baynard, Plant City, Fla., sandhill crane.

Miss Martha M. Beattie, Washington, D. C., alligator.

Private P. S. Bender, United States Army, alligator.

Mr. M. K. Brady, Washington, D. C., Loochoo terrapin, leprous terrapin, and four giant salamanders.

Dr. Vital Brazil, Sao Paulo, Brazil, through Dr. W. L. Schmitt, United States National Museum, 22 Brazilian snakes.

Mr. L. B. Brooks, Remington, Va., barn owl.

Mr. Robert F. Burgess, Washington, D. C., coyote.

Lieut. W. A. Burgess, Manila, P. I., Philippine heron.

Mr. W. B. Byrd, jr., Washington, D. C., screech owl.

Canadian Government, through Hon. J. B. Harkin, Rocky Mountain sheep.

Carnegie Institution, Washington, D. C., Gila monster.

Miss Elizabeth Clayton, Pedro Miguel, Canal Zone, ocelot.

Miss Colley, Washington, D. C., ringed turtle dove.

President Coolidge, White House, alligator, rufus-bellied wallaby, and bay lynx.

Miss Nellie M. Darling, Utica, N. Y., yellow-and-blue macaw.

Miss Virginia Davin, Palmyra, Va., alligator.

Mr. Charles F. Denley, Rockville, Md., sharp-shinned hawk.

Miss Sybil J. Disney, Takoma Park, D. C., brown capuchin.

Capt. John R. Edie, United States Navy, gray fox and three English pheasants.

Mr. A. T. Eisenger, Washington, D. C., double-yellow-head parrot.

Mr. C. L. Fagan, Rahway, N. J., two Inca terns.

Mr. N. H. Field, Washington, D. C., sulphur-crested cockatoo.

Miss Alice T. Flynn, Washington, D. C., grass paroquet.

Mr. Charles R. Grant, jr., Washington, D. C., tortoise.

Rev. E. J. Head, Hickory, N. C., banded rattlesnake.

Mr. Emmett H. Heitmuller, Washington, D. C., alligator.

Mr. J. Henderson, Washington, D. C., red-tailed hawk.

Mrs. William Herbertson, Frederick, Md., two alligators.

Mr. George Hofer, Tucson, Ariz., red-shafted flicker, two Harris' ground squirrels, and gray fox.

Mrs. E. L. Hoffman, Washington. D. C., grass paroquet.

Mr. W. F. Humme, Henderson, Va., two peafowls.

Mr. H. M. Ingram, Addison, Va., alligator.

Mr. Victor Jaffe, Somerset, Md., corn snake.

Mr. A. L. Jones, Juneau, Alaska, two Canada lynxes.

Mr. Neil M. Judd, Washington, D. C., prairie rattlesnake.

Dr. H. C. Kellers, United States Navy, two Philippine green snakes, two hill mynahs, four bleeding-heart doves, six necklaced doves, two Malayan wreathed hornbills, two fruit pigeons.

Mr. S. Kress, Port Limon, Costa Rica, paca and three-toed sloth.

Messrs. Lansburgh & Bro., Washington, D. C., white-throated capuchin.

Mrs. Robert E. Lee, Washington, D. C., ring-necked dove.

Legation of Holland, alligator.

Mr. W. B. Lovett, Washington, D. C., three bald eagles.

Mr. E. B. McLean, Washington, D. C., alligator, five muscovy ducks, three Chinese geese, and Canada goose.

Mrs. R. J. Mayer, Washington, D. C., hedgehog.

Mr. John J. Murphy, St. Cloud, Fla., diamond rattlesnake.

Miss S. M. Perry, Staunton, Va., gray fox.

Dr. John C. Phillips, Washington, D. C., brant.

Mr. J. H. Polkinhorn, Washington, D. C., marmoset.

Mr. B. V. Roberts, Washington, D. C., Virginia rail.

Mr. W. F. Roberts, Washington, D. C., Pennant's paroquet.

Mrs. Geo. J. Schirch, Washington, D. C., Guatemalan deer.

Mr. Edw. S. Schmid, Washington, D. C., alligator.

Mr. E. W. Scott, Washington, D. C., great horned owl.

Mr. P. W. Shufeldt, Belize, B. H., margay.

Mrs. C. F. Spradling, Athens, Tenn., woodchuck, banded rattlesnake, and six western painted turtles.

Dr. H. R. Street, Washington, D. C., Santo Domingo parrot.

Mr. J. E. Tylor, Washington, D. C., raccoon.

Mr. Allen Underwood, two Java finches and Gouldian finch.

Miss Minnie Warner, Washington, D. C., barred owl.

Mr. J. R. Whipple, Washington, D. C., common canary.

Mrs. N. J. Wiley, Washington, D. C., yellow-head parrot.

Miss Genevieve Wimsatt, Washington, D. C., crested mynah.

Mr. Charles Wilson, Washington, D. C., white-throated capuchin.

Mr. W. V. Wilson, Rockville, Md., red fox.

Mr. Hiram Yoder, Tuleta, Texas, 17 turtles.

Mr. Joe Zoffin, Washington, D. C., alligator.

Unknown donor, bare-jawed troupial.

Births.—During the year 101 mammals, birds, and reptiles, born or hatched at the park, were added to the collection. Among the mammals were Rocky Mountain sheep, mouflon, Alpine ibex, American bison, Indian buffalo, yak, guanaco, various deer, Javan and Japanese monkeys, raccoon, rock kangaroo, beaver, and several other rodents. The birds included blue goose, white-cheeked goose, rosy-billed pochard, sacred ibis, and 6 other species; and of snakes, the fer-de-lance and *Bothrops alternatus*. Two eggs were produced by the pair of California condors but failed to hatch.

Exchanges.—From the Zoological Garden of Wellington, New Zealand, were received 4 rock-hopper penguins, 2 paradise ducks, 2 lesser rails, and 2 specimens of tuatera, a lizard-like animal that is of great interest as being the oldest type of reptile now living. The penguin, lesser rail, and paradise duck were species new to the collection. Three female sea lions were received from the Zoological Society of San Diego, Calif.

Purchases.—A single-wattled cassowary, Humboldt's saki, Abyssinian lynx and alligator lizard (*Dracæna guianensis*), all new to the collection, were purchased during the year, also a black leopard. 2 prong-horns, an Australian cassowary, and a small lot of finches and other cage-birds to replenish the collections in the bird house.

Deposits.—Among the animals received on indefinite deposit were an orang and a pair of white fallow deer from Mr. Victor J. Evans, a chaema baboon from Mr. E. R. Grant, and a silver-black fox from the Keystone Fox Ranch.

The Biological Survey, United States Department of Agriculture, transferred to the park a number of animals taken by field agents of the bureau, including ravens, magpies, western porcupines, 2 Mexican pumas, and 13 white pelicans.

REMOVALS

Fifty-five mammals, birds, and reptiles were sent away in exchange to other zoological gardens during the year. Among these were two American bison, an elk, six Japanese deer, four fallow deer, a guanaco, a hippopotamus, an European bear, some small mammals, and a few birds and reptiles.

Losses by death were mainly either of animals that had been long in the collection or of those very recently received. Among the former were a sloth bear that had lived in the park 21 years and 6 months; a cinnamon bear, 17 years; a yak, 18 years and 3 months; a sambar deer and a Bactrian camel, each 14 years and 3 months; a male Rocky Mountain sheep, 8 years and 4 months; a rhea, 16 years and 5 months. A male mona monkey, survivor of the pair, the female of which died a year earlier after having borne 10 young, had been in the collection 16 years. A male Grevy's zebra that died October 9, 1925, was received February 11, 1913, from the United States Department of Agriculture, where it had been used for breeding purposes. Other important animals that had lived for shorter periods were a snow leopard, two sea lions, a female Rocky Mountain sheep, a female Rocky Mountain goat, a capybara, two ostriches, and a kiwi. Loss of reptiles was large as compared with their total number, owing to the lack of quarters that afford suitable conditions for them.

Post-mortem examinations were made by the pathological division of the Bureau of Animal Industry. The following list shows the results of autopsies, the cases being arranged by groups:

CAUSES OF DEATH

MAMMALS

Marsupialia: Pneumonia, 1; gastroenteritis, 1; gastric ulcer, 1; pericarditis, 1; fatty degeneration of liver, 1; infection of jaw, 3.

Carnivora: Enteritis, 1; gastroenteritis, 3; intestinal parasites, 2; abscess of lungs, 1; abscess of shoulder, 1; old age, 1.

Pinnipedia: Pneumonia, 1.

Rodentia: Enteritis, 1; intestinal parasites, 1; difficult parturition, 1.

Primates: Pneumonia, 2; enteritis, 2; gastroenteritis, 1; intestinal parasites, 3; degeneration of heart, 1; osteomalacia, 1; no cause found, 2.

Artiodactyla: Pneumonia, 2; intestinal parasites, 1; impaction of rumen, 1; abscess of lungs, 1; cystic degeneration of liver, 2; necrosis of lip, 1; old age, 3; accident, 1.

Perissodactyla: Internal hemorrhage, 1.

Edentata: Enteritis, 1.

BIRDS

Ratitæ: Abscess of leg, 1; accident, 1.

Ciconiiformes: Pericarditis, 1; no cause found, 2.

Anseriformes: Aspergillosis, 3; internal hemorrhage, 1.

Falconiformes: Aspergillosis, 1.

Gruiformes: No cause found, 1.

Psittaciformes: Aspergillosis, 1; enteritis, 2; internal abscess, 1.

Such animals, lost by death, as were of particular scientific interest, or of value for museum purposes, were transferred to the United States National Museum for preservation. These numbered 40 mammals, 44 birds, and 23 reptiles. A number of rare birds' eggs, including two eggs of the California condor mentioned above, also were sent to the Museum.

Five mammals especially needed by the Carnegie Laboratory of Embryology, Johns Hopkins Medical School, Baltimore, were sent after death to that institution; and five mammals were sent to St. Elizabeths Hospital, Washington, D. C., for special study of the brain.

ANIMALS IN THE COLLECTION JUNE 30, 1926

MAMMALS

MARSUPIALIA

Virginia opossum (*Didelphis virginiana*)	3
Tasmanian devil (*Sarcophilus harrisii*)	1
Flying phalanger (*Petaurus breviceps*)	7
Brush-tailed rock wallaby (*Petrogale penicillata*)	3
Rufous-bellied wallaby (*Macropus billardierii*)	3
Red kangaroo (*Macropus rufus*)	1
Wombat (*Phascolomys mitchelli*)	1

CARNIVORA

Kadiak bear (*Ursus middendorffi*)	2
Alaska Peninsula bear (*Ursus gyas*)	4
Yakutat bear (*Ursus dalli*)	1
Kidder's bear (*Ursus kidderi*)	2
European bear (*Ursus arctos*)	5
Grizzly bear (*Ursus horribilis*)	1
Apache grizzly (*Ursus Apache*)	1
Himalayan bear (*Ursus thibetanus*)	1
Black bear (*Euarctos americanus*)	4
Cinnamon bear (*Euarctos americanus cinnamomum*)	2
Glacier bear (*Euarctos emmonsii*)	1
Sun bear (*Helarctos malayanus*)	1
Polar bear (*Thalarctos maritimus*)	2
Dingo (*Canis dingo*)	3
Gray wolf (*Canis nubilus*)	7
Florida wolf (*Canis floridanus*)	1
Texas red wolf (*Canis rufus*)	1
Coyote (*Canis latrans*)	6
Hybrid coyote (*Canis latrans-rufus*)	4
California coyote (*Canis ochropus*)	1
Black-backed jackal (*Canis mesomelas*)	1
Rough fox (*Cerdocyon cancrivorus*)	1
Red fox (*Vulpes fulva*)	2
Silver-black fox (*Vulpes fulva*)	1
European fox (*Vulpes vulpes*)	1
Kit fox (*Vulpes velox*)	2
Gray fox (*Urocyon cinereoargenteus*)	1
Bush dog (*Icticyon venaticus*)	1
Cacomistle (*Bassariscus astutus*)	2
Panda (*Ailurus fulgens*)	1
Raccoon (*Procyon lotor*)	11
Florida raccoon (*Procyon lotor elucus*)	2
Gray coatimundi (*Nasua narica*)	2
Kinkajou (*Potos flavus*)	1
Mexican kinkajou (*Potos flavus aztecus*)	1
American badger (*Taxidea taxus*)	2
Florida otter (*Lutra canadensis vaga*)	3
Palm civet (*Paradoxurus hermaphroditus*)	2
Egyptian mongoose (*Herpestes ichneumon*)	1
Aard-wolf (*Proteles cristatus*)	1
Spotted hyena (*Crocuta crocuta*)	1
Striped hyena (*Hyæna hyæna*)	1
African cheetah (*Acinonyx jubatus*)	2
Lion (*Felis leo*)	3
Bengal tiger (*Felis tigris*)	1
Manchurian tiger (*Felis tigris longipilis*)	5
Leopard (*Felis pardus*)	1
Black leopard (*Felis pardus*)	1
Jaguar (*Felis onca*)	1
Serval (*Felis serval*)	1
Ocelot (*Felis pardalis*)	1
Brazilian ocelot (*Felis pardalis brasiliensis*)	1
Mexican puma (*Felis azteca*)	3
Mountain lion (*Felis hippolestes*)	1
Abyssinian caracal (*Lynx caracal nubica*)	1
Canada lynx (*Lynx canadensis*)	2
Northern wild cat (*Lynx uinta*)	1
Bay lynx (*Lynx rufus*)	3
Clouded leopard (*Neofelis nebulosa*)	1

PINNIPEDIA

California sea lion (*Zalophus californianus*)	2
San Geronimo harbor seal (*Phoca richardii geronimensis*)	1

RODENTIA

Woodchuck (*Marmota monax*)	4
Prairie dog (*Cynomys ludovicianus*)	43
Harris's ground squirrel (*Ammospermophilus harrisi*)	2
Honduras squirrel (*Sciurus boothiæ*)	1
Albino squirrel (*Sciurus carolinensis*)	3
American beaver (*Castor canadensis*)	2
Grasshopper mouse (*Onychomys leucogaster*)	2
Jumping mouse (*Zapus hudsonius*)	1
African porcupine (*Hystrix africæaustralis*)	1
Malay porcupine (*Acanthion brachyurum*)	2
Tree porcupine (*Coendou prehensilis*)	1
Western porcupine (*Erethizon epixanthum*)	1
Viscacha (*Lagostomus trichodactylus*)	2
Central American paca (*Cuniculus paca virgatus*)	3
Sooty agouti (*Dasyprocta fuliginosa*)	1
Speckled agouti (*Dasyprocta punctata*)	2
Azara's agouti (*Dasyprocta azaræ*)	1
Trinidad agouti (*Dasyprocta rubrata*)	3
Guinea pig (*Cavia porcellus*)	10
Capybara (*Hydrochœrus hydrochœris*)	1

LAGOMORPHA

Domestic rabbit (*Oryctolagus cuniculus*)	10

INSECTIVORA

European hedgehog (*Erinaceus europæus*)	5

PRIMATES

Ring-tailed lemur (*Lemur catta*)	1
Red-fronted lemur (*Lemur rufifrons*)	1
Black lemur (*Lemur macaco*)	2
Marmoset (*Callithrix jacchus*)	1
Gray spider monkey (*Ateles geoffroyi*)	2
Mexican spider monkey (*Ateles neglectus*)	1
White-throated capuchin (*Cebus capucinus*)	4
Brown capuchin (*Cebus fatuellus*)	4
Margarita capuchin (*Cebus margaritæ*)	1
Gelada baboon (*Theropithecus obscurus*)	1
Chacma (*Papio porcarius*)	2
Anubis baboon (*Papio cynocephalus*)	1
East African baboon (*Papio ibeanus*)	1
Mandrill (*Papio sphinx*)	3
Drill (*Papio leucophæus*)	1
Moor macaque (*Cynopithecus maurus*)	2
Barbary ape (*Simia sylvanus*)	2
Japanese macaque (*Macaca fuscata*)	3
Pig-tailed monkey (*Macaca nemestrina*)	1
Burmese macaque (*Macaca andamanensis*)	1
Rhesus monkey (*Macaca rhesus*)	12
Bonnet monkey (*Macaca sinica*)	1
Crab-eating macaque (*Macaca irus*)	1
Philippine macaque (*Macaca syrichta*)	1
Javan macaque (*Macaca mordax*)	6
Black mangabey (*Cercocebus aterrimus*)	1
Sooty mangabey (*Cercocebus fuliginosus*)	3
Hagenbeck's mangabey (*Cercocebus hagenbecki*)	1
White-collared mangabey (*Cercocebus torquatus*)	1
Green guenon (*Lasiopyga callitrichus*)	2
Mona guenon (*Lasiopyga mona*)	2
De Brazza's guenon (*Lasiopyga brassæ*)	1
Lesser white-nosed guenon (*Lasiopyga petaurista*)	1
Chimpanzee (*Pan satyrus*)	2
Orang-utan (*Pongo pygmæus*)	1

ARTIODACTYLA

Wild boar (*Sus scrofa*)	1
Collared peccary (*Pecari angulatus*)	2
Hippopotamus (*Hippopotamus amphibius*)	2
Bactrian camel (*Camelus bactrianus*)	1
Arabian camel (*Camelus dromedarius*)	1
Guanaco (*Lama huanachus*)	3
Llama (*Lama glama*)	5
Reindeer (*Rangifer tarandus*)	4
Fallow deer (*Dama dama*)	5
White fallow deer (*Dama dama*)	3
Axis deer (*Axis axis*)	4
Hog deer (*Hyelaphus porcinus*)	3
Sambar (*Rusa unicolor*)	1
Barasingha (*Rucervus duvaucelii*)	6
Burmese deer (*Rucervus eldii*)	1
Japanese deer (*Sika nippon*)	9
Red deer (*Cervus elaphus*)	14
Kashmir deer (*Cervus hanglu*)	2
Bedford deer (*Cervus xanthopygus*)	5
American elk (*Cervus canadensis*)	4
Virginia deer (*Odocoileus virginianus*)	1
Guatemala deer (*Odocoileus sp.*)	1
Mule deer (*Odocoileus hemionus*)	1
Brocket (*Mazama sartorii*)	1
Prong-horn (*Antilocapra americana*)	1
Blesbok (*Damaliscus albifrons*)	2
White-tailed gnu (*Connochætes gnu*)	1
Brindled gnu (*Connochætes taurinus*)	1
Lechwe (*Onotragus leche*)	1
Sable antelope (*Egocerus niger*)	1
Indian antelope (*Antilope cervicapra*)	3
Nilgai (*Boselaphus tragocamelus*)	2
Gemsbok (*Oryx gazella*)	1
East African eland (*Taurotragus oryx livingstonii*)	1
Mountain goat (*Oreamnos americanus*)	3
Tahr (*Hemitragus jemlahicus*)	9
Alpine ibex (*Capra ibex*)	3
Aoudad (*Ammotragus lervia*)	1
Rocky Mountain sheep (*Ovis canadensis*)	9
Arizona mountain sheep (*Ovis canadensis gaillardi*)	1
Mouflon (*Ovis europæus*)	5
Greenland musk-ox (*Ovibos moschatus wardi*)	2
Zebu (*Bos indicus*)	1
Yak (*Poëphagus grunniens*)	4
American bison (*Bison bison*)	14
Indian buffalo (*Bubalus bubalis*)	4

PERISSODACTYLA

Malay tapir (*Tapirus indicus*)	1
Brazilian tapir (*Tapirus terrestris*)	1
Baird's tapir (*Tapirella bairdii*)	1
Zebra-horse hybrid (*Equus grevyi-caballus*)	1
Zebra-ass hybrid (*Equus grevyi-asinus*)	1

PROBOSCIDEA

Abyssinian elephant (*Loxodonta africana oxyotis*)	1
Sumatran elephant (*Elephas sumatranus*)	1

BIRDS

RATITÆ

South African ostrich (*Struthio australis*)	3
Somaliland ostrich (*Struthio molybdophanes*)	2
Nubian ostrich (*Struthio camelus*)	1
Rhea (*Rhea americana*)	4
Australian cassowary (*Casuarius australis*)	1
Single-wattled cassowary (*Casuarius uniappendiculatus*)	1
Sclater's cassowary (*Casuarius philipi*)	1
Emu (*Dromiceius novæhollandiæ*)	2

SPHENISCIFORMES

Rock-hopper penguin (*Catarrhactes pachyrhynchus*)	3

CICONIIFORMES

American white pelican (*Pelecanus erythrorhynchos*)	9
European white pelican (*Pelecanus onocrotalus*)	2
Roseate pelican (*Pelecanus roseus*)	2
Australian pelican (*Pelecanus conspicillatus*)	2
Brown pelican (*Pelecanus occidentalis*)	8
California brown pelican (*Pelecanus californicus*)	5
Florida cormorant (*Phalacrocorax auritus floridanus*)	3
Great white heron (*Ardea occidentalis*)	1
Great blue heron (*Ardea herodias*)	1
Goliath heron (*Ardea goliath*)	1
American egret (*Casmerodius egretta*)	1
Black-crowned night heron (*Nycticorax nycticorax nævius*)	67
Boatbill (*Cochlearius cochlearius*)	2
White stork (*Ciconia ciconia*)	1
Black stork (*Ciconia nigra*)	1
Marabou stork (*Leptoptilus crumenifcrus*)	2
Wood ibis (*Mycteria americana*)	2
Sacred ibis (*Threskiornis æthiopicus*)	1
Black-headed ibis (*Threskiornis melanocephalus*)	3
Australian ibis (*Threskiornis strictipennis*)	2
White ibis (*Guara alba*)	2
Scarlet ibis (*Guara rubra*)	4

ANSERIFORMES

Crested screamer (*Chauna cristata*)	2
Mallard (*Anas platyrhynchos*)	10
Black duck (*Anas rubripes*)	5
Australian black duck (*Anas superciliosa*)	1
Gadwall (*Chaulelasmus streperus*)	1
Falcated duck (*Eunetta falcata*)	1
European widgeon (*Mareca penelope*)	3
Baldpate (*Mareca americana*)	3
Green-winged teal (*Nettion carolinense*)	3
European teal (*Nettion crecca*)	3
Baikal teal (*Nettion formosum*)	6
Blue-winged teal (*Querquedula discors*)	1
Garganey (*Querquedula querquedula*)	6
Paradise duck (*Casarca variegata*)	1
Shoveller (*Spatula clypeata*)	1
Pintail (*Dafila acuta*)	10
Bahaman pintail (*Dafila bahamensis*)	1
Wood duck (*Aix sponsa*)	7
Mandarin duck (*Dendronessa galericulata*)	10
Canvasback (*Marila valisineria*)	6
European pochard (*Marila ferina*)	3
Redhead (*Marila americana*)	10
Ring-necked duck (*Marila collaris*)	1
Tufted duck (*Marila fuligula*)	1
Lesser scaup duck (*Marila affinis*)	1
Greater scaup duck (*Marila marila*)	1
Rosy-billed pochard (*Metopiana peposaca*)	5
Hawaiian goose (*Nesochen sandvicensis*)	2
Snow goose (*Chen hyperboreus*)	1
Greater snow goose (*Chen hyperboreus nivalis*)	1
Blue goose (*Chen cærulescens*)	7
White-fronted goose (*Anser albifrons*)	5
American white-fronted goose (*Anser albifrons gambeli*)	1
Bean goose (*Anser fabalis*)	2
Pink-footed goose (*Anser brachyrhynchus*)	2
Chinese goose (*Cygnopsis cygnoides*)	8
Bar-headed goose (*Eulabeia indica*)	2
Canada goose (*Branta canadensis*)	4
Hutchins's goose (*Branta canadensis hutchinsii*)	3
White-cheeked goose (*Branta canadensis occidentalis*)	10
Cackling goose (*Branta canadensis minima*)	2
Brant (*Branta bernicla glaucogastra*)	8
Barnacle goose (*Branta leucopsis*)	7
Muscovy duck (*Cairina moschata*)	1
Pied goose (*Anseranas semipalmata*)	1
Black-bellied tree duck (*Dendrocygna autumnalis*)	3
Eyton's tree duck (*Dendrocygna eytoni*)	4
Mute swan (*Cygnus gibbus*)	4
Trumpeter swan (*Cygnus buccinator*)	1
Whistling swan (*Cygnus columbianus*)	1
Black swan (*Chenopis atrata*)	2

FALCONIFORMES

California condor (*Gymnogyps californianus*)	3
Turkey vulture (*Cathartes aura*)	4
Black vulture (*Coragyps urubu*)	1

King vulture (*Sarcoramphus papa*)	2
Secretary bird (*Sagittarius serpentarius*)	1
Griffon vulture (*Gyps fulvus*)	1
African black vulture (*Torgos tracheliotus*)	1
Cinereous vulture (*Ægypius monachus*)	2
Caracara (*Polyborus cheriway*)	4
Wedge-tailed eagle (*Uroaëtus audax*)	2
Golden eagle (*Aquila chrysaëtos*)	5
White-bellied sea eagle (*Cuncuma leucogaster*)	2
Bald eagle (*Haliæetus leucocephalus leucocephalus*)	8
Alaskan bald eagle (*Haliæetus leucocephalus alascanus*)	3
Bateleur eagle (*Helotarsus ecaudatus*)	1
Broad-winged hawk (*Buteo platypterus*)	1
Red-tailed hawk (*Buteo borealis*)	8
Pigmy falcon (*Poliohierax semitorquatus*)	1
Sparrow hawk (*Falco sparverius*)	3

GALLIFORMES

Panama Curassow (*Crax panamensis*)	2
Razor-billed curassow (*Mitu mitu*)	2
Crested guan (*Penelope boliviana*)	1
Mexican guan (*Ortalis vetula*)	2
Vulturine guinea fowl (*Acryllium vulturinum*)	2
Peafowl (*Pavo cristatus*)	11
Albino peafowl (*Pavo cristatus*)	1
Silver pheasant (*Gennæus nycthemerus*)	1
Lady Amherst's pheasant (*Chrysolophus amherstiæ*)	1
Ring-necked pheasant (*Phasianus torquatus*)	12
Hungarian partridge (*Perdix perdix*)	1
Chukar partridge (*Alectoris chukar*)	1
Valley quail (*Lophortyx californica vallicola*)	1
Scaled quail (*Callipepla squamata*)	5
Massena quail (*Cyrtonyx montezumæ*)	1

GRUIFORMES

East Indian gallinule (*Porphyrio calvus*)	2
Pukeko (*Porphyrio stanleyi*)	1
Black-tailed moor hen (*Microtribonyx ventralis*)	2
American coot (*Fulica americana*)	1
Lesser rail (*Hypotænidia philippensis*)	2
South Island weka rail (*Ocydromus australis*)	2
Short-winged weka (*Ocydromus brachypterus*)	2
Sandhill crane (*Megalornis mexicana*)	4
Little brown crane (*Megalornis canadensis*)	3
White-necked crane (*Megalornis leucauchen*)	1
Indian white crane (*Megalornis leucogeranus*)	1
Lilford's crane (*Megalornis lilfordi*)	1
Australian crane (*Mathewsena rubicunda*)	2
Demoiselle crane (*Anthropoides virgo*)	4
Crowned crane (*Balearica pavonina*)	1
Kagu (*Rhynochetos jubatus*)	2

CHARADRIIFORMES

Ruff (*Philomachus pugnax*)	3
Lapwing (*Vanellus vanellus*)	1
Yellow-wattled lapwing (*Lobivanellus indicus*)	1
South American stone-plover (*Œdicnemus bistriatus vocifer*)	2
Pacific gull (*Gabianus pacificus*)	1
Great black-backed gull (*Larus marinus*)	3
Herring gull (*Larus argentatus*)	3
Silver gull (*Larus novæhollandiæ*)	21
Laughing gull (*Larus atricilla*)	2
Inca tern (*Noddi inca*)	1
Victoria crowned pigeon (*Goura victoria*)	1
Australian crested pigeon (*Ocyphaps lophotes*)	4
Bronze-wing pigeon (*Phaps chalcoptera*)	2
Marquesan dove (*Gallicolumba rubescens*)	1
Bleeding-heart dove (*Gallicolumba luzonica*)	6
Wood pigeon (*Columba palumbus*)	7
Mourning dove (*Zenaidura macroura*)	1
Mexican dove (*Zenaidura graysoni*)	1
White-fronted dove (*Leptotila fulviventris brachyptera*)	4
Necklaced dove (*Spilopelia tigrina*)	9
Ringed turtledove (*Streptopelia risoria*)	5
Zebra dove (*Geopelia striata*)	3
Bar-shouldered dove (*Geopelia humeralis*)	1
Inca dove (*Scardafella inca*)	1
Cuban ground dove (*Chæmepelia passerina aflavida*)	1
Green-winged dove (*Chalcophaps indica*)	1
Superb fruit pigeon (*Lamprotreron superba*)	1
Bronze fruit pigeon (*Muscadivores ænea*)	2

PSITTACIFORMES

Kea (*Nestor notabilis*)	1
Roseate cockatoo (*Kakatoe roseicapilla*)	14
Bare-eyed cockatoo (*Kakatoe gymnopis*)	1
Leadbeater's cockatoo (*Kakatoe leadbeateri*)	6
White cockatoo (*Kakatoe alba*)	1
Sulphur-crested cockatoo (*Kakatoe galerita*)	9

Great red-crested cockatoo (*Kakatoe moluccensis*)	1
Mexican green macaw (*Ara mexicana*)	2
Severe macaw (*Ara severa*)	1
Blue-and-yellow macaw (*Ara ararauna*)	7
Red-and-blue-and-yellow macaw (*Ara macao*)	5
Petz's paroquet (*Eupsittula canicularis*)	5
Golden-crowned paroquet (*Eupsittula aurea*)	3
Weddell's paroquet (*Eupsittula weddellii*)	3
Blue-winged parrotlet (*Psittacula passerina*)	13
Golden paroquet (*Brotogeris chrysosema*)	1
Tovi paroquet (*Brotogeris jugularis*)	6
Orange-winged paroquet (*Brotogeris chiriri*)	2
Yellow-naped parrot (*Amazona auropalliata*)	1
Mealy parrot (*Amazona farinosa*)	1
Orange-winged parrot (*Amazona amazonica*)	3
Blue-fronted parrot (*Amazona æstiva*)	1
Red-crowned parrot (*Amazona viridigenalis*)	3
Double yellow-head parrot (*Amazona oratrix*)	11
Yellow-headed parrot (*Amazona ochrocephala*)	5
Festive parrot (*Amazona festiva*)	1
Lesser white-fronted parrot (*Amazona albifrons nana*)	1
Santo Domingo parrot (*Amazona ventralis*)	4
Cuban parrot (*Amazona leucocephala*)	3
Maximilian's parrot (*Pionus maximiliani*)	1
Dusky parrot (*Pionus fuscus*)	1
Blue-headed parrot (*Pionus menstruus*)	1
Amazonian caique (*Pionites xanthomeria*)	5
Black-headed caique (*Pionites melanocephala*)	2
Lesser vasa parrot (*Coracopsis nigra*)	1
Greater vasa parrot (*Coracopsis vasa*)	1
Red-faced love-bird (*Agapornis pullaria*)	8
Gray-headed love-bird (*Agapornis madagascariensis*)	8
Abyssinian love-bird (*Agapornis taranta*)	1
Blue-bonnet paroquet (*Psephotus hæmatorrhous*)	1
Pennant's paroquet (*Platycercus elegans*)	1
Black-tailed paroquet (*Polytelis melanura*)	2
King paroquet (*Aprosmictus cyanopygius*)	2
Crimson-winged paroquet (*Aprosmictus erythropterus*)	1
Ring-necked paroquet (*Conurus torquatus*)	1
Nepalese paroquet (*Conurus nepalensis*)	2
Grass paroquet (*Melopsittacus undulatus*)	12

CUCULIFORMES

Donaldson's touraco (*Turacus donaldsoni*)	1

CORACIIFORMES

Giant kingfisher (*Dacelo gigas*)	1
Groove-billed toucanet (*Aulacorhamphus sulcatus*)	2
Malayan wreathed hornbill (*Rhytidoceros undulatus*)	2
Morepork owl (*Spiloglaux novæseelandiæ*)	1
Barred owl (*Strix varia*)	7
Florida barred owl (*Strix varia alleni*)	2
Snowy owl (*Nyctea nyctea*)	1
Screech owl (*Otus asio*)	5
Great horned owl (*Bubo virginianus*)	6
Eagle owl (*Bubo bubo*)	1
American barn owl (*Tyto alba pratincola*)	7
Red-shafted flicker (*Colaptes cafer collaris*)	3

PASSERIFORMES

Cock of the rock (*Rupicola rupicola*)	1
Silver-eared hill-tit (*Mesia argentauris*)	3
Red-billed hill-tit (*Liothrix luteus*)	19
Black-gorgeted laughing thrush (*Garrulax pectoralis*)	2
White-eared bulbul (*Otocompsa leucotis*)	3
Red-eared bulbul (*Otocompsa jocosa*)	2
Black-headed bulbul (*Molpastes hæmorrhous*)	3
Piping crow-shrike (*Gymnorhina tibicen*)	2
European raven (*Corvus corax*)	1
American raven (*Corvus corax sinuatus*)	8
Australian crow (*Corvus coronoides*)	1
American crow (*Corvus brachyrhynchos*)	1
American magpie (*Pica pica hudsonia*)	3
Yucatan jay (*Cissilopha yucatanica*)	1
Blue jay (*Cyanocitta cristata*)	2
Green jay (*Xanthoura luxuosa*)	3
Laysan finch (*Telespyza cantans*)	1
Blue honey-creeper (*Cyanerpes cyaneus*)	1
Blue-winged tanager (*Tanagra cyanoptera*)	1

Blue tanager (*Thraupis cana*)	1
Giant whydah (*Diatropura progne*)	3
Paradise whydah (*Steganura paradisea*)	2
Shaft-tailed whydah (*Tetrænura regia*)	1
Napoleon weaver (*Pyromelana afra*)	1
Red-billed weaver (*Quelea quelea*)	1
Buffalo weaver (*Textor albirostris*)	2
Madagascar weaver (*Foudia madagascariensis*)	7
St. Helena waxbill (*Estrilda astrilda*)	4
Rosy-rumped waxbill (*Estrilda rhodopygia*)	1
Nutmeg finch (*Munia punctulata*)	3
White-headed nun (*Munia maja*)	2
Black-headed nun (*Munia atricapilla*)	15
Chestnut-breasted finch (*Munia castancithorax*)	3
Java finch (*Munia oryzivora*)	27
Masked grassfinch (*Poëphila personata*)	5
Black-faced Gouldian finch (*Poëphila gouldiæ*)	1
Red-faced Gouldian finch (*Poëphila mirabilis*)	1
Diamond finch (*Steganopleura guttata*)	5
Zebra finch (*Tæniopygia castanotis*)	8
Cutthroat finch (*Amadina fasciata*)	14
Red-headed finch (*Amadina erythrocephala*)	1
Yellow-headed marsh-bird (*Agelaius icterocephalus*)	1
Australian gray jumper (*Struthidea cinerea*)	1
Starling (*Sturnus vulgaris*)	9
Shining starling (*Lamprocorax metallicus*)	4
Crested mynah (*Æthiopsar cristatellus*)	1
Malay grackle (*Gracula javana*)	2
Bare-jawed troupial (*Gymnomystax melanicterus*)	1
Hooded oriole (*Icterus cucullatus*)	1
Yellow-tailed oriole (*Icterus mesomelas*)	1
Purple grackle (*Quiscalus quiscula*)	2
Greenfinch (*Chloris chloris*)	3
European goldfinch (*Carduelis carduelis*)	4
Brambling (*Fringilla montifringilla*)	4
Yellowhammer (*Emberiza citrinella*)	1
House finch (*Carpodacus mexicanus frontalis*)	2
San Lucas house finch (*Carpodacus mexicanus ruberrimus*)	2
Canary (*Serinus canarius*)	17
Gray singing finch (*Serinus leucopygius*)	5
Gay's finch (*Phrygilus gayi*)	1
White-throated sparrow (*Zonotrichia albicollis*)	1
San Diego song sparrow (*Melospiza melodia cooperi*)	2
Saffron finch (*Sicalis flaveola*)	9
Seed eater (*Sporophila gutturalis*)	1
Blue grosbeak (*Guiraca cærulea*)	3
Red-crested cardinal (*Paroaria cucullata*)	9

REPTILES

Alligator (*Alligator mississipiensis*)	22
Tuatera (*Sphenodon punctata*)	2
Horned toad (*Phrynosoma cornutum*)	1
Gila monster (*Heloderma suspectum*)	5
Beaded lizard (*Heloderma horridum*)	1
Gould's monitor (*Varanus gouldii*)	1
Philippine monitor (*Varanus salvator*)	1
Alligator lizard (*Dracæna guianensis*)	1
Rock python (*Python molurus*)	1
Regal python (*Python reticulatus*)	1
Anaconda (*Eunectes murinus*)	2
Boa constrictor (*Constrictor constrictor*)	4
Cuban boa (*Epicrates angulifer*)	2
Brazilian tree-boa (*Epicrates crassus*)	1
Black snake (*Coluber constrictor*)	2
Chicken snake (*Elaphe quadrivittata*)	1
Corn snake (*Elaphe guttata*)	2
Pine snake (*Pituophis melanoleucus*)	1
Water snake (*Natrix sipedon*)	3
Cordate pit-viper (*Bothrops alternatus*)	3
Fer-de-lance (*Bothrops lanceolatus*)	7
Florida rattlesnake (*Crotalus adamanteus*)	3
Western diamond rattlesnake (*Crotalus atrox*)	4
Banded rattlesnake (*Crotalus horridus*)	3
Snapping turtle (*Chelydra serpentina*)	2
Florida snapping turtle (*Chelydra osceola*)	1
Musk turtle (*Sternotherus odoratus*)	1
Mexican musk turtle (*Kinosternon sonoriense*)	1
South American musk turtle (*Kinosternon scorpioides*)	5
Pennsylvania musk turtle (*Kinosternon subrubrum*)	2
Wood turtle (*Clemmys insculpta*)	1
Leprous terrapin (*Clemmys leprosa*)	1
European pond turtle (*Emys orbicularis*)	5
South American terrapin (*Nicoria punctularia*)	1
South African turtle (*Homopus areolatus*)	1
Reeves turtle (*Geoclemys reevesi*)	1
Loochoo turtle (*Geoemyda spengleri*)	1
Painted turtle (*Chrysemys picta*)	2
Western painted turtle (*Chrysemys belli*)	1
Central American cooter (*Pseudemys ornata*)	2

Gopher tortoise (*Gopherus polyphemus*) ---- 2
Duncan Island tortoise (*Testudo ephippium*) ---- 1
Indefatigable Island tortoise (*Testudo porteri*) ---- 1
Albemarle Island tortoise (*Testudo vicina*) ---- 2
South American tortoise (*Testudo denticulata*) ---- 1
African tortoise (*Testudo hermanni*) ---- 1
Angulated tortoise (*Testudo angulata*) ---- 1
South African tortoise (*Testudo sp.*) ---- 2
Chicken turtle (*Deirochelys reticularia*) ---- 1

BATRACHIANS

Giant salamander (*Megalobatrachus japonicus*) ---- 2

Statement of the collection

	Mammals	Birds	Reptiles and batrachians	Total
Presented	25	69	55	149
Born and hatched in National Zoological Park	39	42	22	103
Received in exchange	4	13	4	21
Purchased	24	90	9	123
Transferred from other Government departments	10	42	1	53
Deposited	10	5	15	30
	112	261	106	479

SUMMARY

Animals on hand July 1, 1925	1,620
Accessions during the year	479
Total animals handled	2,099
Deduct loss (by death, return of animals, and exchange)	480
	1,619

Status of collection

	Species	Individuals
Mammals	178	461
Birds	291	1,042
Reptiles and batrachians	48	116
Total	517	1,619

Examination of the list of animals shows that the collection is now weak in large and important forms; and, taking into consideration, further, the fact that many of those still included are very old, it is evident that greater expenditure for new stock must be made in the near future if the park is to keep its place among the principal zoological collections of the country.

VISITORS

The attendance record as determined by daily estimate was slightly less than that of 1925, but exceeded the attendance of any other previous year.

The attendance by months was as follows:

July	231, 750
August	357, 300
September	249, 600
October	108, 000
November	138, 300
December	79, 925
January	63, 200
February	112, 825
March	147, 950
April	397, 300
May	343, 500
June	283, 250
Total for year	2, 512, 900

Schools, classes, and similar organizations, recorded among the visitors, number 309, with a total of 24,309 individuals. Schools came from points as far distant as Maine and Illinois.

IMPROVEMENTS

The necessity of making extensive repairs to buildings and other structures and to roads, during the year, allowed only a small expenditure to be made for new work.

A new toilet building for men was constructed near the Adams Mill Road entrance to replace one which had become inadequate and unfit for use.

The boundary fence of the park was rebuilt for a distance of about 1,360 feet.

A new drainage system for the cages and walks on the south side of the lion house was put in and 300 feet of large pipe laid to connect it with the main sewer, the original drain being now altogether inadequate.

The roadway from Adams Mill Road entrance to and around the administration building was rebuilt, with some modification to provide a better grade.

A large amount of repair to roofs was done during the early part of the year, the felt with which they are covered having deteriorated with age. Several of the buildings, especially the bird house, leaked badly.

Grading was begun along the new western boundary of the park, near Cathedral Avenue. The highway which forms the boundary there had been excavated in connection with building operations on adjacent land, leaving for several hundred feet along the park line an abrupt bank 10 to 30 feet high. A survey of the region showed that at least 9,000 cubic yards must be cut from the bank to make a slope that would be permanent, while considerably more excavation would be required in order to make the land suitable for the purposes of the park. By cooperating with the Office of Public Buildings and Public Parks, which needed the excavated material for fill along the new Rock Creek drive, it was possible to do a considerable amount of grading at comparatively small cost to the park. It is hoped that the grading can be completed within the next year, so that the fence can be established on the new boundary line.

UNIFORMS FOR POLICE

A provision of the appropriation act made available the sum of $1,000 during the year for furnishing uniforms to the policemen of the park. This makes it possible to maintain a standard of personal appearance that could not well be required of such employees when compelled to equip themselves.

It is highly desirable that similar provision be made for keepers. In caring for the animals they are brought into contact with the public to a considerable extent, are often called on for information, and at times have to caution and restrain visitors. They should therefore be distinctly recognizable as belonging to the personnel of the park.

BIRD HOUSE

For several years past attention has been called in each successive report to the urgent need of a suitable building in which to exhibit the collection of birds. It is a great satisfaction therefore to note that the appropriation act for the fiscal year ending June 30, 1927, carries an item of $49,000 for beginning the construction of such a building, and authorizes the making of contracts for it to a total cost not exceeding $102,000. This is for the house only, and the cages, interior and exterior, which it is estimated will cost $25,000, are to be provided for in a subsequent appropriation.

A scheme of arrangement for the new building was proposed by the late Mr. Howland Russell, a well known architect, and final plans on which contract may be based at the present writing are being made in the office of Mr. A. L. Harris, the municipal architect of the District of Columbia. The first appropriation is contemplated to permit necessary excavation, and construction of the foundation and walls. It is planned to begin construction in the spring of 1927 so that the entire building may be finished that year with the additional appropriation for its completion estimated in the appropriation bill for this coming year. The completion of such a building will be hailed by all with the greatest satisfaction, for the present structure is antiquated, unfitted for modern needs, and in such bad repair that it is difficult to keep it in proper condition to house exhibits. The new building will give opportunity to form a collection of living birds worthy of a national organization. The interest of the District Commissioners in its development is greatly appreciated.

RADIO TALKS

The popular appreciation of the Smithsonian series of radio talks having brought a request in March, 1925, for a second course, it was thought that the wide interest taken by the public in the National Zoological Park made that a suitable starting point for a series of nature talks. Accordingly such a series was planned and given under the title "Radio Nature Talks from the National Zoological Park." Thirty-one talks were given between October 3 and May 22, through the cooperation of station WRC. Each opened with a brief statement of current news of the park, usually by the director, who then introduced the speaker of the evening. A 15-minute talk followed on some subject related to the work of the park. The 23 speakers who participated were mainly from the several bureaus of the Smithsonian Institution and the United States Department of Agriculture, but several others also contributed. It is expected that the series will be resumed in September.

The program for the year was as follows:

October 3, 1925: Introduction to the Zoo and to Doctor Mann, by Mr. Austin H. Clark. The nature and purpose of this series of talks, by Dr. William M. Mann.

October 10, 1925: Zoo notes and answers to questions, by Dr. William M. Mann. The Gorilla at Home, by Mr. C. R. Aschemeier, National Museum.

October 17, 1925: Zoo notes and answers to questions, by Dr. William M. Mann. Giant Tortoises, by Miss Doris M. Cochran, National Museum.

October 24, 1925: Behind the cages at the Zoo, by Dr. William M. Mann.

October 31, 1925: What a small boy wants to know about the Zoo; a dialogue between Master Hugh U. Clark of the Cook School and Dr. William M. Mann.

November 7, 1925: Zoo notes, by Dr. William M. Mann. The Musk Ox at Home, by Mr. Edward A. Preble, Biological Survey.

November 14, 1925: Zoo notes, by Mr. Austin H. Clark. Our Autumn Birds, by Mr. Frederick C. Lincoln, Biological Survey.

November 21, 1925: Zoo notes, by Dr. William M. Mann. Howlers and Spider Monkeys, by Maj. Edward A. Goldman, Biological Survey.

November 28, 1925: Zoo notes, by Dr. William M. Mann. The Reptiles of the District of Columbia, by Mr. Maurice K. Brady.

December 5, 1925: Collecting living Animals in South America, by Dr. William M. Mann.

December 12, 1925: Zoo notes, by Dr. William M. Mann. Whales, by Mr. Austin H. Clark, Smithsonian Institution.

December 19, 1925: Zoo notes, by Dr. William M. Mann. Our Winter Birds, by Mr. Clarence R. Shoemaker, National Museum.

December 26. 1925: Parrots at Home, by Dr. Alexander Wetmore, assistant secretary, Smithsonian Institution.

January 9, 1926: Zoo notes, by Dr. William M. Mann. The Natural History of Paradise Key, Fla., by Dr. Thomas E. Snyder, Bureau of Entomology.

January 16, 1926: Zoo notes, by Dr. William M. Mann. The Bears of Okefinokee Swamp, by Dr. Francis Harper, secretary of the Boston Society of Natural History (read by Mr. Austin H. Clark). This talk was received in exchange through the courtesy of Mr. Thornton W. Burgess and stations WBZ at Springfield and WBZA at Boston, Mass.

January 23, 1926: Zoo notes, by Dr. William M. Mann. Bird Life in Kamchatka, by Mr. Austin H. Clark, Smithsonian Institution.

January 30, 1926: Zoo notes, by Mr. Austin H. Clark. Bird Life in Venezuela, by Mr. Austin H. Clark, Smithsonian Institution.

February 13, 1926: The Origin of the Earth, by Prof. Harlow Shapley, director of the Harvard College Observatory (read by Mr. Edward B. Husing of the staff of station WRC). This talk was given through the courtesy of Professor Shapley and station WEEI, Boston.

February 20, 1926: Zoo notes, by Mr. Austin H. Clark. Experiences in South America, by Dr. Waldo L. Schmitt, National Museum.

February 27, 1926: Announcement of the Smithsonian-Chrysler expedition to Tanganyika Territory, by Dr. William M. Mann. Hunting Bighorns with a Camera, by Dr. Vernon L. Kellogg, secretary, National Research Council.

March 13, 1926: Zoo notes, by Dr. William M. Mann. Winter Butterflies, by Mr. Austin H. Clark, Smithsonian Institution. Farewell address by Dr. Mann.

March 20, 1926: Zoo notes, by Mr. Austin H. Clark. Some Animals of Tanganyika Territory, by Mr. A. Brazier Howell, Biological Survey.

March 27, 1926: Zoo notes, by Mr. Austin H. Clark. The Educational Value of the Zoo, by Dr. Frank W. Ballou, superintendent of public schools, Washington, D. C.

April 10, 1926: Zoo notes, by Mr. Austin H. Clark. Toads, by Dr. Remington Kellogg, Biological Survey.

April 17, 1926: Zoo notes, by Mr. Austin H. Clark. My Trip to Africa for Animals, by Mr. Arthur B. Baker, acting director, National Zoological Park.

April 22, 1926: Reading, by Mr. Austin H. Clark, of a letter from Dr. William M. Mann which was written on board the steamer *Llanstephan Castle* and posted at Marseille.

May 1, 1926: Zoo notes, by Mr. Austin H. Clark. Ferns, by Dr. William R. Maxon, National Museum.

May 8, 1926: Zoo notes. Our giant Moths, by Mr. Austin H. Clark, Smithsonian Institution.

May 15, 1926. Zoo notes, by Mr. Austin H. Clark. The American Bison, by Dr. Edward W. Nelson, Biological Survey.

May 22, 1926: Reading, by Mr. Austin H. Clark, of a letter from Dr. William M. Mann which was written on board the steamer *Llanstephan Castle* and posted at Aden. The Mammals of the District of Columbia, by Dr. Vernon Bailey, Biological Survey.

May 29, 1926: Zoo notes, by Mr. Austin H. Clark. Birds of the Chaco of Argentina, by Dr. Alexander Wetmore, assistant secretary, Smithsonian Institution.

SMITHSONIAN-CHRYSLER AFRICAN EXPEDITION

The absence at the park of certain large and important African animals that are usually considered essential to a zoological collection, was brought by the director to the attention of Mr. Walter P. Chrysler, automobile manufacturer. He became interested and agreed to finance an expedition to Africa to secure some of the animals needed. Tanganyika Territory, in eastern Africa, which seemed to afford the best conditions, was selected as the field of operations and an expedition was organized and equipped which left New York March 20, in charge of Dr. W. M. Mann, director of the park. Just at the close of the year a report was received of the first operations in the field and the securing of some valuable animals.

Respectfully submitted.

A. B. Baker,
Acting Director.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE ASTROPHYSICAL OBSERVATORY

Sir: The Astrophysical Observatory was conducted under the following passage of the independent offices appropriation act approved March 3, 1925:

Astrophysical Observatory: For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings and miscellaneous expenses, $31,180, of which amount not to exceed $26,840 may be expended for personal services in the District of Columbia.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, and a cement observing station and frame cottage for observers on a plot of 10,000 square feet leased from the Carnegie Solar Observatory on Mount Wilson, Calif. Since October, 1925, the observatory building on Mount Harqua Hala, which we have occupied since 1920, has been closed because the work has been removed to Table Mountain, Calif. By the generosity of Mr. John A. Roebling, a tunnel for instruments, a dwelling for the field director, a shop, and a garage have been constructed at the new site. A dwelling for the assistant is also contemplated within Mr. Roebling's grant.

During the year the Astrophysical Observatory has assumed part of the cost of the maintenance of the observing station at Montezuma, Chile, which was erected in 1920, with means furnished by Mr. Roebling. The constructions there comprise a tunnel for instruments, a dwelling, shop, and garage, and a telephone line 12 miles to Calama.

The present value of the buildings and equipment for the Astrophysical Observatory owned by the Government is estimated at $50,000. This estimate contemplates the cost required to replace the outfit for the purposes of the investigation.

WORK OF THE YEAR

A new station.—The National Geographic Society, having become interested in our efforts to obtain an accurate series of measurements of the variation of solar radiation, made a grant in March, 1925, of

$55,000 to be expended by Dr. C. G. Abbot for the following purposes:

1. To select the best location in the Eastern Hemisphere for a solar-radiation station to cooperate with the two now operated by the Astrophysical Observatory for the measurement of solar variation.

2. To equip the station selected.

3. To send an expedition to be known as the National Geographic Society Solar-Radiation Expedition Cooperating with the Smithsonian Institution to continue solar-radiation observations as long as the grant permits, estimated at four years.

In furtherance of this project, Mr. W. H. Hoover, hitherto director of the Argentine solar-radiation observatory at La Quiaca, and Mr. F. A. Greeley, hitherto assistant at Harqua Hala and at Montezuma, were engaged as director and assistant for the new station. Apparatus was ordered, and Mr. Andrew Kramer, instrument maker to the Astrophysical Observatory, was transferred to construction work under the National Geographic Society's grant. Mr. Aldrich undertook the finer work of constructing galvanometer, pyrheliometer, bolometer, and pyranometer parts, and of standardizing them as well as oversight over the preparations.

Doctor Abbot went abroad to Algeria, Egypt, Baluchistan, and South West Africa to select the location. Preference was given to the Brukkaros Mountain in South West Africa (long. 17°·48′ E., lat. 25° 52′ S.). This is an isolated cup-shaped peak 5,002 feet in elevation, rising precipitously from a level plateau of 3,000 feet elevation. The average yearly rainfall in the vicinity is 3½ inches. A Hottentot reservation surrounds the mountain, and the nearest town is Berseba, 7 miles south, where there are only two white inhabitants, the others Hottentot. Supplies would come from Keetmanshoop, 60 miles distant by auto. Water in small but sufficient quantity is found on Mount Brukkaros.

The construction is undertaken by the public-works department of South West Africa under Mr. A. Dryden, inspector. It is proposed to have a tunnel for instruments, a small dwelling for observers, a shop, a reservoir, and garage. Wire telephones will be installed by the Government of South West Africa and rented to the expedition. Work was begun in April and it was hoped to send the expedition in early autumn.

Though so isolated, the location is in other respects very promising. The average rainfall of only 3½ inches occurs as a rule one-third in February, one-third in March, and the rest scattering. Doctor Abbot was in the vicinity 12 days in March, of which 11 would have been favorable for observing. If this is characteristic of the rainy season, it promises well for the year as a whole. It is also favorable that the greatest cloudiness comes in the months of February and March, rather than December and January, as is the case in the two American stations. Good months may be expected in Africa when the poorest observing weather occurs in America. The clearness of the sky in that part of South West Africa is extraordinary, and the wind velocity is usually very low.

New station at Table Mountain, Calif.—Actual experience over five years at Mount Harqua Hala, Ariz., has proved less satisfactory than was expected. Although the number of days when it was possible to observe averaged above 70 per cent, there were many months when most of the days were extremely hazy. Especially is this apt to occur in June, July, August, and early September, months when in former years we were accustomed to obtain excellent conditions at Mount Wilson. These unfortunate conditions required the discarding of many observations made at Harqua Hala. Though recently means have been found, as will be explained below, to minimize this disadvantage, yet it was very unfavorable to the morale of the observers to be required to stay in so extremely isolated a spot, and yet to know that the results in some parts of the year were not as good as might have been obtained in very much more agreeable living conditions.

After consulting all available records, and after having special observations made during the autumn, winter, and spring months, it was decided that Table Mountain in California (long. 117° 41′ W., lat. 34° 23′ N., alt. 7,500 feet) would be preferable at all times of the year from the point of view of the sky conditions. Its excellent status for summer was well known already, because it lies only 30 miles away and almost in sight from Mount Wilson, where the summer observations of Messrs. Abbot and Aldrich for many years were reliable guides. As for comfort of the observers, Table Mountain is remarkable, for it lies near a good auto road, only four hours from Los Angeles, and is in a grove of great pine trees, forming part of the Los Angeles County Park. A store and amusement hall are within a mile, and many cottages are still nearer.

Mr. John A. Roebling added to his generous gifts a sufficient sum to defray costs of construction of road, tunnel-shaped observatory, a cottage for director, a second cottage for assistant, a shop, garage, and other accessories. The members of the board of supervisors of Los Angeles County were exceedingly helpful and cordial, especially in their approval of the sole occupancy of a site within the park for the observatory, in constructing an auto road and water service to connect with existing roads and reservoirs at Camp McClellan, and in cooperating with the Smithsonian Institution in erecting a telephone line to connect with the outside world.

Mr. A. F. Moore, field director at Harqua Hala and Table Mountain, designed and superintended all the construction, the removal from Harqua Hala, and the installation at the new site. He, himself, did no small share of the actual labor involved. Since October, 1925, the observations have been going on regularly at Table Mountain. The high quality of the sky conditions has been found to amply justify the removal, and despite an unusually stormy spring in that part of the United States, the number of observing days thus far has kept on a par with the average of five years at Harqua Hala.

From the beginning of the work at the new station, the methods of observing and reduction have been put in the most complete accord with latest experience and with those employed at Montezuma. Furthermore, as it had been found that on very hazy days the brightness of the sky around the sun contributed an amount not negligible to the reading of the pyrheliometers, there were substituted on those instruments new vestibules of four times the former length. In this way the cone of sky, as seen from the sensitive part of the instrument, is cut down from a diameter of 10° to a diameter of 3⅓°. Had this improvement been devised and made in 1920 a good many now worthless observations made at Harqua Hala might have been saved.

Montezuma station.—When, in the year 1924, Mr. Roebling informed the Institution that he felt that his part in developing the solar radiation work should be ended with June 30, 1925, it was necessary to procure other support, or abandon the Chilean observatory. Accordingly, letters were prepared asking the National Academy of Sciences, the Chief of the United States Weather Bureau, and the director of the meteorological office of the Air Ministry of Great Britain whether in their judgment the public value of the observations warranted asking for sufficient increase of the governmental appropriation for the Astrophysical Observatory to carry on the Montezuma station.

President Michelson of the National Academy of Sciences appointed a committee consisting of Dr. W. W. Campbell, chairman, Dr. R. A. Millikan, and Dr. G. N. Lewis, to consider the matter. Their report, which was unanimously adopted by the Academy, follows:

NATIONAL ACADEMY OF SCIENCES,
Washington, D. C., April 30, 1924.

Prof. A. A. MICHELSON,
President National Academy of Sciences,
Washington, D. C.

DEAR SIR: Your committee, charged with the duty of considering the proposed program of the Smithsonian Institution for measuring the heat radiations of the sun, begs to present the following report:

Dr. C. G. Abbot, Director of the Astrophysical Observatory of the Smithsonian Institution, several years ago made the notable discovery that the intensity of the heat received by the earth from the sun varies in remarkable extent and manner. Through the last two years, beginning with February, 1922, the sun's heat radiations to the earth have been continuously subnormal. The consequences of this deficiency in heat received can not be predicted at this time, but the general subject is undoubtedly one of great importance. We regard it as a national duty and a national opportunity that the observations be continued for a long time to come, and certainly through two complete sunspot cycles of 11 years each.

The principal stations for securing these observations have been located at points noted for their pure skies and their very great number of clear days in the year: At Mount Harqua Hala in Arizona, in the Northern Hemisphere, and at Montezuma in Chile, in the Southern Hemisphere.

The observing station in Chile has been operating successfully since August, 1918, but funds are not in sight to continue its activities beyond July, 1925.

For the reasons briefly stated above, this committee recommends that the National Academy of Sciences advise and request the National Government, through the Director of the Bureau of the Budget and the Appropriation Committees of Congress, to make financial provision for maintaining the Smithsonian Institution's Observatory in Chile without interruption of service.

Respectfully submitted,

GILBERT N. LEWIS,
R. A. MILLIKAN,
W. W. CAMPBELL, *Chairman.*

In transmitting it to the Secretary of the Smithsonian Institution, President Michelson himself wrote:

NATIONAL ACADEMY OF SCIENCES,
June 5, 1924.

MY DEAR MR. SECRETARY: Your communication of April 12, 1924, and that of the assistant secretary of the Institution in regard to funds for the maintenance after July, 1925, of the Chilean observatory under the direction of the Smithsonian Institution were referred to a special committee of the National Academy of Sciences, and I am inclosing, for your information and such use as you may desire to make of it, a copy of the report presented by that committee and approved by the academy.

It will be noted that this report recommends that the National Academy of Sciences "advise and request the National Government, through the Director of the Bureau of the Budget and the Appropriation Committees of Congress, to make financial provision for maintaining the Smithsonian Institution's observatory in Chile without interruption of service." Assuming that the Smithsonian Institution will communicate direct with the Bureau of the Budget, the academy will take no further action unless you find that it can serve you further in the matter.

The value of knowing the variations in heat available from solar radiation to the earth can not be overestimated. I am glad that the academy has been given this opportunity to aid in your efforts to secure funds from Congress for the purpose, and hope that your efforts in this direction will be successful.

Very respectfully yours,

A. A. MICHELSON, *President.*

Hon. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution,
Washington, D. C.

Professor Marvin, Chief of the United States Weather Bureau, replied:

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF THE CHIEF, WEATHER BUREAU,
Washington, April 28, 1924.

Dr. CHARLES G. ABBOT,
Assistant Secretary, Smithsonian Institution,
Washington, D. C.

DEAR DOCTOR ABBOT: Replying to your letter of the 12th instant, I am very glad of the opportunity of expressing my views regarding the desirability of continuing the solar radiation station at Montezuma, Chile, after July, 1925.

When we remember that without the heat and light received from the sun, life on the earth would be impossible, it becomes evident that any facts that can be established relative to the sun, and especially as to the rate at which it radiates heat and light to the earth, are of fundamental importance.

With reference to the work of the Astrophysical Observatory of the Smithsonian Institution, I have already made the following statement in the Monthly Weather Review for March, 1920, page 150:

"The solar radiation investigations conducted by Doctor Abbot constitute a monumental research of the highest possible order and command only the admiration of all. * * * The whole question of short and long period solar variability, and the terrestrial response thereto in terms of weather, is obviously one of great importance to applied meteorology and to science generally. It is very necessary, therefore, that the splendid observational work done by the Astrophysical Observatory be generously supported and extended."

At this point I would like to say emphatically that I consider the systematic and continuous observation of the intensity of solar radiation to be of basic and fundamental importance, and I think it is a mistake to try to justify these observations on the ground that they will enable us to improve the forecasting of the weather from day to day. We do not know as yet what may be the ultimate practical value of the knowledge to be gained by a long series of observations, but the collection of the observations is necessary because the data constitute important facts of a fundamental, scientific character, and are pretty certain ultimately to have important practical applications to the welfare of man. The basic research is fully justified on its own merits, leaving the practical application of the information gained to be developed in the future.

For the determination of the law of the variability of solar radiation continuous observations are required for a long period of years at two or more stations as widely separated as possible. The stations of the Astrophysical Observatory at Montezuma, Chile, and on Mount Harqua Hala, Ariz., seem to be admirably adapted for this observational work, and the observatory staff has the requisite skill and experience to handle the delicate apparatus required and make the necessary complicated reductions. The small sum required to maintain the station at Montezuma, now that it is equipped, will in my opinion be money well invested.

Very truly yours,

C. F. MARVIN, *Chief of Bureau.*

Doctor Simpson, director of the Meteorological Office of the Air Ministry of Great Britain, replied:

METEOROLOGICAL OFFICE, AIR MINISTRY,
ADASTRAL HOUSE, KINGSWAY,
London, W. C. 2, May 14, 1924.

DEAR DOCTOR ABBOT: I have received your letter dated April 12 asking for my opinion regarding the desirability of maintaining the Montezuma solar station after July, 1925.

Surely on this matter there can be no two opinions. The fluctuations in the amount of radiation emitted by the sun, which you and your collaborators have demonstrated, are of such fundamental importance to astronomical, geophysical, and meteorological science that I can not imagine scientific opinion resting satisfied unless arrangements are made for observing and recording these fluctuations. That we are not able at the moment to apply the knowledge gained to clearly demonstrated, practical, and economical purposes does not weigh at all with scientific opinion. If astronomical research is a fit subject for the expenditure of money, the branch of astronomy concerned with the variation of solar radiation can not be allowed to suffer for want of funds. I realize that this view is open to the attack that if the work is of so much importance to the rest of the world why should America be called upon to provide all the funds. My only reply is that, in the existing state of the world, if America does not supply the funds the work will cease. This is a fact and must be recognized as such.

There is still the question as to the necessity for two stations. Past experience affords the best answer to this question. When you first observed the large fluctuations they were so contrary to general expectation that they could not be credited until they had been confirmed by entirely separate observations, taken under largely different climatic conditions. The simultaneous observations at Montezuma and Harqua Hala have demonstrated the reality of the changes.

In the future when other changes are investigated, especially the smaller day to day changes, the same desire for confirmation will be felt if only one station is in operation. I, therefore, think that it will be a great loss to science, to civilization itself, if the Montezuma station is closed before another equally good station is established to check the observations made in Arizona.

Yours sincerely,

G. C. Simpson.

Although disallowed by the Bureau of the Budget, the increase was favorably acted upon by the Congress. Hence from and after July 1, 1925, the salaries and part of the other expenses of Montezuma Observatory have been carried on the Astrophysical Observatory appropriation. The costs of maintenance of the solar radiation work as a whole are still supplemented to the extent of about $5,000 per annum from the income of the Hodgkins fund of the endowment of the Smithsonian Institution.

As heretofore the daily solar constant values from Montezuma have been received at Washington by cable. Until December 31, 1925, they were forwarded daily to Mr. H. H. Clayton at Canton, Mass., to promote his studies of the dependence of weather on solar variation. Beginning January 1, 1926, at the request of the Chief of the United States Weather Bureau, the solar constant data have been published upon the daily weather map. Also they have been furnished to Science Service, and, whenever requested, to the telegraph companies in accordance with the following announcement:

Beginning January 1, 1926, the Smithsonian Institution will furnish gratis through the United States Weather Bureau, through either of the telegraph companies, or through the Associated Press, or Science Service, if any or all of these organizations shall request it for the use of their clients, daily or 10-

day mean values of the solar constant of radiation as early and as frequently as results are available from its field stations in Chile and California. In general, results are available about 24 hours after the field observations. The Institution declines, however, to furnish regularly data of this kind to individuals who may request them, since this would be in the nature of discrimination as between citizens, and, besides, too burdensome for the Institution's staff.

Hitherto the values sent out daily have been stated to be "Preliminary." Since October, 1925, they have come from Montezuma alone. Considerable time must yet elapse before the data will have accumulated at Table Mountain sufficiently to permit of the statistical study requisite before daily values can be received from that station. A definitive revision of all work since 1920 is now in progress, and when it is done all values hitherto published, and all those hereafter to be published, will be, it is expected, in their final form.

Washington work—Revision of data.—As already remarked, much of the time of the director, Doctor Abbot, of Mr. Aldrich, and of the instrument maker, Mr. Kramer, was employed in connection with the preparations for the National Geographic Society Solar-Radiation Expedition Cooperating with the Smithsonian Institution. This expedition will result in a very great increase of the value of the work of the two existing stations, by confirming or correcting their indications of solar variability.

The remainder of the staff at Washington, comprising Mr. F. E. Fowle and Mrs. Bond, aided lately by Miss Marsden, who is employed at the cost of private funds, have been at work on a complete revision of all Mount Montezuma data. The reasons for this are: (1) That with improved apparatus the basis for the existing "short method" tables had been modified; (2) that various improvements of methods of reduction have been discovered; and (3) that with a longer series of observations now available it is possible both to draw better curves for the "short method," and to more accurately determine the systematic corrections required to eliminate traces of error still remaining, on account of atmospheric haziness and humidity.

For these purposes about 125 days were entirely remeasured and fully rereduced by Langley's fundamental method, used with newly devised precautions for exact results. From the excellent values of atmospheric transmission coefficients resulting, combined with a newly contrived function of atmospheric brightness and humidity, from which all influences of solar variation were removed by introducing for the first time the pyrheliometer reading as a factor, a new basis was laid for the "short method." Among other very valuable improvements the corrections for those regions of the spectrum, not daily observed, which lie in the far ultra-violet and far infra-red were redetermined.

As a result of all this painstaking work, the newly derived solar constant values show in their accordance, as well as in the various internal evidences which their computations afford, that they are of a new and higher order of accuracy than ever reached before.

A new proof of solar variability.—Many writers having expressed doubt as to the certainty of variations of the sun, either of short or long interval, a new and simple proof has been formed by Doctor Abbot, and will be published in the Monthly Weather Review for May, 1926. It rests on the basis that if the atmosphere had uniform temperature, transparency and humidity, and if the sun was observed by means of the pyrheliometer, always at the same altitude above the horizon, then the solar constancy or variation would exhibit itself directly, without recourse to the complex obser-

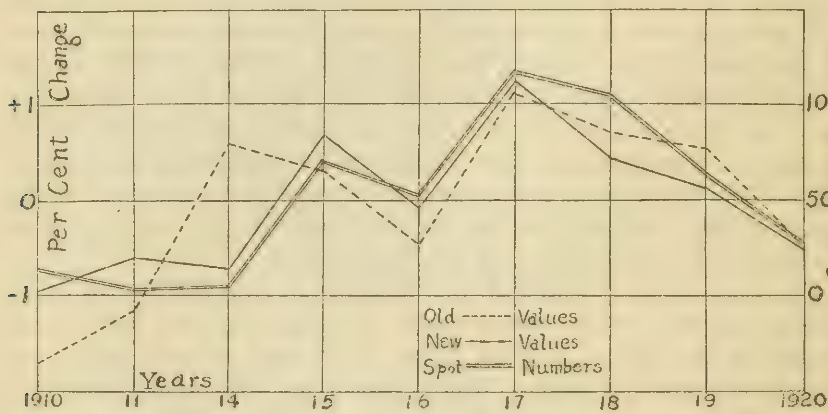

FIG. 1.—Solar variation confirmed by results of selected pyrheliometry.

Mount Wilson data of July, 1910–1920, excluding 1912, 1913, when volcanic dust from Mount Katmai made sky conditions not comparable.

Thin full curve, pyrheliometry of selected days.

Dotted curve, solar constant values hitherto published.

Double curve, sun-spot numbers.

vations and computations associated with the bolometer. In other words, at such times the atmosphere could be regarded as a screen of unchanging influence, and the readings of the pyrheliometer would be directly proportional to the intensity of solar rays.

Testing this new idea on all the observations made in the months of July at Mount Wilson, Calif., between the years 1910 and 1920, Doctor Abbot found it necessary to exclude the years 1912 and 1913 on account of the veiling effect of dust from the volcano, Mount Katmai. Many individual days were excluded also from each July, because the atmospheric conditions differed too much from the usual ones.

From the remaining observations was plotted the full curve of Figure 1. Taking the identical days used in this study, the mean solar constant values as heretofore published in Volume IV of the Annals give the dotted curve.

Both curves agree very harmoniously except in 1914, when they differ by about 1 per cent. They unite to indicate a range of solar variation in July, 1910, to 1920, of over 2 per cent. Along with them is plotted in a double line the variation of sun-spot numbers. Even in details the agreement is quite remarkable.

From another arrangement of the same data, Doctor Abbot found that those individual days on which the sun's rays appeared to the pyrheliometer more intense (when observed through unchangingly transparent atmospheres), appeared to yield on the average higher solar constant values, as heretofore published. Similarly low days for the pyrheliometer were low for the solar constant. Thus is confirmed by this new test the reality of both long and short interval solar variations. The test is not, however, as satisfactory in the latter as in the former application. As the new method has other valuable applications, it is being used also with all Montezuma and Harqua Hala observations since 1920.

Personnel.—The present personnel of the Astrophysical Observatory is as follows:

Director, Dr. C. G. Abbot.
Research assistant, Mr. F. E. Fowle.
Research assistant, Mr. L. B. Aldrich.
Field director, Mr. A. F. Moore.
Field director, Mr. H. B. Freeman.
Assistant, Mr. F. A. Greeley.
Assistant, Mr. E. E. Smith.
Instrument maker, Mr. A. Kramer.
Computer, Mrs. A. M. Bond.

Summary.—In three promising directions the work of the observatory, aimed to secure accurate determinations of solar variability, has been promoted. 1. The National Geographic Society has undertaken to equip and support for several years a cooperating solar radiation station at the best location available in the Eastern Hemisphere. This project is rapidly going forward, and observations may begin at Mount Brukkaros, South West Africa, by October, 1926. 2. By Mr. J. A. Roebling's generosity, the station at Mount Harqua Hala has been removed and reestablished on Table Mountain, Calif., 2,000 feet higher, and much more favorable for observing as well as much less isolated than Mount Harqua Hala. Improved apparatus and methods were introduced there from the beginning of observations, in October, 1925. 3. A complete revision of all Montezuma observations is well advanced. New methods of measurement and reduction are employed identical with those introduced at Table Mountain. The results thus far reached show greatly superior accuracy.

By a new and simple test, the reality of solar variation is confirmed. At the recommendation of the National Academy of Sciences and

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of eminent astronomers, physicists, and meteorologists, the Congress has increased its appropriations for the Astrophysical Observatory sufficiently to enable the Smithsonian Institution to continue the two field observatories at Montezuma and Harqua Hala.

Respectfully submitted.

C. G. ABBOT, *Director.*

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 8

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Sir: I have the honor to submit the following report on the operations of the United States Regional Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1926.

Attention was called in the last annual report, as well as in a number of those preceding, to the urgent need of a sufficient sum to again set in motion the work of the central bureau of the International Catalogue in order to resume actual publication. As the United States is at present the only nation sufficiently prosperous to aid undertakings of this character it is urgently hoped that an effort be made to obtain a sufficient grant in this country to at least publish the current volumes of the catalogue after which the accumulation on hand from 1914 to date could be published, possibly as a cumulative index.

Briefly, the status of the organization is this: When the work was begun in 1901, authorized by an international conference held in London in which all of the principal countries of the world were represented, no capital fund was available but through the influence and generosity of the Royal Society sufficient credit was established to enable the central bureau to begin publication. Material for the catalogue was furnished by the various countries through regional bureaus without charge, the cost of collecting being borne, then, as now, by each participating country. At first the income from the catalogue did not meet current expenses, but in 1914, just before the beginning of the war, the actual cost of publication and receipts approximately balanced. This was a decidedly encouraging condition, and the many friends of the enterprise looked forward with hope that the near future would show a sufficient income over the cost to repay the Royal Society for funds advanced. All these conditions were changed at the beginning of the war, and when printing was stopped in 1921 the Royal Society had advanced £7,500, in addition to gifts received from the British Government and the Carnegie Corporation of New York, which sum and interest is still owing the society. Should publication be resumed by means of a loan or gift, the large stock of completed sets of the catalogue, now in the hands of the central bureau in London, could be disposed of to new subscribers of the catalogue wishing to complete their records to the date of the beginning of the enterprise, and if these sets were sold for even half of their original price the receipts would be sufficient to repay the amount advanced by the Royal Society. The money needed to resume publication would not be expected to include payment of these obligations, but would be used solely to defray the necessary costs of printing and publishing until subscription receipts were sufficient to pay expenses.

The International Catalogue was never intended to be a commercial enterprise, but rather the means whereby investigators and students might be supplied at cost with data necessary to keep them in touch with scientific progress throughout the world. No private undertaking publishing an index of 10,000 pages annually, in editions of 1,000, could possibly assemble, classify, index, and print approximately 250,000 references, which was the average number contained in each annual issue, and afford to sell the finished work at anywhere near the price charged by the International Catalogue, for the cost of all the clerical and technical labor involved in preparing the original manuscript was borne by the regional bureaus as their contribution to the need of scientific bibliography.

Material for the catalogue is collected by the various regional bureaus supported in every case by the countries they represent, this support being mainly derived through governmental grants. The work of editing and publishing the material furnished by the various regional bureaus was intrusted to a Central Bureau in London whose support was derived from the sale of the catalogue to subscribers. The subscription price was $85.00 for each annual issue containing about 10,000 pages assembled in 17 volumes varying in size to meet the requirements of the several sciences.

The cost of printing and publishing alone has to be met through funds derived from the sales of the catalogue. This cost was, in 1914, approximately $35,000 which in 1922 was estimated, on account of war conditions, to have increased to more than twice this sum.

However, based on the offer of a large and reliable commercial printing house in the United States it is estimated that the cost would be no greater now than it was in 1914, provided not less than 10,000 pages per year were printed and the work were distributed evenly throughout the year. Assuming this estimate to be approximately correct it is believed that with a capital fund sufficient to pay for two annual issues the catalogue would again become self-supporting, for the current income, even if less than half the edition were sold, would be sufficient to pay the running expenses of the central bureau together with a large part of the printing cost and two years would be sufficient time to advertise and establish the enterprise on a permanent financial basis.

Respectfully submitted.

LEONARD C. GUNNELL,
Assistant in Charge.

DR. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution for the fiscal year ended June 30, 1926.

FRANCIS HENRY PARSONS

Mention should be made at the outset of the death on July 25, 1925, of Mr. Francis Henry Parsons, who had retired a few months before from the position of assistant in charge of the Smithsonian division of the Library of Congress, after 25 years of service. (A brief sketch of Mr. Parsons' career is given under the heading Necrology on page 32 of this report.)

CHANGES IN STAFF

There were a number of changes in the library staff during the year. The most important was the appointment of Miss Isabel L. Towner to the position, newly classified by the Personnel Board, of assistant librarian in the National Museum, to fill the vacancy caused by the retirement, and subsequent death, of Mr. Newton P. Scudder. Miss Towner was appointed from the civil service list after reinstatement by Executive order. Her training and experience fit her well for the duties of the position, for she is a graduate of Goucher College and of the New York State Library School, and has spent nearly 20 years in practical library work, chiefly in Government and scientific libraries.

Miss Sarah Young, junior librarian, resigned in October, and was succeeded by Mr. R. Webb Noyes, a graduate of Bowdoin College and for some time a student at the New York State Library School. His experience was gained chiefly in university and State libraries, especially the New York State Library, where he collaborated with Miss J. Dorcas Fellows in preparing the twelfth edition of the Decimal Classification, by Melvil Dewey.

Miss Minnie Murrill, who for several years had been a cataloguer in the Museum, resigned to accept a position in the library of the University of Alabama. Her position was filled temporarily, and will be filled permanently as soon as the person chosen becomes available.

Miss Agnes Auth was promoted, at the close of the year, to the position of minor library assistant, one of the two new positions that were granted to the library by Congress as of July 1, 1926.

Miss Auth's former position as messenger was reclassified to that of library aid, and was filled by the appointment of Mrs. Mary Arnold Baer.

The vacancy in the position of assistant messenger, occasioned by the appointment of Mr. John Anderson to a position elsewhere in the Institution, was filled by the transfer of Mr. William Helvestine from another Government department.

At different times during the year various persons were employed temporarily. Among these were Miss Ellen D. McBryde, Miss Mary Martin, Mrs. Victoria B. Turner, Mrs. M. Landon Reed, Mrs. Madaline Amphlett, Miss Helen Turnbull, Mr. William P. Wright, Mr. Clarence Gunther, Mr. Walter Jaeger, and Mr. Carl Haardt.

EXCHANGE OF PUBLICATIONS

As is well known, the growth of the Smithsonian Library is due almost entirely to the exchange of publications between the Institution and its branches and other learned institutions and societies throughout the world. These publications come to the library direct, or through the International Exchange Service, which is administered by the Institution. During the past year 30,541 packages, of one or more publications each, came to the library by mail, and 7,352 through the exchange. The number of the latter was more than three times that of the year before. The special effort to complete broken sets, by listing wants and writing follow-up letters, which was begun the previous year, was continued with vigor. Exchange relations were opened with many new societies. Most of the 1,225 letters written by the library had to do with the exchange of publications.

MAIN LIBRARY

The publications sent to the Smithsonian deposit, which is the main library of the Institution, numbered 5,088, comprising 3,649 complete volumes, 843 parts of volumes, 175 pamphlets, and 421 charts. Documents of foreign governments, more or less statistical in character, to the number of 7,305, were also sent, without being stamped or entered, to the Document Division of the Library of Congress.

Many dissertations were received from the universities of Basel, Berlin, Bern, Breslau, Cornell, Erlangen, Giessen, Greifswald, Halle, Heidelberg, Johns Hopkins, Kiel, Königsberg, Liège, Louvain, Lund, Neuchâtel, Pennsylvania, Strassbourg, Utrecht, Venezuela, Warsaw, and Zürich; and from technical schools at Berlin, Charlottenburg, Geneva, Karlsruhe, and Zürich. Fewer dissertations than usual came from Germany, Austria, and Switzerland. Instead, the library received from the universities in those countries hundreds of abstracts, each giving merely the author's name, the subject of the paper, and a brief summary of its contents.

OFFICE LIBRARY

The office library, which consists chiefly of some of the more frequently used society publications, the aeronautical collection, the art-room collection, the employees' library, and various books, mainly of a reference nature, in the administrative offices, was increased during the year by 243 volumes, 1 part of a volume, and 18 pamphlets. Of these, 54 were added to the aeronautical collection. It may be stated in passing that this collection, owing to its rapidly growing importance, will soon be raised to the dignity of a division—the tenth by number—of the Smithsonian library and named the Langley Aeronautical Library in memory of the third secretary of the Institution, whose researches and experiments marked the successful beginning of aeronautics in the United States.

Many important books were received during the year, but the outstanding one was probably the North American Indian, volume 13, by Edward S. Curtis, presented by Mrs. E. H. Harriman. This was deposited with others of the series in the library of the Bureau of American Ethnology.

The circulation, which showed a considerable gain over the previous year, was 2,618. Of this number, 2,183 were magazines. A corresponding increase was apparent in the number of books and periodicals consulted in the reference room, those most in demand being the aeronautical collection and the transactions of the learned societies.

It is gratifying to report that, after a lapse of nine years, binding was resumed for the office library. Of the 172 volumes bound, 41 belonged to the exhibition set of Smithsonian publications.

The work done in connection with the general catalogue of the Smithsonian library, which is kept in the office reading room, was as follows:

Volumes catalogued	3,495
Volumes recatalogued	134
Charts catalogued	403
Cards typed	1,525
Library of Congress cards filed	688
New authors added	348

MUSEUM LIBRARY

During the year the library of the National Museum was increased by 1,660 volumes and 1,466 pamphlets, making a total of 66,808 volumes and 104,417 pamphlets. Most of the accessions were, of course, obtained by exchange, but some were obtained by purchase and an unusually large number by gift. The largest gift was from the Library of Congress. This comprised 606 volumes and 808 parts of volumes from its collection of duplicates—some stamped Smithsonian Deposit, others Library of Congress—and was sent to the Museum library to help complete its sets of society publications pertaining mainly to natural history. Generous gifts were also received from Secretary Walcott, who, as usual, contributed hundreds of items to the library, particularly to the section of geology and paleontology; Dr. W. H. Holmes, who gave 83 volumes and 363 pamphlets to the general collection; Dr. W. H. Dall, who added 173 titles to the section of mollusks; Dr. C. W. Richmond and Mr. J. H. Riley, who gave many books and pamphlets, some of them very rare, to the main collection, as well as to the section of birds and other sections; and Mr. N. M. Judd, who contributed 18 volumes to the section of American archeology. Among other donors were Assistant Secretary Wetmore, Mr. A. N. Caudell, Mr. John Gallagher, Dr. O. P. Hay, Dr. A. Hrdlička, Dr. W. R. Maxon, Dr. G. S. Miller, Mr. S. A. Rohwer, and Dr. W. Schaus.

The number of sectional libraries in the Museum is now 37. These, while in a measure independent working units, are in a real sense very important parts of the general library. During the year the study of their resources and problems that was begun the year before was continued, with a view to strengthening their collections and making them more available. The sectional libraries are as follows:

Administration.
Administrative assistant's office.
American Archeology.
Anthropology.
Biology.
Birds.
Botany.
Echinoderms.
Editor's office.
Ethnology.
Fishes.
Foods.
Geology.
Graphic Arts.
History.
Insects.
Invertebrate Paleontology.
Mammals.
Marine Invertebrates.
Mechanical Technology.
Medicine.
Minerals.
Mineral Technology.
Mollusks.
National Gallery of Art.
Old World Archeology.
Organic Chemistry.
Paleobotany.
Photography.
Physical Anthropology.
Property clerk's office.
Reptiles and Batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate Paleontology.
Wood Technology.

TECHNOLOGICAL LIBRARY

The technological library, located in the old Museum Building, consists chiefly of material having to do with the arts and industries, together with certain classes of the natural history collection that are little called for, or for which there is not room in the new building. During the year, in addition to keeping up the current work, the assistant in charge, with the help of those who from time to time took his place, continued the reorganization that was begun the year before. About 1,500 cards were added to the shelf list. The loans were 245. It is hoped that the work of reorganizing this library can be finished in the course of the next fiscal year.

ASTROPHYSICAL OBSERVATORY LIBRARY

The library of the Astrophysical Observatory was increased by 105 volumes, 17 parts of volumes, 36 pamphlets, and 4 charts. The number of volumes bound was 124. The loans are included with those of the office library.

A beginning was made in checking up the various series of astrophysical periodicals and supplying the missing numbers. This work will soon be completed. The shelf list will also be finished and an inventory taken.

BUREAU OF AMERICAN ETHNOLOGY LIBRARY

The activities of the library of the Bureau of American Ethnology are described in the report of the chief of that bureau, by whom the library is administered.

NATIONAL GALLERY OF ART LIBRARY

Although the library of the National Gallery of Art is administered as a sectional library of the National Museum and will probably continue to be as long as the National Gallery is housed in the Natural History Building, it is usually thought of as one of the nine divisions of the Smithsonian library. As such it is given a place by itself in the annual report. Its accessions during the year were 155 volumes, 479 parts of volumes, and 130 pamphlets. It now totals 581 volumes and 665 pamphlets, a small but carefully chosen and valuable nucleus for the larger library soon to be collected.

FREER GALLERY OF ART LIBRARY

The library of the Freer Gallery of Art is restricted to the interests represented by the collections of art objects pertaining to the arts and cultures of the Far East, India, and Persia and the nearer

East; by the life and works of James McNeil Whistler and of certain other American painters whose pictures are owned by the gallery; and, further, to a very limited degree, by the Biblical manuscripts of the fourth and fifth centuries, which, as the possession of the Freer Gallery, are known as the Washington manuscripts.

During the year, 735 persons visited the library, of whom more than 100, including a number of college teachers and students, came for the purpose of serious study, many being especially interested in the facsimiles of the Biblical manuscripts. The library was increased by 500 volumes, of which 462 are in the Chinese and Japanese languages, and by 72 parts of volumes and 142 pamphlets.

NATIONAL ZOOLOGICAL PARK LIBRARY

While this library is still quite small, numbering about 1,500 volumes and pamphlets, it has been so carefully selected that it represents a very valuable working collection. It increased the past year by only 9 volumes, but two of these were volumes 3 and 4 of the monumental work, A Natural History of the Ducks, by John C. Phillips. Five volumes were bound.

SUMMARY OF ACCESSIONS

The accessions for the year, with the exception of those to the library of the Bureau of American Ethnology, may be summarized as follows:

Library	Volumes	Other publications	Total
Astrophysical Observatory	105	57	162
Freer Gallery of Art	500	214	714
National Gallery of Art	155	609	764
National Zoological Park	9		9
Smithsonian deposit, Library of Congress	3,649	1,439	5,088
Smithsonian office	243	19	262
United States National Museum, including the technological library	1,660	1,466	3,126
Total	6,321	3,804	10,125

An estimate of the number of volumes, pamphlets, and charts in the Smithsonian library, including the Smithsonian deposit in the Library of Congress, on June 30, 1926, was as follows:

Volumes	514,071
Pamphlets	139,525
Charts	23,887
Total	677,483

This number does not include the many thousands of parts of volumes in the library awaiting completion of the volumes.

SPECIAL ACTIVITIES

The regular staff, with the aid of a number of trained temporary employees, undertook many special tasks that required attention as a condition to carrying out further plans for reorganization and development.

The sorting of the large accumulations of miscellaneous material in the Museum library, begun the previous year, was practically completed.

In the Museum library, too, the sets of society publications were checked up and missing numbers listed. Many of these were supplied from the duplicates in the Library of Congress, as has been said in an earlier part of this report. It is hoped that most of the others can be obtained by exchange, either from the societies themselves, or from other libraries. To this end, toward the close of the year hundreds of want-letters were written; and many duplicates were taken out and transferred to the west stacks of the Smithsonian Building, where they were added to those from other divisions of the library and put in order. Later they will be listed and disposed of by exchange or by gift. This work of checking up and supplying numbers lacking in the various series in the library will continue to receive special attention from the staff.

It should be mentioned in this connection that the six sets of the publications of the Institution and its branches that are kept in the Smithsonian library were found upon examination to have many gaps. These it was still possible, in the main, to fill, so that the sets are now nearly complete.

The shelves of the main collection in the Museum library were arranged, a task that occupied months, as they had not been arranged for a long time and were in a very confused state. This was preliminary to taking an inventory of the library, which will be begun as soon as the shelf list, on which much progress was made during the year, is finished.

There was an intensive effort to bring the filing of the Concilium Bibliographicum cards up to date, with the result that the whole of the alphabetic set and part of the methodical set were filed. In all, 16,906 cards were filed. This work involved the rearrangement of the cards already in the cases. Many cards remain unfiled, but the outlook is hopeful, and the current cards are being filed as they come in. The two sets referred to are the only ones now being received, as the systematic set was discontinued toward the close of the year.

Another activity that required no little time was the preparation of 1,793 volumes for binding, of which 1,497 were for the Museum, 172 for the office, and 124 for the Astrophysical Observatory. This was more than double the number bound in any year during the previous six years, and almost as many as were bound altogether during the previous five years. When these volumes return to the shelves they will greatly improve the appearance and increase the usefulness of the library.

Preliminary steps were taken toward modernizing and expanding the catalogue, a work that during the coming year will be especially emphasized, for one of the chief needs of the library now is a dictionary catalogue, both of the main collections and of the sectional libraries.

Mention might be made, too, of the fact that the exhibition set of Smithsonian publications was packed and sent, together with the corresponding sets of the publications of the National Museum and the Bureau of American Ethnology, to Philadelphia, for exhibition at the Sesquicentennial. These sets, with the International Catalogue of Scientific Literature, comprise nearly 900 volumes.

INTERLIBRARY LENDING

The library of the Smithsonian Institution is primarily for the use of those employed in the Institution and its branches, and of others who come to it from outside for the purpose of research, but it extends the privilege of borrowing from its collections to all libraries. For many years this privilege has been taken advantage of increasingly.

No restrictions are placed on the loans, except that the librarian who borrows the material is expected to take the usual care of it and return it in a reasonable time. He also, of course, pays express charges both ways, for it is customary to send material and have it returned either by messenger, as in the case of Washington libraries, or by express.

Some books, especially duplicates, are occasionally sent out on semipermanent charge, to be used as an aid in special research, and to be kept as long as needed, or until called for. Rare and valuable books are seldom lent, but they may always be consulted at the library. Photostat copies of parts of them may also be made if desired.

The library not only lends material; it borrows it, too, and that almost daily. Some of this, especially from the Library of Congress, is sent to the library on semipermanent deposit, and constitutes a very important addition to its regular working collections.

The libraries with which the Smithsonian library carries on most regularly this exchange of material are, besides the Library of Congress, those of the Department of Agriculture, the Geological Survey, the Hygienic Laboratory, the Army Medical Museum, the Coast and Geodetic Survey, the Bureau of Fisheries, the Weather

Bureau, the Bureau of Mines, the Air Service, the National Research Council, the National Advisory Committee for Aeronautics, and the principal learned societies, colleges, universities, museums, and art galleries of the East and Middle West. It also lends to public libraries, and sometimes borrows from them.

Respectfully submitted.

William L. Corbin,
Librarian.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE PUBLICATIONS

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government bureaus under its administrative charge during the year ending June 30, 1926:

The Institution proper published during the year 8 papers in the series of Smithsonian Miscellaneous Collections, 1 annual report, and pamphlet copies of the 22 articles contained in the report appendix, and 1 special publication. The Bureau of American Ethnology published 1 annual report. The United States National Museum issued 1 annual report, 2 volumes of proceedings, 3 complete bulletins, 1 part of a bulletin, and 3 parts of 2 volumes in the series of Contributions from the United States National Herbarium, and 45 separates from the proceedings. The National Gallery of Art issued Catalogue of Collections, II.

Of these publications there were distributed during the year 168,932 copies, which included 147 volumes and separates of the Smithsonian Contributions to Knowledge, 20,222 volumes and separates of the Smithsonian Miscellaneous Collections, 35,671 volumes and separates of the Smithsonian annual reports, 1,945 Smithsonian special publications, 96,804 volumes and separates of the various series of National Museum publications, 12,993 publications of the Bureau of American Ethnology, 251 publications of the National Gallery of Art, 68 volumes of the Annals of the Astrophysical Observatory, 48 reports of the Harriman Alaska Expedition, 738 reports of the American Historical Association, and 65 publications presented to but not issued directly by the Smithsonian Institution or its branches.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

Of the Smithsonian Miscellaneous Collections, volume 73, 1 paper was issued; volume 77, 5 papers; volume 78, 2 papers; in all, 8 papers as follows:

VOLUME 73

No. 3. Opinions Rendered by the International Commission on Zoological Nomenclature. December 16, 1925. 40 pp. (Publ. 2830.)

VOLUME 77

No. 4. An Introduction to the Morphology and Classification of the Foraminifera. By Joseph A. Cushman. July 21, 1925. 77 pp., 16 pls., 11 text figs. (Publ. 2824.)

No. 8. The Morphology of Insect Sense Organs and the Sensory Nervous System. By R. E. Snodgrass. February 16, 1926. 80 pp., 32 text figs. (Publ. 2831.)

No. 9. Fossil Footprints from the Grand Canyon. By Charles W. Gilmore. January 30, 1926. 41 pp., 12 pls., 23 text figs. (Publ. 2832.)

No. 10. An Archeological Collection from Young's Canyon, near Flagstaff, Ariz. By J. Walter Fewkes. January 12, 1926. 15 pp., 9 pls., 3 text figs. (Publ. 2833.)

No. 11. Music of the Tule Indians of Panama. By Frances Densmore. April 16, 1926. 39 pp., 5 pls. (Publ. 2864.)

VOLUME 78

No. 1. Explorations and Field Work of the Smithsonian Institution in 1925. April 8, 1926. 132 pp., 128 text figs. (Publ. 2865.)

No. 2. Mexican Mosses Collected by Brother Arsène Brouard. By I. Thériot. June 15, 1926. 29 pp., 14 text figs. (Publ. 2867.)

SMITHSONIAN ANNUAL REPORTS

Report for 1924.—The complete volume of the Annual Report of the Board of Regents for 1924 was received from the Public Printer November 12, 1925.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1924. xii+535 pp., 103 pls., 43 text figs. (Publ. 2795.)

The appendix contained the following papers:

The origin of the solar system, by J. H. Jeans.
The electrical structure of matter, by Prof. Sir Ernest Rutherford.
The physicist's present conception of an atom, by R. S. Millikan.
The vacuum—there's something in it, by W. R. Whitney.
The use of radium in medicine, by Antoine Béclère.
Clear fused quartz made in the electric furnace, by Edward R. Berry.
The drifting of the continents, by Pierre Termier.
The probable solution of the climatic problem in geology, by William Ramsay.
A modern menagerie; more about the National Zoological Park, by N. Hollister.
Nests and nesting habits of the American eagle, by Francis H. Herrick.
The breeding places of the eel, by Johs. Schmidt.
Cankerworms, by R. E. Snodgrass.
A botanical trip to Ecuador, Peru, and Bolivia, by A. S. Hitchcock.
Orchid collecting in Central America, by Paul C. Standley.
Sketches from the notebook of a naturalist-traveler in Oceania during the year 1923, by Casey A. Wood.
Historical tradition and oriental research, by James Henry Breasted.
Shamanism of the natives of Siberia, by I. M. Casanowicz.
Egypt as a field for anthropological research, by Prof. P. E. Newberry.
North American Indian dwellings, by T. T. Waterman.
The nature of language, by R. L. Jones.
John Mix Stanley, artist-explorer, by David I. Bushnell.
Herluf Winge, by Th. Mortensen.

Report for 1925.—The report of the executive committee and proceedings of the Board of Regents of the Institution, and the report of the secretary, both forming parts of the annual report of the Board of Regents to Congress, were issued in pamphlet form in December, 1925.

Report of the executive committee and proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1925. 11 pp. (Publ. 2835.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1925. 122 pp. (Publ. 2834.)

The general appendix to this report, which was in press at the close of the year, contains the following papers:

The spiral nebulæ and the structure of space, by Carl Wirtz.
Immensities of time and space, by A. Vibert Douglas.
Certain aspects of high-pressure research, by P. W. Bridgman.
Lightning and other high-voltage phenomena, by F. W. Peek, jr.
Chemical elements and atoms, by G. Urbain.
The manufacture of radium, by Camille Matignon.
The chemistry of solids, by Cecil H. Desch.
Terrestrial magnetism in the twentieth century, by Daniel L. Hazard.
Some causes of volcanic activity, by Arthur L. Day.
Geology in the service of man, by W. W. Watts.
The yeasts: A chapter in microscopical science, by A. Chaston Chapman.
Tropical cyclones and the dispersal of life from island to island in the Pacific, by Stephen Sargent Visher.
Isolation with segregation as a factor in organic evolution, by David Starr Jordan.
The biological action of light, by Leonard Hill.
Animal life at high altitudes, by Maj. R. W. G. Hingston.
The nest of the Indian tailor bird, by Casey A. Wood.
The needs of the world as to entomology, by L. O. Howard.
From an egg to an insect, by R. E. Snodgrass.
The rôle of vertebrates in the control of insect pests, by W. L. McAtee.
Carnivorous butterflies, by Austin H. Clark.
The potato of romance and of reality, by W. E. Safford.
The relation of geography to timber supply, by W. B. Greeley.
The historical geography of early Japan, by Carl Whiting Bishop.
The excavations of the sanctuary of Tanit at Carthage, by Byron Khun de Prorok.
The Smithsonian Institution.
Sir Archibald Geikie, by Sir Aubrey Strahan.
Ned Hollister (1876–1924), by Wilfred H. Osgood.

SPECIAL PUBLICATION

North American Wild Flowers. Vol. 1. By Mary Vaux Walcott. 1926. Quarto, portfolio binding, 80 plates in color, 1 page descriptive text for each. (Not for general distribution; issued through subscriptions.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The publications of the National Museum are: (*a*) The annual report, (*b*) the Proceedings of the United States National Museum, and (*c*) the Bulletin of the United States National Museum, which includes the contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

During the year ending June 30, 1926, the Museum published 1 annual report, 2 volumes of proceedings, 3 complete bulletins, 1 part of a bulletin, 2 complete volumes and 3 parts of 2 volumes in the series Contributions from the United States National Herbarium, and 45 separates from the proceedings.

The issues of the bulletin were as follows:

Bulletin 100. Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. Volume 2, part 4. Silicious and Horny Sponges collected by the United States Fisheries steamer *Albatross* during the Philippine expedition, 1907–1910. By H. V. Wilson.

Bulletin 131. The Minerals of Idaho. By Earl V. Shannon.

Bulletin 132. Revision of the North American Moths of the Subfamilies Laspeyresiinae and Olethreutinae. By Carl Heinrich.

Bulletin 133. Observations on the Birds of Argentina, Paraguay, Uruguay, and Chile. By Alexander Wetmore.

Of the separate papers of the Contributions from the United States National Herbarium the following were issued:

Volume 22, part 9. Studies in American Phaseolineae. By C. V. Piper.

Volume 24, part 6. A Bibliographic Study of Beauvois' Agrostographie. By Cornelia D. Niles. With introduction and botanical notes, by Agnes Chase.

Volume 24, part 7. The North American Species of Stipa. Synopsis of the South American Species of Stipa. By A. S. Hitchcock.

Of the separates from the proceedings, 4 were from volume 66, 13 from volume 67, 25 from volume 68, and 3 from volume 69.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the bureau has continued under the direction of the editor, Mr. Stanley Searles.

During the year one annual report was issued.

Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society Known as "Those Who Worship the Little Spotted Buffalo"; The Traditional Origin of the Fox Society Known as "The Singing Around Rite," by Truman Michelson. 664 pp., 1 pl., 1 fig.

Publications in press or in preparation are as follows:

Forty-first Annual Report. Accompanying papers: Coiled Basketry in British Columbia and Surrounding Region (Boas, assisted by Haeberlin, Roberts, and Teit); Two Prehistoric Villages in Middle Tennessee (Myer).

Forty-second Annual Report. Accompanying papers: Social Organization and Social Usages of the Indians of the Creek Confederacy; Religious Beliefs and Medical Practices of the Creek Indians; The Culture of the Southeast (Swanton); Indian Trails of the Southeast (Myer).

Bulletin 82. Archeological Observations North of the Rio Colorado (Judd).
Bulletin 83. Burials of the Algonquian, Siouan, and Caddoan Tribes West of the Mississippi (Bushnell).
Bulletin 84. The Language of the Kiowa Indians (Harrington).

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian Institution and are communicated by him to Congress as provided by the act of incorporation of the association.

The annual report for 1920 and the supplemental volume to the report for 1922 were issued during the year. The annual reports for 1921 and 1922, and the supplemental volume to the report for 1923 were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Twenty-eighth Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with the law, on December 15, 1925.

SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication, to which are referred for consideration and recommendation all manuscripts offered to the Institution and its branches. Seven meetings were held during the year and 96 manuscripts acted upon.

Respectfully submitted.

W. P. True, *Editor.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDED JUNE 30, 1926

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution and a statement of the appropriations by Congress for the following Government bureaus in the administrative charge of the Smithsonian Institution: The National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the National Gallery of Art; also for an additional assistant secretary and for printing and binding for the fiscal year ended June 30, 1926.

SMITHSONIAN INSTITUTION

Condition of the endowment fund July 1, 1926

The sum of $1,000,000 deposited in the Treasury of the United States under act of Congress is part of a permanent endowment fund, which includes the original Smithson fund and additions accumulated by the deposit of savings and bequests from time to time. Subsequent bequests and gifts and the income therefrom, when so required, are invested in approved securities. The several specific funds so invested are now constituted and classed as follows:

Consolidated fund

Avery fund	$34, 690. 87
Virginia Purdy Bacon fund	62, 272. 93
Lucy H. Baird fund	1, 528. 09
Chamberlain fund	35, 000. 00
Hamilton fund	500. 00
Caroline Henry fund	1, 223. 33
Hodgkins general fund	37, 275. 00
Bruce Hughes fund	13, 839. 90
Morris Loeb fund	3, 519. 00
Lucy T. and George W. Poore fund	18, 536. 42
Addison T. Reid fund	7, 299. 16
Rhees fund	357. 34
George H. Sanford fund	675. 72
Smithson fund	1, 468. 74
Total consolidated fund	218, 186. 50
Charles D. and Mary Vaux Walcott research fund	11, 520. 00

The total amount of dividends and interest, etc., received by the Institution from the Freer estate during the year for all purposes was $255,354.66 and the amount received from sale of Freer estate stocks and bonds was $988,510.

The itemized report of the auditor, the Capital Audit Co., certified public accountants, is filed in the office of the secretary.

DETAILED SURVEY OF FINANCIAL OPERATIONS

Parent fund

Balance on hand or in time deposits, July 1, 1925		$7,062.45
Receipts:		
Income, consisting of interest and receipts from miscellaneous sources available for general purposes	$56,287.77	
International exchanges, repayments to the Institution	4,883.75	
Total receipts		61,171.52
Total resources for general purposes		68,233.97
General expenditures:		
Care and repair of buildings	8,087.04	
Furniture and fixtures	610.08	
General administration	25,298.01	
Library	3,225.03	
Publications (comprising preparation, printing, and distribution)	15,163.60	
Researches and explorations	4,526.05	
International exchanges	3,871.95	
Total general expenditures		60,782.56
Balance June 30, 1926		7,451.41

Funds for specific objects, including payment and return of funds advanced for field expenses and other temporary transactions during the year

Balance on hand or in time deposits July 1, 1925		$86,773.19
Receipts:		
Avery fund	$2,817.90	
Virginia Purdy Bacon fund	3,849.96	
Lucy H. Baird fund	87.21	
Laura Welsh Casey fund	5,000.00	
Frances Lea Chamberlain fund	1,995.00	
Costa Rica botanical explorations	800.00	
Endowment campaign donations	417.00	
Endowment campaign expense fund	25,500.00	
Endowment fund, general	20.80	
Dr. W. L. Abbott Haitian botanical expedition	10.00	
Hamilton fund	178.50	
Harriman trust fund	12,815.00	
Caroline Henry fund	70.68	
Hodgkins fund, specific	6,300.00	
Bruce Hughes fund	788.88	

Receipts—Continued.		
Jamaican botanical exploration	$550.00	
Morris Loeb fund	3,684.39	
National Gallery of Art building plans fund	20.89	
North American Wild Flowers publication fund	29,706.19	
Osage fund	500.00	
Paleontological researches	1,200.00	
Lucy T. and George W. Poore fund	2,657.20	
Addison T. Reid fund	1,076.10	
Rhees fund	54.78	
John A. Roebling funds	3,696.45	
W. A. Roebling mineral fund	1,000.00	
George H. Sanford fund	104.76	
American Silurian Crinoids Vol. fund, Springer	2,000.00	
Charles T. Simpson fund	750.00	
Smithsonian-Chrysler expedition	40,000.00	
Smithsonian Scientific Series fund	10,300.00	
Swales fund	800.00	
Charles D. and Mary Vaux Walcott fund	720.00	
Refund of temporary advances, etc	6,743.10	
Total receipts		$166,214.79
Total resources		252,987.98
Expenditures:		
Avery fund, invested and expended	2,038.32	
Virginia Purdy Bacon fund, expended	3,241.97	
Laura Welsh Casey fund, expended	766.57	
Chamberlain fund, for specimens, etc., expended	738.42	
Costa Rica botanical explorations, expended	800.00	
Endowment campaign expense fund, expended	26,859.28	
Haitian botanical explorations, expended	510.00	
Harriman trust fund, for researches and specimens, expended	11,069.83	
Hodgkins fund, specific for researches, expended	3,909.61	
Bruce Hughes fund, expended	7.00	
Jamaican botanical explorations, expended	550.00	
Morris Loeb fund, expended	4,380.95	
North American Wild Flowers publication fund, expended	58,146.10	
Osage fund, expended	14.32	
Paleontological researches, expended	505.00	
Lucy T. and George W. Poore fund, invested and expended	4,377.28	
Addison T. Reid fund, invested and expended	663.00	
Rocket investigation, Goddard	750.00	
John A. Roebling fund, solar research, etc., expended	16,188.95	
W. A. Roebling mineral fund, expended	588.84	
George H. Sanford fund, invested	60.40	
Charles T. Simpson fund, expended	338.38	
Smithsonian-Chrysler expedition, expended	39,334.51	
Smithsonian Scientific Series, expended	1,391.25	
Swales fund, for specimens, expended	353.21	

Expenditures—Continued.		
Charles D. and Mary Vaux Walcott fund, expended	$111.00	
Temporary advances for field expenses, etc	3,953.26	
Total expenditures		$181,647.45
Balance June 30, 1926		71,340.53

Charles L. Freer bequest

Balance on hand or in time deposits, July 1, 1925		$78,117.11
Receipts:		
Dividends, interest, and miscellaneous receipts	$255,354.66	
Sale of stocks and bonds	988,510.00	
Total receipts		1,243,864.66
Total resources		1,321,981.77
Expenditures:		
Operating expenses of the gallery, salaries, purchase of art objects, field expenses, and incidentals	$153,934.37	
Investments in sinking fund, including interest	127,602.50	
Reinvestment of funds from sale of stocks and bonds	984,347.44	
Total expenditures		1,265,884.31
Balance June 30, 1926		56,097.46

SUMMARY

Total balances of all funds, July 1, 1925	171,952.75
Receipts during year ending June 30, 1926:	
Parent fund for general expenses	61,171.52
Revenue and principal of funds for specific objects, except Freer bequest	166,214.79
Freer bequest	1,243,864.66
Total	1,643,203.72
Expenditures:	
General expenses of the Institution	60,782.56
Specific objects, except Freer bequest	181,647.45
Freer bequest	1,265,884.31
Total balances of all funds June 30, 1926	134,889.40
Total	1,643,203.72

All payments are made by check, signed by the Secretary of the Institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In some instances deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven satisfactory. During the year the interest derived from this source, together with other similar items, has resulted in a total of $1,748.21.

The following appropriations for the Government bureaus in administrative charge of the Smithsonian Institution were made by Congress for the fiscal year 1926:

Bureau:		Appropriation
International Exchanges		$46,260
American Ethnology		57,160
International Catalogue of Scientific Literature		8,000
Astrophysical Observatory		31,180
Additional Assistant Secretary		6,000
National Museum—		
Furniture and fixtures	$21,800	
Heating and lighting	77,560	
Preservation of collections	441,082	
Building repairs	12,000	
Books	1,500	
Postage	450	
		554,392
National Gallery of Art		21,028
National Zoological Park		157,000
Printing and binding		90,000
Total		971,020

Respectfully submitted.

Henry White,
Frederic A. Delano,
R. Walton Moore,
Executive Committee.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDED JUNE 30, 1926

ANNUAL MEETING DECEMBER 10, 1925

Present: The Hon. William H. Taft, Chief Justice of the United States, chancellor; the Hon. Charles G. Dawes, Vice President of the United States; Senator Reed Smoot; Senator Woodbridge N. Ferris; Representative Albert Johnson; Representative R. Walton Moore; Mr. Charles F. Choate, jr.; Mr. Henry White; Mr. Robert S. Brookings; Mr. Frederic A. Delano; and the secretary, Dr. Charles D. Walcott.

APPOINTMENT OF REGENTS

The secretary reported the following appointments: Ex officio, March 4, 1925, Vice President Charles G. Dawes; by the President of the Senate, March 11, 1925, Senator Woodbridge N. Ferris, of Michigan, to fill the vacancy caused by the expiration of the term of Senator A. O. Stanley; by joint resolutions of Congress, citizen regents for six years, January 7, 1925, Mr. Robert S. Brookings; February 26, 1925, Judge George Gray.

DEATH OF JUDGE GRAY

The secretary announced the death of the Hon. George Gray on August 7, 1925, who was first appointed as a senatorial regent on December 20, 1892, serving until the expiration of his term on March 2, 1899. He was next appointed as a citizen regent on January 14, 1901, and served until August 7, 1925.

Throughout this long service, the last 10 years of which he was chairman of the executive committee, Judge Gray was an active supporter of the work of the Institution and always ready to give time and thought to its interests. He was a valued member of the board and will long be missed both personally and officially.

Mr. Choate offered the following resolutions, which were adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned of the death on August 7, 1925, of the Hon. George Gray, a member of the board for over 30 years, the last 10 of which he served as chairman of the executive committee: Be it therefore

Resolved, That the board here place on record an expression of their profound sorrow at the passing away of their colleague, whose deep interest and wise judgment in the affairs of the Institution, to which he was always ready to devote his great learning and experience, made him a valued coworker in its behalf, and one whose loss will be keenly felt.

Resolved, That while Judge Gray's distinguished career as United States Senator, jurist, and public-spirited citizen had won for him a high and secure position on the roll of our country's honored men, it is desired to add a tribute to his personal qualities, his never-failing courtesy, and his charm of manner, which endeared him to his colleagues on this board.

Resolved, That a copy of these resolutions be transmitted by the secretary to the family of our deceased associate, with the respectful sympathy of the board in the loss they have sustained.

VACANCY IN THE EXECUTIVE COMMITTEE

The secretary stated that Judge Gray's death had caused a vacancy in the membership of the executive committee, which the chancellor had filled by an ad interim appointment of Mr. Moore; and, further, that at a recent meeting of the committee Mr. White had been elected chairman.

Mr. Johnson offered the following resolutions, which were adopted:

Resolved, That the temporary appointment of the Hon. R. Walton Moore as a member of the executive committee be approved and made permanent.

Resolved, That the election by the executive committee of Hon. Henry White as chairman be confirmed.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE

Mr. White, as chairman of the executive committee, submitted the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1927, be appropriated for the service of the Institution, to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

Mr. White submitted in print the annual report of the executive committee, showing the financial condition of the Institution at the close of the fiscal year 1925.

ANNUAL REPORT OF THE PERMANENT COMMITTEE

Solar radiation researches.—As stated previously, this work is under the direction of Dr. Charles G. Abbot, assistant secretary of the Institution and director of the Astrophysical Observatory; and his report shows satisfactory progress at the stations at Mt. Montezuma, Chile; Table Mountain, Calif.; and at Washington, D. C. The operations have been financed by an annual grant of $5,000 from the Hodgkins fund of the Institution, and through the generosity of Mr. John A. Roebling.

National Geographic Society grant.—This organization has recognized the necessity for a new solar radiation station in the Eastern Hemisphere, to cooperate with those of the Astrophysical Observatory in Chile and California, and has generously made a grant of $55,000 to Doctor Abbot for the purpose of installing such a station. Doctor Abbot recently sailed for Europe and Africa for the purpose of selecting the best possible site for the new station.

Freer sinking fund.—This fund, as has been explained, was established for the purpose of safeguarding the principal and income of the Freer Foundation. Under the plan of reinvesting a certain excess of the income, the fund has now reached the sum of $262,347.50.

Consolidated fund.—This fund consists of bequests, gifts, and interest earnings, in excess of the $1,000,000 authorized by law to be deposited in the United States Treasury at 6 per cent interest. It now amounts to $218,186.50.

Increase of endowment.—Under the authority of the board, the permanent committee has inaugurated a movement for increasing the endowment of the Institution.

ANNUAL REPORT OF THE SECRETARY

In presenting his printed annual report to June 30, 1925, the secretary said that since the last annual meeting of the board, 132 publications have been issued, 67 of these by the Institution proper, 62 by the National Museum, and 3 by the Bureau of American Ethnology. During the fiscal year 1925 the Institution distributed 171,865 copies of its publications. Two papers by your secretary have summarized several seasons' work on certain of the life forms of the Cambrian and Lower Ozarkian rocks of the Canadian Rockies; three papers by Assistant Secretary Abbot and his associates, presenting a résumé of 20 years' work on the sun's radiation and the present status of the investigation on the relation of solar radiation to weather, have attracted wide and favorable attention from meteorologists throughout the world; a paper by Doctor Cushman on the foraminifera, which are minute fossil forms now used in locating and defining oil strata, has been in constant demand by the oil companies and by universities for training the much needed young oil geologists.

It was stated in the 1924 report that an effort would be made to issue two Smithsonian annual reports in order to bring them up to date. This was accomplished, the reports for 1923 and 1924 having both appeared, and the manuscript for the 1925 volume is now ready to go to the printer.

The National Museum issued the usual number of proceedings, papers, and several bulletins, including the monographic work on the Spider Crabs of America, by Mary J. Rathbun, and another of the popular series on Life Histories of North American Birds, by A. C. Bent. The outstanding publication by the Bureau of American Ethnology was the Handbook of the Indians of California, by Kroeber, for which there is an increasing demand.

ANNUAL REPORT OF THE NATIONAL GALLERY OF ART COMMISSION

The fifth annual meeting of the commission was held December 8, 1925. The report of the secretary of the commission for the calendar year 1925 stated that additions to the collections fell short of the average of previous years, not greatly exceeding a hundred thousand dollars in estimated value, which was attributable in large part to the lack of suitable housing space. The most noteworthy accessions were: A statue of Carrara marble, entitled the Lybian Sibyl, by W. W. Story, gift of the Henry Cabot Lodge estate; and a marine painting by Edward Moran, a bequest of Mrs. Clara L. Tuckerman; also an important collection of art objects and ceramics, presented and bequeathed by the Rev. Alfred Duane Pell, of New York.

The commission was of the opinion that it would be advisable to assemble at the National Gallery at intervals of five or more years all of the paintings purchased through the Ranger fund, in view of the provision that the National Gallery may reclaim any picture so purchased during the five-year period beginning 10 years after the death of the artist represented. By thus assembling the pictures a more intimate knowledge could be gained of them, and the wisest selection would thus be assured. Fifty-two paintings have been acquired and distributed to various institutions in accordance with the terms of Mr. Ranger's will during the four years since the bequest became operative.

Consideration was given to the matter of procedure in considering acceptance of bequests and gifts of art works, and after discussion the following resolution was adopted:

"*Resolved*, That the advisory committee of the National Gallery of Art Commission shall consist of the full membership of the commission; that in carrying out the functions of the advisory committee a quorum shall consist of seven members, four of whom shall be artists or museum directors."

The present officers, Mr. Gari Melchers, chairman, and Dr. W. H. Holmes, secretary, and the executive committee, were then reelected for the ensuing year.

The report of the commission was accepted and Mr. Johnson submitted the following resolutions, which were adopted:

Resolved, That the Board of Regents hereby approves the recommendation of the National Gallery of Art Commission that W. K. Bixby, W. H. Holmes, and H. L. Pratt be reelected as members of the commission for the ensuing term of four years, their present terms having expired.

Resolved, That the board also approves the recommendation of the commission that John Russell Pope, architect, be elected a member of the commission to fill the vacancy caused by the termination of the appointment of A. Kingsley Porter.

ADMINISTRATIVE APPOINTMENTS BY THE SECRETARY

The secretary announced the appointment of Dr. Alexander Wetmore as assistant secretary of the Smithsonian Institution, and of Dr. William M. Mann as superintendent of the National Zoological Park.

GOVERNMENT ACTIVITIES UNDER THE INSTITUTION

The secretary made a comprehensive statement regarding the estimates and appropriations for the Government branches under the administrative charge of the Institution.

INVESTMENTS OF THE FREER FUND

The board adopted the following resolution as submitted by Mr. Moore:

Resolved, That the permanent committee be, and it is hereby, authorized to sell any part of the stock * * * held under the will of Mr. Freer at such price as it may think desirable, after ascertaining all the facts that are available, and invest the proceeds in high-grade bonds and mortgages.

ASTROPHYSICAL OBSERVATORY

The National Geographic Society having made a grant of $55,000 to Doctor Abbot to select and install a new solar radiation station in the Eastern Hemisphere, to cooperate with those of the Astrophysical Observatory in Chile and California, Doctor Abbot sailed on October 31 via England and France on this mission.

Inspection of weather records show that three suitable regions remain distinct from those occupied and from each other. These are southwest Algeria, northeast Baluchistan, and South Africa. Doctor Abbot will examine these and install the new observatory in the most promising one.

Having found from five years' experience that summer conditions are unfavorable at the solar station on Mount Harqua Hala, Ariz., that station has been removed to Table Mountain, Calif., at a cost of about $10,000, defrayed by Mr. John A. Roebling. The new location has an altitude of 7,500 feet, being 2,000 feet higher than Harqua Hala, and is more accessible. Observations during the past 10 months indicate that it will prove superior to Harqua Hala.

Mr. Roebling, who has given over $123,000 to promote the Smithsonian solar investigations and the studies of world weather based thereon, has withdrawn further support, as he thinks that the time has come for others to carry on the work.

FREER GALLERY OF ART

Early in October word was received from Mr. Carl W. Bishop, associate curator of the Freer Gallery and leader of its archeological expedition to China, that Governor Yen Hsi-siang, of Shansi, had given him permission to operate anywhere within the boundaries of his Province. This constitutes by far the most important forward step taken since the work began, two and a half years ago; and for the first time in history the difficult task of prosecuting archeological research in China openly and on a basis of cooperation with the Chinese authorities was begun. This is the only method from which results of full scientific value may be reasonably expected.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1926

ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1926.

THE NEW OUTLOOK IN COSMOGONY[1]

By J. H. Jeans

Astronomy has always stood aloof from the other sciences; her field of research is apart, her methods are entirely her own, and, most significant of all, her results have different values from those of other sciences. While these reward mankind by utilitarian gifts, new methods for the production of wealth, the increase of pleasure or the avoidance of pain, astronomy has so far given us only food for intellectual contemplation. This is preeminently true of cosmognony, the branch of astronomy which is concerned with the problem of how the astronomical bodies come to be where they are and as they are.

From the practical standpoint, the outstanding difference between astronomy and the other sciences is the difference of scale. Most sciences progress by pursuing nature into the realms of the infinitely small, but for astronomy and cosmogony progress lies in the direction of the infinitely great, or, to be more exact, of the unthinkably great. For we now know with fair certainty that there is no infinitely great. A number of considerations combine to show that the universe is finite, and it is just because we know this, and are beginning to discover the actual limits to the size of the universe, and to its duration in time, that the present position in astronomy and cosmogony is of quite unusual interest. These sciences stand to-day somewhat in the position in which geography found itself when the world had been circumnavigated and the limits of what remained unexplored first begun to be known.

It was not until 1838 that the distance of a star was measured, and the scale of structure of the universe revealed. In that year three astronomers, Bessel, Henderson, and Struve, independently measured the distances of three different stars. In each case the method employed was the "parallactic" method: the motion of the earth in its orbit causes the near stars to appear to move against the background formed by the remote stars, and from observations of the amount of this apparent motion the distances of the near stars can be deduced. But it has long been clear that the majority of

[1] Reprinted by permission from The Nineteenth Century and After, Vol. XCVIII, No. 586, December, 1925.

stars are much too far away for their distance to be measured in this manner, and in no event could the method tell us the distances of the most remote stars in the universe, for it can not succeed unless the star under observation is seen against a background of even more distant stars. It is only quite recently that other methods have provided a measure for sounding the furthest depths of the universe.

The most fruitful of these methods depends on the special properties of a certain class of stars called "Cepheid variables," after their prototype, the star δ Cephei. These stars do not shine with a steady light; at intervals which are always perfectly regular, but may range for different stars from a few hours to several days, they flash out to two or three times their original brightness. Just as the mariner recognizes a lighthouse from amongst a crowd of other lights by the regular succession of its flashes and the nature of these flashes when they come, so the astronomer recognizes a Cepheid variable by the regularity, period, and nature of its light variations. In 1912 Miss Leavitt, of Harvard Observatory, discovered a simple relation between the periods and the luminosities of the Cepheids which occur in the Smaller Magellanic Cloud; the slower the light variation of the Cepheid the more luminous it is—broadly speaking, its luminosity varies inversely as a definite power of its period. More recently Doctor Shapley, the present director of Harvard Observatory, has shown that this relation, now generally known as the "period-luminosity law," is true of Cepheid variables in general. Whenever the astronomer detects a Cepheid variable and can measure the length of its period, he can deduce the amount of light it emits. By comparing this with its apparent brightness, as observed through a terrestrial telescope, it is easy to determine its distance from us. The method is simply that of a mariner who estimates his distance from land by identifying a lighthouse, looking up its candlepower in a book of reference, and noticing its apparent brightness at the spot where he happens to be. The analogy to the parallactic method would of course be if the mariner, knowing the speed of his ship, should try to estimate his distance from land by noticing the rate at which a church spire or chimney on the coast appeared to move against a background of distant hills. This method does not demand the existence of a lighthouse of known candlepower, but would obviously be useless for a mariner far out at sea, and, as we have already noticed, it could in no case give the distance of the most remote objects visible.

The discovery of the "period-luminosity law" opened up a new world as regards exact survey of astronomical distances. It was first used by Doctor Shapley himself to determine the distances of the remarkable objects known as "globular star clusters." These, as their name implies, are closely packed groups of stars of approximately globular shape; seen through a powerful telescope, they look rather like a swarm of bees, and produce the impression of being nests or birthplaces of families of stars. Only 69 of these objects are known, and, as practically no new ones have been discovered since the time of the Herschels, it is likely that there are none left to discover. They are all rich in Cepheid variables. Doctor Shapley finds that the distances of these 69 clusters range from 21,000 to 216,000 light-years. In this and similar measurements the light-year is taken as the unit of distance because it is futile to express astronomical distances in terms of miles or other ordinary terrestrial standards of measurement. Light takes some eight minutes to travel from the sun to the earth, so that in one year it travels about 64,000 times the distance from the earth to the sun; this is the distance that the astronomer describes as one light-year and takes as his unit of length. We begin to realize what is meant by the distance of a star cluster being hundreds of thousands of light-years if we reflect that what our telescope shows us is not the star-cluster as it now is, but the cluster as it was when primeval man dwelt on earth. Through the long prehistoric ages, through the slow dawn of civilization, and through the rise and fall of empires and dynasties, the light which left the cluster in remote ages has been traveling toward us at the rate of 186,000 miles every second and has only just reached us.

Quite recently Doctor Hubble, of Mount Wilson Observatory, has discovered Cepheid variables in certain of the spiral nebulæ, and so is able to estimate the distances of these nebulæ. The most remote of the nebulæ so far discussed proves to be the well-known "Andromeda nebula" (M. 31), at a distance of 950,000 light-years; others are at comparable distances. Using a slightly different method, Doctor Shapley has estimated the distance of the star cloud N. G. C. 6822 as being about a million light-years.

The two objects just mentioned are the most remote at present known. Are we to suppose that they fix the approximate limits of the universe, or must we look forward to a continual expansion of the observed size of the universe as the power of our telescopes continually increases? It is not possible to give a final answer to this question, but a considerable mass of evidence points to the former alternative as being probably the true one. Our sun is one of a group of some two or three thousand million stars which form a disk-shaped or biscuit-shaped structure girdled by the Milky Way. It has long been understood that this particular star group can not be of infinite extent. If it were, the sky would appear as a continuous blaze of light, and the gravitational force produced by this infinite mass of stars would be so intense that our sun and other stars would move with almost infinite velocities. The star field can not even be of uniform density as far as our telescopes can reach, for if it were the number of stars visible in different telescopes would be proportional to the cubes of their apertures. This is not in actual fact found to be the case; a 2-inch telescope has ten times the aperture of our naked eye, but does not reveal a thousand times as many stars. Thus the stars must thin out quite perceptibly even within the distances we can sound with a 2-inch telescope. By a refinement of this method it has been found possible to explore the limits of size of the star field of which our sun is a member and to estimate the number of stars it contains.

This star field, although it may quite possibly be the largest single object in the universe, is by no means the whole universe. Outside it, or possibly on its outer confines, lie a variety of other objects, in particular the star clusters, all of which are much smaller, and the spiral and other nebulæ, the largest of which approximate to it in size. The theory of "island universes" which was originally propounded by Sir W. Herschel, but subsequently fell into disfavor, seems to be reinstated by recent observational work, and we now get the best picture of the universe by thinking of it as consisting of a number of subuniverses, detached from one another like islands on an ocean. We can form a rough estimate of the extreme distance of some of these islands from a consideration of the extreme faintness of the individual stars; but the Cepheid variables, the lighthouses on these islands, enable the astronomer to map out their positions with comparative accuracy. Our own star system is a very big island indeed, with the sun not far from its center; the big nebula in Andromeda is another big island, smaller but of comparable size; while the star clusters and smaller nebulæ are islands on a smaller scale. Considerations similar to those already mentioned, which enable astronomers to assign limits to the size of our star field, show that we must also fix limits to this ocean of island universes, and it seems probable that the limits do not lie very far beyond the two most remote objects whose distances have so far been measured, namely, the spiral nebula M. 31 at 950,000 light-years, and the star cloud N. G. C. 6822 at about 1,000,000 light-years.

To fix our ideas we may suppose, although it is little more than a guess, that the most remote objects of all in our universe are at four times the distance of these two remote objects, and so at 4,000,000 light-years from us. We may now attempt to get these ideas into focus by constructing a model of the complete universe on the scale of a million million miles to the foot. The amount of reduction involved in such a scale is best visualized, perhaps, by thinking in terms of motions rather than of distances. Light, which can circle the earth seven times in a second, would move in our model with a speed rather below that at which a blade of grass grows in the spring. On this scale the whole universe will be represented by a sphere of the size of our earth, the star cloud of which our sun is a member will be an island of about the size of Yorkshire, while the big Andromeda nebula will be rather larger than the Isle of Wight, although with very ill-defined boundaries. The whole solar system in this model can be easily covered by a grain of sand, while our earth, now shrunk to less than a ten-millionth of an inch in diameter, is hardly larger than a single molecule in this grain of sand.

Such is the universe which the astronomer hands over to the cosmogonist for interpretation. The cosmogonist, accepting the universe as it is, must try to discover why it is thus and not otherwise. What the astronomer regards as a compilation of observed facts is for the cosmogonist the last link in a long chain of processes, a crosscut through the warp and the woof of cause and effect. While the astronomer is satisfied if he can see the universe as it is, the cosmogonist must ever strive to see it as it has been and as it will be. Just as one of the astronomer's main problems is to assign limits to the universe in space, so one of the main problems for the cosmogonist is to assign similar limits in time.

There must be such limits. The universe can not go on forever as it now is, and neither can it have existed in its present condition from all eternity. Every star is continually radiating energy away into space, and we have no knowledge of any appreciable part of this radiation coming back or of the stars replenishing their sources of energy in any way. The universe is running down like a clock which no one winds up.

The sun has some ten thousand million million million square inches of surface, and every square inch is radiating away energy at a rate which represents the energy output of a 50-horsepower engine. If this energy were supplied to the sun from a power station, coal would have to be burned at the rate of about a million million million tons a minute. This makes it clear that the sun's energy can not, as was at one time thought, originate in the combustion of the sun's mass. At a later date Meyer suggested that the sun's energy might be continually replenished by the infall of meteorites, while Helmholtz subsequently propounded his well-known contraction theory, according to which the energy of the sun's radiation is provided by the falling in of the sun's mass under his own gravitational attraction. Both these theories implied limits to the duration of the sun's radiation, and both limits were far too short to accord with known facts. Meteorites could not have been falling into the sun forever, or the sun would already be of infinite mass; in actual fact it was shown that meteorites could not have been falling into the sun at the requisite rate for more than about 20,000,000 years, or the sun would by now have become more massive than it actually is. Similarly as regards the Helmholtz theory—the sun can not have been contracting to the requisite extent for more than about 20,000,000 years, or it would have shrunk already to less than its present dimensions.

Such periods of time are impossibly small for the sun's life. Geologists find evidence that things have been much as they now are on our earth for periods of at least hundreds of millions of years, while physical research on the radioactive contents of certain Canadian rocks fixes their age at 1,400,000,000 years at the least, and analysis of other rocks gives confirmatory evidence. If, as is generally accepted, the sun is the parent of our earth, the sun must at least be older than the oldest of terrestrial rocks. It was at one time thought possible that radioactivity could provide our sun with energy for an almost unlimited span of radiation, but the possibility did not materialize. Sir Ernest Rutherford calculated that even if the sun started life in the most radioactive state possible, namely as a sphere of pure uranium, its radioactivity could provide for at most 5,000,000 years of radiation at the present rate. It was by now abundantly clear that the true source of the sun's energy must be such as to provide the sun with a length of life of a different order of magnitude from anything hitherto thought of.

In 1905 Einstein's first theory of relativity appeared. This required that an increase in the energy of any material system should be accompanied by an increase in its mass. It had for some years been recognized as a special property of electrified bodies that their mass increased pari passu with their energy; the theory of relativity now showed this to be a general property of matter in all states and conditions. The converse must of course also be true, so that a body, such as our sun, which is losing energy by radiation must also be losing mass. When the rate of loss of energy of any body is known, it is easy to calculate the corresponding rate of loss of mass; from the sun's known rate of radiation it is found that its mass must be diminishing at the rate of about 250,000,000 tons a minute.

This statement does not necessarily imply that there are fewer atoms or molecules in the sun at the end of the minute than there were at its commencement. If the sun were merely cooling down, like a red-hot cannon ball suspended in space, the heat agitation of each molecule would be less at the end of each minute than at its commencement, so that, on the average, the molecules would be moving more slowly and so have smaller mass. The aggregate of the decreases of mass of all the innumerable molecules in one minute would amount to exactly the 250,000,000 tons in question. The crux of the situation lies in the circumstance that at most a millionth part of the total mass of the sun is of this easily shed kind, and that if this were the only part of its mass of which the sun could dispossess itself, its radiation could not possibly last for more than a few millions of years. Suppose, however, that processes are at work in the sun's interior by which the molecules can be not merely slowed down, but actually annihilated. In such a case the whole mass of the annihilated molecule is turned into energy, and the whole mass of the sun—two thousand million million million million tons—becomes available for transformation into radiation. At the present rate of radiation, represented by 250,000,000 tons a minute, the total mass of the sun would provide radiation for fifteen million million years.

The most likely way in which mass could be completely transformed into radiation would be by the positive and negative electric charges of which all matter is constructed rushing into one another and mutually annihilating one another. When the two terminals of a charged Leyden jar are brought into contact, we see a spark and hear a snap—a thunderstorm in miniature—which show that energy has been set free somewhere. In actual fact we know that the energy came from the rushing together of electric charges of opposite sign which have neutralized one another. Recent research has shown quite conclusively that a hydrogen atom consists of two electrically charged particles, one, the electron, being negatively charged, and the other, the proton, being positively charged; there is nothing else. If these two charged particles could be brought into actual contact it is fairly certain that the charges would neutralize one another, and, as we have no experience of uncharged electrons or protons, it may reasonably be supposed that the electron and proton would annihilate one another also. It is even more probable that there would be nothing left to annihilate, for it is already known that the whole mass of the electron comes from its electric charge, so that to speak of an uncharged electron is a contradiction in terms, and the same is almost certainly true of the proton. Thus, in the falling together of the electron and proton of the hydrogen atom, the whole mass of the atom ought to be transformed into radiation. It hardly seems likely that more complex atoms would annihilate themselves in a single process of the kind; more probably there would be a successive falling in of electrons one at a time, so that the atom would gradually diminish its mass, and, of course, also its complexity. But the details of the process are unimportant; in whatever way the annihilation of mass is achieved, the final result is the same, as also, of course, is the total amount of radiation which is set free.

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In 1914 Professor H. N. Russell, of Princeton, propounded a scheme of stellar evolution whose main features at least have won general acceptance. According to this scheme, all the stars are moving down the same evolutionary ladder. Some start at the top, some perhaps join in part of the way down, but all pursue the same course and all end in the same way. At the top of the ladder are stars of the very highest luminosity, radiating perhaps ten thousand times as much light and heat as our sun. Moving down the ladder, the luminosity of the stars decreases, we pass stars like Sirius radiating some forty times as much as our sun, then, well down on the ladder, our sun and stars of similar luminosity; finally, on still lower rungs, are stars so faint as to be almost invisible. No doubt there are even lower rungs occupied by stars which have become perfectly invisible, but these need not concern us here.

Since the appearance of Russell's theory, it has gradually emerged that the stars on the highest rungs are of far greater mass than those on the lowest rungs. Not only so, but all the stars on any one rung—i. e., all stars having the same luminosity—are of approximately equal mass, and there is a gradual diminution of mass as we pass down the ladder. If, then, as there is no serious reason for doubting, the stars are all moving down the ladder as their evolution progresses, it follows that they must all the time be diminishing in mass. Having reached this conclusion, it becomes natural to conjecture that the diminution of mass precisely represents the output of radiation. The hypothesis becomes something more than a conjecture when it is found that it satisfies every quantitative test which can be applied to it.

Since the rate of radiation of the stars on each rung of the ladder is known, it becomes an easy matter to calculate the rate at which they would be moving down the ladder on the hypothesis that their diminution of mass is the exact equivalent of their radiation. A simple addition then gives the time which a star would take, on the same hypothesis, to pass from any one rung of the ladder to any other. It is found, for instance, that the time from Sirius to our sun is about 6,400,000 years; from the brightest of known stars to the faintest is of the order of two hundred million million years, while from the brightest to our sun is rather over seven million million years. It is significant that these hypothetical ages for different types of stars fit in well with estimates that can be made from certain purely astronomical evidence which is wholly independent of any hypotheses as to the source of steller radiation. Unfortunately the evidence is all too technical for discussion here, but it leaves little room for doubt that the long-standing problem of the origin of stellar radiation has been solved, and that the solution is the amazingly simple one that the origin of a star's heat is the star's mass. He lives by transforming his mass into radiation; we can estimate his present age by noticing how much of him is left, and another calculation, based on the same datum tells us how much longer a life he may expect. The interval from top to bottom of the evolutionary ladder, about two hundred million million years, is the total life of a star, and stars differ one from another mainly in being merely higher or lower on the ladder, younger or older.

The ages of the stars are not the same thing as the age of the universe, nor even are they necessarily comparable with that age. The stars may be likened to icebergs coming down from the North and melting as they drift into tropical waters. We can estimate the ages of the icebergs within our vision, but we can not say for how long the stream of icebergs has been drifting down from pole to equator nor for how long new icebergs will continue to form and come down to replace those that pass southward to their doom. Over the polar regions where the icebergs are born a veil of fog is drawn, and we do not know how to look behind that veil. But the problem of the ages of those stars which are now in being is a comparatively simple one, and for all practical purposes these constitute the universe for the astronomer and cosmogonist alike. To each star can be assigned a total span of life of the order of a hundred million million years followed by darkness and possibly ultimate extinction; to our sun we can assign a past life of about seven million million years, so that as regards time, although not as regards magnificence, the greater part of his life is yet to come.

The ages which we must now attribute to our sun and the other stars are many hundreds of times longer than was, until quite recently, thought probable or even possible. This extension of the time scale will call for a rearrangement of ideas in many departments of cosmogony and astronomy. Many of the questions involved are of a highly technical nature, but one is comparatively simple as well as of great interest. Of the various theories which have been put forward to explain the origin of our earth and the other planets, the so-called tidal theory seems (to the present writer at least) to offer enormously more advantages and to be open to far fewer objections than any of the others. According to this theory, our sun, some time in the past in his voyage through space, must have encountered a star more massive than himself traveling on a course which came so near to his own that enormous tides were raised on his surface, tides of such colossal height that the tops of the tidal waves lost all contact with the underlying parts and started on independent careers of their own as planets. When submitted to mathematical treatment this theory shows itself able to account for the main features of the arrangement of the solar system in a very gratifying way. It was, however, until quite recently, open to one very serious objection. The distances of the stars from one another are enormously great in comparison with their dimensions. If we take six cricket balls and place one each in Europe, Asia, Africa, Australia, North America, and South America, we have a model showing the arrangement of the six stars nearest to our sun and their distances apart relative to their dimensions. Since the stars are generally very many of their diameters apart, it must be a very rare event for their tracks to come to within a few diameters of one another, and yet the tidal theory requires an approach to within less than two diameters before planets can be born. Under the old views as to the ages of the stars it was exceedingly unlikely that a specified star such as our sun should have experienced so close an approach throughout the whole of his life, and this constituted a serious objection to the tidal theory. But the recent extension of the ages of the stars has removed this reproach; stars which have wandered about amongst other stars for millions of millions of years must be expected to have had several fairly close approaches to their neighbors. Even now, however, approaches of the extreme closeness necessary to give birth to planets must be counted as somewhat rare; a small proportion only of the stars in the sky are likely to be surrounded by families of planets and so to form possible abodes of life.

At one time it seemed possible that cosmognony might come down from her lofty pedestal and make good for her former deficiency in the matter of utilitarian gifts by bringing the most utilitarian gift of all—the secret of obtaining free energy. For if the stars are incessantly turning matter into energy, there would seem to be no reason why mankind should not learn their secret, and obtain mechanical power by annihilating small quantities of matter instead of laboriously winning, transporting, and burning millions of tons of coal; the total consumption of coal in the British Isles produces less heat, light, and energy than could be obtained by the annihilation of an ounce of matter per day. But, so far as can at present be seen, this dream is not destined to be fulfilled. An analysis of the facts of astronomy suggests that there must be all sorts and types of matter mixed together in the stars; some only, not all, of these types are changing into energy at an appreciable rate, and these particular types, for good or for bad, are absent from our earth. They probably consist of elements heavier than uranium, the heaviest element known on earth; it is even possible that the capacity for spontaneous disintegration shown by the atoms of uranium and the other radioactive elements, the heaviest of terrestrial substances, may represent the surviving vestiges of an earlier power of these same atoms to lessen their mass by throwing off radiation.

INFLUENCES OF SUN RAYS ON PLANTS AND ANIMALS

By C. G. Abbot

[With 5 plates]

The delight which we take in the lovely shapes, colors, and odors of the many species of flowering plants suggests a different emphasis on a famous argument. Hardly any work was more celebrated in its time than Dean Paley's "Natural Theology," although it is little read now. The author conceives one to be wandering upon a desolate moor remote from human habitation. He chances to strike his foot upon a round object so curious as to arouse his careful attention. It is, in short, a watch, provided with the little wheels, the springs, the hands, the hour marks, and all the intricate parts that we know so well. Although there is no man in sight, nor indeed any habitation for many miles, there arises this conclusion: The plain evidence of complex contrivance for a sagacious purpose demands the previous existence of a highly intelligent contriver. The watch could not just have happened to come into being.

We need not follow the logical unfolding of the theme, in which the able Dean argues from the evidences of design in the human body to the existence of an intelligent creator. Paley's argument was indeed illustrated mainly from the animal kingdom, but, as we shall see, plants exhibit adaptations almost equally curious.

Our present thought, however, is slightly different. Such contrivances as the human eye and ear, and others which Paley refers to, are plainly suitable means to attain certain objects of utility. If they be evidences of design, the character of the Designer that seems to be suggested is the careful Parent providing necessary things for the use of His children. But a rose or a violet seems to turn our thought differently. It might well be the expression of a beauty-loving, benevolent, pleasure-providing Creator, designing not merely necessities, but delicately refined joys and pleasures, for the promotion of graces of character in His noblest creatures.

The sun's place in plant life is more extraordinary by far than it is in the animal economy. Growing vegetation is a laboratory where sun rays unite carbonic acid gas of the air with watery fluid brought up through the roots of the plant, building up from these two simple materials some of the most complex substances known to organic chemistry. Although consisting mainly of water, traces of the other chemical elements are dissolved in the fluid which the roots imbibe, sufficient to complete those complex compounds so indispensable to life.

It has been estimated that a square mile of dense hardwood forest may use over 500 tons of carbonic acid gas and over 1,000,000 tons of water in a season for such chemical activities. In dry countries such prodigality with water would be, of course, impossible. This figure represents a depth of nearly 1½ feet of liquid water over the whole area, which is from one-third to one-sixth of the total yearly rainfall of very moist climates, and exceeds by fivefold the yearly rainfall of some of the great deserts.

Only a small part of the imbibed water is retained by vegetation. The leaves have a multitude of little mouths, called stomata, which, when under the influence of light, suck in carbonic acid gas and exude oxygen and water vapor. In darkness, plants exude carbonic acid gas slowly. This seems to be an attribute of all living cells, plant as well as animal. It no doubt goes on in the light with plants also, but is obscured by the opposite reaction just mentioned. The combined area of all the stomata hardly amounts to 1 per cent of the area of the leaves, so that it is hard to see how so much material can pass through such tiny orifices. It has, indeed, been shown that if one-half the leaf area were kept wet with fresh, strong caustic potash solution, it could not absorb carbonic acid gas faster than the stomata.

Brown and Escombe resolved the puzzle. They showed by laboratory experiments that when carbonic acid gas is admitted through a small orifice into a medium which absorbs it as fast as admitted, the amount transmitted is proportional, not to the area, but to the diameter of the orifice. For example, the same area of opening, if split up into four parts, will admit twice as much carbonic acid gas as when forming only one orifice, since the diameter of the large orifice is but twice the diameters of the four small ones. This paradox, of course, depends on a more rapid rate of flow of the gases through the smaller apertures.

Nature avails herself of this strange secret by crowding stomata something like 1,000,000 to the square inch. She thus adapts her leaves to suck in their sustenance and give out the waste products almost as rapidly as if the whole leaf were one aperture, while really about 99 per cent of its surface is closed to protect the delicate cells within.

Even this is not the whole story. The stomata, like mouths of animals, may be either wide open, shut, or partly open, and they go through all of these variations. It is not known exactly how they are regulated. We, at least, do not suppose that the plants use volition as men do in opening their mouths. Yet it is conceivable that, if sunlight was exceedingly bright on a hot summer day, the evaporation of water could be so great that the chemical products left behind would exceed the requirements of the plant, and kill it by overfeeding. Against such a possibility perhaps the stomata might need to be partially closed. On the other hand, if the air was very free from clouds and moisture, and a strong cool breeze blowing, the plant might become chilled by excessive evaporation unless the stomata were partly closed. There are, at all events, automatic devices within the leaf mechanism which attend to this needful regulation of the stomata. Beside these regulating devices, the leaves themselves, under the influence of changing sunlight, turn face toward or edge toward the sun according to the plants' requirements.

If the penetration of gases through the stomata in such profusion was a great puzzle, the ascent of the sap is, perhaps, even more extraordinary. For imagine a forest of gigantic Eucalyptus trees, which sometimes reach heights of 500 feet, and conceive of the energy demanded to lift in a single summer hundreds of thousands of tons of water on each square mile from the ground to the leafy tops. A common vacuum pump, it is well known, can not lift water above 33 feet, so that we dismiss at once the thought that the air pressure is working for the trees. What form of energy and application of force are these which the tree commands to do this lifting?

The energy is the heat of sun rays, and the forces at work are the capillary attraction and surface tension of water. By means of the capillary tubelike network of cells, which run from the roots up through the trunk of the tree, there is formed a connection between the stomata of the leaves and the water of the ground. These enormously numerous capillary passages are filled with fluid, partly liquid, partly gaseous. At their orifices, which are the stomata of the leaves and twigs, the sun's heat produces a continuous evaporation of pure water, leaving behind in the tree the traces of chemicals which the soil furnishes with the water and which yield plant food.

We seldom think of the forces of capillarity and surface tension which come into play, though they are the same that raise kerosene oil in a lamp wick, and that make drops of oil spread over a wet pavement. These forces are limited in their action to distances far less than the thickness of a single sheet of tissue paper, but are extremely powerful in circumstances where they are at their maximum strength. For instance, a single drop of water introduced between two flat glasses slightly inclined to each other, will run rapidly to the narrowest spaces, and will draw the two plates together so strongly as even to bruise or crush the glass. Similarly, two blocks of ice placed loosely together, and so that the water which melts from them can drain away, will be drawn together by the remaining water so closely that the two ice blocks become united into one by cohering together. This process is called regelation. On the contrary, the fluid, mercury, which does not wet glass, will, on account of surface tension escape from between two glasses, even if by doing so it must create a vacuum behind.

The rise of water and other liquids in very fine tubes is a consequence of surface tension, which in this connection is often called capillary force. The height to which a column of liquid will rise in a tube which it wets is inversely proportional to the diameter of the tube. The extreme fineness of the porous structure of the trunks, twigs, and leaves of trees, therefore, is adapted to convey the liquids imbibed by the roots to very great heights. The evaporation of water from the stomata of the leaves and twigs makes place for the continuous renewal of liquid by capillary action from below. This upward current is conveyed by the interior part of the tree stem. As it has been observed to reach great heights in dead trees, we must adopt some such physical explanation as has been given, and not invent a mysterious "life force" for the purpose, as older botanists were prone to do.

The soft, live, outer part of the plant, just within the bark, has another function. It is to carry downwards to the extremities of the roots the chemical products built up in the leaves and green parts under the action of sunlight.

Thus, in a live plant, as in a live animal, there is a fluid circulation. The manner of it, to be sure, is exceedingly different. Instead of the force pump, which we call the heart, there is substituted in the plant the force of capillary action, lifting the watery fluid to the tops of majestic trees. It brings, dissolved, the chemical plant foods from the ground, and so feeds the trees. The return current, much less in volume, is probably maintained by still another modification of surface tension which we call osmotic pressure. This is a force, which often greatly exceeds atmospheric pressure. It is always existing between watery solutions of chemical substances in different concentrations, tending to drive the more concentrated solution into the one less concentrated. Thus, the force of osmotic pressure tends to produce a uniform mixture. In a tree, it takes the more concentrated products of solar chemistry from the laboratory of the leaves, and conveys them downward through the living layers under the bark to the roots, to nourish these, and to be laid up, beyond the influence of wintry frost, for the renewal of the leaves in the spring.

The reader should not conclude from what has been said that the life processes of a tree are wholly understood. On the contrary, the best informed plant physiologists admit that they are confronted by a maze of mysteries which become more bewildering with additional research. They are becoming convinced that the simple protoplasmic living cells in plants and animals have much in common. A plant, like an animal, is to be looked upon as a colony of cells. Just as in a society of bees, or of ants, some individuals are told off and become modified in structure to perform certain duties necessary to the life of the society as a whole, so in plants and in animals the protoplasmic cells are, as physiologists say, differentiated, some for one function, some for another. By what physical agencies this is done is the mystery of life. Thus, we have in the plant the root with a variety of cells, some for imbibing ground water, others for storing food during wintry cold, still others forming a protecting covering. Again in the stem are some adapted for mechanical resistance to pressures like those of winds, others promoting the passage of foodstuffs, and still others protecting the interior from exposure. In the leaves there are the variety of special cells, adapted for the several different functions involved in nature's solar chemistry. Finally, in the flowers and ripening fruits are other varieties of cells set apart for the many functions associated with reproduction.

All of these modifications of the primordial cell work together in admirable harmony to promote life and growth of the cell colony which we call a plant. One may be apt to think of it as very inferior to the cell colony which we call the animal. For does it not lack a nervous system for communication, and also the capacity for motion? But the latest researches seem to show that the plant is not so deficient in these respects as might be supposed. What, for instance, causes a bending of the stem toward the light, and the development of rudimentary buds into growing shoots when the terminal bud is lost, if there be no communication of useful impulses through the body of a plant? What leads to the great storage of food in the root system, to prepare for the dormant period of winter, and for the uprush of the sap in spring, to cause the leaves and buds to burst forth? These are but a few of the great mysteries which, the closer they are studied, the higher they tend to raise our admiration. Finally, the plant kingdom has the great superiority over the animal that, like the farmer among men, it furnishes by its unique employment of solar radiation, not only the means to feed its own living cells, but all those of the animal world besides.

Already, therefore, we have discovered in the plant two indispensable activities of the sun. The first is the mysterious combining influence of certain solar rays, which, acting in green leaves, build up the most complex life chemicals from such simple materials as carbonic acid gas of the air and weakly impregnated water from the ground. This is an action as yet inimitable in the laboratory. We have yet to learn its intricacy and causation. The second indispensable action of solar energy is to evaporate from the leaves and twigs enormous quantities of water. Thus are left behind, in suitable concentration for the use of the chemistry of plants, the various needful chemicals brought up in extremely diluted form in the water imbibed by the roots.

But this is not all. In producing this immense evaporation, the sun counteracts its own influence to unduly heat and scorch the delicate leaves. Turning liquid water to vapor requires a very large supply of heat. So the sun-heat absorbed by the leaves is safely dissipated. Indeed, as in the human body, there is a rough uniformity of temperature preserved in plant leaves, and largely by the regulatory action of evaporation. Some plants, indeed, have automatic mechanisms which turn their parts toward the sun, or edgewise to its rays, according to requirement. These plant motions are well known, as we see them in the sunflower and the nasturtium, and are, indeed, very common in the plant realm.

Fourthly, the sun maintains a suitable temperature. Plant growth requires a state of temperature whose range is practically limited between 0° and 50° C. (32° and 122° F.). It is this state of affairs which the sun maintains constantly in the tropics, and through a part of the year in temperate and polar zones. Later we shall note some curious effects which temperature regulation may produce in plants.

Such are the four great services of sun rays to plants, but in their response to these influences the plants exhibit a most interesting variety. Astonishing changes in growth and texture may be brought about merely by altering the temperature of environment, the duration of sunlight, and the intensity and spectral quality of sun rays. Changes in the water ration, the chemistry of the soil, and the concentration of carbonic acid gas in the air, also produce profound effects, but as these are but indirectly affected by the sun, we shall not discuss them, but turn our attention to the direct influences first mentioned.

Col. Boyce Thompson has munificently established in Yonkers, New York, a laboratory splendidly equipped for the investigation of such effects, as well as for the study of plant diseases. In basement rooms there are provided cooling pipes and automatic regulators adapted to keep plants for as long as desired at definite temperatures and under powerful batteries of electric lamps adapted as a substitute for sun rays. The potted plants are mounted on little perambulators so that when the desired time of exposure in one temperature has elapsed, they may be removed to different temperature surroundings. Instances of the curious results are shown in the accompanying illustrations.

In another part of the laboratory is a glass-roofed hothouse. But the glass is not all the same. One part is tinged with violet, another with blue green, another with yellow orange, another with red, and one is of clear glass. Thus the rays of sun and sky are modified by the absorption of the glass so that different regions of the spectrum are most effective for the several little gardens. It is very curious to see the changes of color in a lady's dress as she passes from garden to garden under the control of these different colored lights. These conditions change remarkably the character of the plant growth as shown by the accompanying illustrations.

There is also a great movable roof which can be rolled over the hothouses. This is provided with clusters of powerful electric lamps sufficient to be a substitute for sunlight. With this apparatus, experiments in the effect of continuous and partial time illumination are performed. Some of the results are shown in the illustrations. This field has also had much attention by Doctor Garner and associates of the United States Department of Agriculture.

Everyone knows how a potato in a dark cellar in springtime sends out its white sprouts, which stretch away sometimes a yard or more toward some feeble crack of light. Here we see two things of importance. First, that the healthy green development necessary to sound growth can not take place without adequate light, and, second, that insufficient light leads to monstrous elongation of plant stems.

In the solar chemistry of the leaves, their green coloring matter, called chlorophyl, seems to be indispensable. Yet it does not itself join permanently in the reactions, but rather seems to be what is called a catalyst, which in chemistry means some substance that is necessary to cause reactions to happen, but is not itself a part either of the original materials or of the end products. What must happen in plant chemistry is the joining of each molecule of carbonic acid gas with a certain number of molecules of water, and the removal from the mixture of one molecule of oxygen, leaving the compound a single stable molecule of the type called a sugar. There are many sugars and near sugars. Of these our ordinary cane-sugar molecule includes 12 atoms of carbon with 11 atoms of oxygen and 22 atoms of hydrogen. Much simpler sugarlike substances exist, but all, as we remarked above, have the general formula $C_nO_mH_{2m}$, where C, O, H, stand for atoms of carbon, oxygen, and hydrogen, and n and m stand for numbers which may run up nearly to a score.

The sugars are closely allied to the starches, whose molecules have the same general relations of numbers of the three chemical constituents, but contain several or many times as many atoms as the sugars. Starches are stored up by the plants in great profusion in their roots, tubers, and fruits. They break up readily into sugars. Starches, sugars, and, in addition, cellulose, in whose molecules are also found the same general proportions of the three constituents, carbon, oxygen, and hydrogen, as in starch and sugar, compose the main part of plant substance. Some of the other chemical elements, to be sure, are necessary to healthy plants, though in very small proportions. The chemical formulae of some of these compounds are excessively complicated, and raise our admiration for plant chemistry.

As plants must have light in order to grow, they strongly compete for it by stretching toward the sky. Where light is inadequate the stems lengthen. This is called by botanists etiolation. Its effect is very marked in the comparative shapes of two pines, one growing alone on a clearing, the other in a thick wood. Another well-known effect of scarcity of light is to thin and broaden the leaves. This is taken advantage of by some tobacco growers, who by erecting semitransparent tents over their crops produce a higher grade of tobacco.

It is at first sight quite surprising, but after all quite in harmony with the facts of etiolation, that plants grow tall faster in the night than in the day. Their maximum rate of growth is just after sunset, when it is apt to be over twice as rapid as in midday.

There is also a curious expansion and contraction of plant stems in growing. The contraction seems to be caused by the rapid evaporation of water from the leaves during the daylight hours, and a resulting upward tension of the liquid in the conducting channels of the stem, which relieves the horizontal pressures to some extent.

When we inquire which of the spectrum rays, and in what intensity, are required for plant growth and for seed formation, we find that a great gap in exact knowledge exists here. Most of the experiments hitherto made relate to plants of little or no commercial value, and lack exactness both as to the intensity and the quality of the rays used. It would be, indeed, difficult and costly to employ the spectroscope to select rays for such experiments, because the use of a slit and numerous optical pieces so greatly reduces the intensity of the rays of every color. Most experimenters, therefore, have made shift to employ colored glasses to give certain rough separations of color.

These experiments indicate that the blue and violet and ultra-violet rays are the most important for plant growth. Deep red rays also are very active to promote photosynthesis, but the green rays lying between these spectral regions seem to behave as darkness to the plant. It is greatly to be hoped that more exact measurements of wave length and intensity may soon be associated with studies of the growth and fruiting of the valuable food crops and the favorite flowers. It will be necessary to use very large and costly apparatus in such an investigation, because not more than 10 per cent of the intensity of sun rays may be expected to remain after the rays have been collected and accurately selected by the optical spectroscopic train. It may be that specific functions like flower bearing, seed developing, leaf growing, and stem expansion may be found to require different and very special qualities and intensities of rays for optimum conditions. The experiment is fascinating, for perhaps new and remarkable varieties of the most useful plants may be developed by controlling their radiation supply.

With the higher plants, it must be sunshine or death. With man and the higher animals, it must be sunshine or sickness. To be sure, there is nothing in the life of man or animals like the photosynthesis of the food of all plants and all animals which goes on in green leaves. That is unique with plants. But child humanity in dusky cities, shut in by smoke and dust from receiving the ultra-violet rays of the sun and sky, is afflicted by rickets and other ills which yield to the healing influence of exposure of the body to full sun rays in the manner that nature intended.

The outstanding exponent of this solar therapy is Doctor Rollier of Switzerland, who has maintained a sanitarium for sun treatments since 1903. Of later years, he has been imitated in other countries. One would hardly think of sun rays as dangerous, but the patients of Doctor Rollier commence their treatments on the first day with only 20 minutes exposure, and of the feet alone. From this gentle beginning there is a gradual progress to the stage of complete exposure of the person for hours. Naturally there accompanies this course a gradual darkening of the skin. The patients become brown and hardy looking. Skin sores disappear.

Two principal diseases successfully treated by solar therapy are rickets and surgical tuberculosis. Rickets, as everyone knows, is a sort of lack of stamina, apt to invade the whole body of children. A weak digestion, a poor appetite, emaciation, profuse night sweating, weakness of the limbs, tenderness of the bones, enlargements of the wrists and ends of the ribs, bow legs, curvature of the spine, misshapen head, contracted chest—all these deformities and miseries may come in the early years of the poor little patient.

The layman is apt to think of tuberculosis as a disease of the lungs, but essentially the same malady attacks many other parts of the body. Glands of the neck, skin, bones, joints, mucous membranes, intestines, and liver are commonly infected by the tubercle-bacillus. In cases of superficial tuberculosis, recognizing how the germs may pass from one part to another in the blood stream, the surgeon is frequently called in to excise the infected part before it does its fatal mischief in a less accessible organ of the body. This gives rise to the term surgical tuberculosis.

It appears to be definitely proved that ultra-violet rays of less than 3,200 Ångströms in wave length are the active agents in the cure of rickets by ray therapy. As the ozone of the higher air cuts off solar radiation at about 2,900 Ångströms, it leaves but a narrow band of solar rays available. Not only in rickets but in certain superficial skin diseases, physicians have used with advantage the quartz-mercury vapor arc light, which is rich in ultra-violet rays of these and shorter wave lengths. Recent experiments in poultry raising at the Maine Agricultural Experiment Station are exceedingly instructive in this line, though it would be rash to carry over the results unquestioned to human pathology.

In the summer of 1924, about 250 one-week old chicks were separated into six groups for different treatments. Those of Group 1 ran about in the open sunlight as they pleased, but came indoors to eat. The remaining five groups lived in a glass-roofed greenhouse. Groups 2 and 3, however. in addition to the light which reached them from sun and sky, were exposed for 20 minutes each day to the rays of a quartz mercury vapor lamp, rich in the ultra-violet. The remaining three groups had only the sun's light as it came through their glass-roofed house.

All the groups had the usual regular food, composed of chick grain, dry mash, sour milk, and rock grit, and had access to fresh water and sand bath. Groups. 3 and 4 were given, in addition to the regular diet, chopped alfalfa and grass, and Group 6 had, in addition to the regular diet, a small ration of cod-liver oil.

What was the result? Groups 1, 2, 3, which had either full sunlight or glass transmitted sunlight plus ultra-violet rays, all thrived. Groups 4 and 5 began to act less vigorously than these others by the end of the fourth week. They ate with less appetite and scratched less. Chickens of Group 6. which had the cod-liver oil, although they did not relish this medicine, yet thrived better than Groups 4 and 5, but not as well as Groups 1, 2, 3. These differences became more and more marked. The chickens of Groups 4 and 5 developed weak legs. They remained smaller in size. Their plumage looked rough. By the end of the ninth week, the fowls of Groups 1, 2, 3, all having developed normally, were about double the weight of the spindling chicks of Groups 4 and 5. The chicks of the first three groups had their bones well set and full sized, while the bones of Groups 4 and 5 were small, curved and weak. Chickens of Group 6 were intermediate in their development. Fifteen deaths occurred in groups 4 and 5, and only one in Groups 1, 2, 3.

Why this difference? Evidently it was solely due to some deficiency in radiation. Figure 1 shows graphically what the difference was. A narrow band of rays in the extreme ultra-violet—far beyond the extreme limit visible to the eye, and exactly in the region, by the way, where the ozone of the upper air begins to work absorption on solar rays—this little group of feeble sun rays was cut off by the glass cover of the greenhouse. These indispensable rays were supplied in sufficient measure by the daily 20 minute exposures to the mercury vapor arc. The want of them was partly made up to Group 6 by the medicine of cod-liver oil. Groups 4 and 5, lacking both the saving medicine and the rays, languished.

It is astonishing to remember that this very group of rays, thus proved so indispensable to the development of growing creatures, just misses being cut off from sun rays by the trace of ozone which exists in our upper atmosphere. So near, apparently, as this is the world to lacking a condition favorable to life, that if the ozone band, which cuts off the spectrum of the sun and stars completely at 2,900 Ångströms of wave length, had extended to 3,200 Ångströms in full force, the mischief would have been done. And yet the solar spectrum has little energy there but runs on through the visible and infra-red regions in great strength to 20,000 Ångströms.

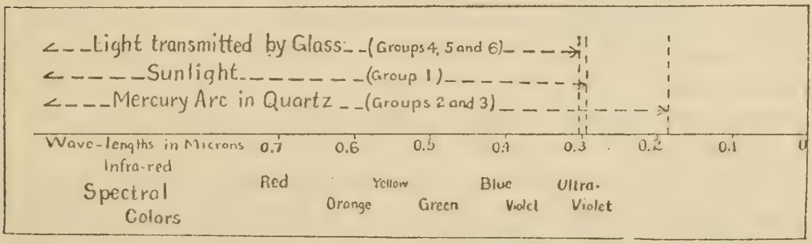

FIG. 1.—Spectral colors arranged according to wave length, showing spectral limits of the light received by groups of chickens

Another astonishing thing has lately been discovered. Doctors Steenbock and Daniels, experimenting with rats in the years 1922 and after, were testing the value of butter fat and cod-liver oil for the prevention or cure of rickets. Their experiments also involved the use of ultra-violet light. Some of the animals having been radiated upon and others not, they were confined in cages in common. The doctors were surprised to find that both sets of rats grew alike, except in one instance where some nonirradiated animals began to grow only when, after five weeks, irradiated rats were for the first time put into their cage.

It seemed as if the irradiated rats were able to supply to the nonirradiated ones something that hitherto they had lacked. On trying various experiments, it was found that irradiating the air, or touching nonirradiated rats with their irradiated brethren did not give the magic curative influence. The effect was indirect, not a consequence of direct action on the outside of the body. Finally the secret appeared. Some bodily excretions of the irradiated animals were eaten by the others and produced the extraordinary result.

Various articles of diet were then tried in irradiated and non-irradiated condition. It was proved that many, but not all, grains, fats, and oils, when shined upon by ultra-violet rays receive and hold curative properties adapted to conquer the disease of rickets. Cod-liver oil, then, is by no means alone as a carrier of the curative agent. Some modification takes place in many other kinds of foods, if irradiated, which makes them effective to cure rickets by indirect ray-therapy, fully as effectively as by the direct application of the rays to the skin of the patient himself. The irradiated oil may indeed be boiled with strong alkali and reduced to a soap and still retain its curative property unimpaired.

It appears that while there are several rare chemical substances in cod-liver oil which possess this curative virtue when irradiated, the most active of them is one named cholesterol. While this substance does not occur in plant foods, there are certain somewhat similar chemicals in the grains which are named phytosterols, and some of these have similar value against rickets. Not only in rickets, but in some allied disorders, this new discovery may prove of high medical value.

As regards light therapy and rickets, the conclusions so far arrived at are these:

(1) Exposure of an animal to light of wave length less than about 3,200 Ångströms will cure rickets and also prevent its occurrence on a diet that normally will produce rickets.

(2) Cod-liver oil will act just like ultra-violet light in curing and preventing rickets.

(3) Some other substances have a slight curative value in rickets, but most other oils—such as cottonseed oil—have no antirachitic value.

(4) These oils without antirachitic value can most of them be made antirachitic by exposing them to ultra-violet light.

(5) A large number of solid food materials also become antirachitic on exposure to ultra-violet light.

(6) Cholesterol—a practically universal constituent of animal cells—becomes activated by ultra-violet light. So also does phytosterol which is a constituent of plant cells, so that presumably food materials are made antirachitic by activating the cholesterol and phytosterol in them.

(7) Since the human tissues contain cholesterol, the skin on absorbing ultra-violet light has its cholesterol activated, and this activated cholesterol, being absorbed into the blood, acts just like cod-liver oil absorbed from the intestines in promoting bone formation.

The striking results obtained in the treatment of surgical tuberculosis by Doctor Rollier at his Swiss solar sanitarium are indicated by the following table:

Results of light treatment in surgical tuberculosis (*Rollier*)

	Cured	Improved
	Per cent	*Per cent*
Skin tuberculosis	81.25	18.75
Bone and joint	75.98	7.80
Glandular	89.80	5.20
Peritonitis	80.30	8.20
Genito-urinary	77.80	22.20
Kidney	52.94	33.00

Total mortality 0.9 per cent.

X-ray photographs, after the light treatment, give striking evidence of the effect upon bone formation. According to Rollier, finger bones that have entirely disappeared may be so completely recalcified as to be indistinguishable, in radiographs, from normal tissue, and adults seem to be as easily affected as children. This means that, for early cases at least, the disease can be checked, and motion preserved in the affected joint, the gradual establishment of motion going hand in hand with the healing process.

Rollier insists on the fact that the benefit is always proportional to the degree of pigmentation. Without knowing accurately which wave lengths are responsible for pigmentation, and which are most beneficial in the treatment of tuberculosis, it is not possible to be very sure in this matter, and here as in plant physiology an alliance between the doctor of medicine and physicists, expert in isolating rays and exactly measuring radiation intensities, would be of great advantage.

The subject of the influence of sun rays on plants and animals has only recently come to the fore. Doubtless the future holds in store for us here, as in other lines, highly wonderful and inspiring revelations of the importance of sun rays in the welfare of man.

THE GANTRY CRANE USED FOR INCREASING THE LENGTH OF THE DAY IN THE GREENHOUSES

There are forty-eight 1,000-watt gas-filled incandescent lamps on the crane. In practice, this crane is used to illuminate the first greenhouse from 6 in the evening until midnight. It is moved at midnight over the second house and illuminates this house until 6 a. m. The first house is given an additional concentration of carbon dioxide. This runs about [illegible] of 1 per cent. The illumination on the soil in which the plants are grown is of the order of 720 foot candles, Macbeth illuminator measurements, or 0.27 gram calories per square centimeter per second, as measured by the pyrheliometer

THE EVENING PRIMROSE IS A TYPICAL "LONG-DAY PLANT"

The specimen on the right, exposed to a 10-hour day, is unable to develop flowering stems. That on the left, exposed to the full length of a Washington summer day is nearly ready to flower

THE KLONDIKE COSMOS IS A TYPICAL "SHORT-DAY PLANT"

The specimens on the right, exposed to full-length Washington summer days, were unable to flower. Those on the left, exposed to an 8-hour day, flowered at a height of a few inches

A SERIES OF LETTUCE PLANTS GROWN IN THE CONSTANT LIGHT ROOM UNDER ARTIFICIAL LIGHT ENTIRELY

Plants received respectively 5, 7, 12, 17, 19, and 24 hours of illumination in every 24-hour day. They have been in the light room 38 days, and were small plants bearing two or three leaves when placed in the room

SERIES OF PLANTS GROWN IN SERIES OF SPECTRAL GLASS HOUSES

House 1 is greenhouse glass, which transmits to 312 millimicrons; 2 is Corning's G-86-B glass, which transmits to 296 millimicrons; 3 is Corning's Noviol glass, which cuts off most of the ultra-violet and transmits only to 390 millimicrons; 4 cuts off all of the ultra-violet and part of the blue—it transmits to 471 millimicrons; 5 cuts off all of the ultra-violet, violet, blue, and one-half of the green—it transmits only to 526 millimicrons. These light filters are used in covering small greenhouses and sunlight is the light source. The picture shows that there is very little change in the form of the plant when the ultra-violet is admitted and when it is entirely cut off, and that cutting off the violet and blue rays (house 4) gives a much taller plant, with a tendency to twine.

ON THE EVOLUTION OF THE STARS[1]

By C. G. Abbot

[With 6 plates]

1. There are 92 chemical elements, beginning with hydrogen and ending with uranium. Oxygen is the eighth, iron the twenty-sixth, silver the forty-seventh, gold the seventy-ninth, and radium the eighty-eighth. Nearly all of them are found on the earth, and a great many of them in the sun and stars. There are many ways of identifying them on the earth, but only one way in the sun and stars. The spectroscope reveals the signs of the chemical elements in the light of the heavenly bodies.

The spectrum is a band of beauty. Its colors blend from violet through indigo, blue, green, yellow, orange, to red most charmingly. But in the spectrum of light from the sun, or from the stars, one sees the band of color shot across with many dark lines. It is these lines which tell the chemical story.

Here are the lines of green color that iron gives when heated in the electric arc. Here are the dark lines that are produced when light shines through iron vapor. Here are those very lines in the spectrum of the sun. Hence, there is iron in the sun. The proof is just as plain as that which tells us that ages ago a queer-toed animal walked in the mud of Massachusetts, for we have found fossils of his tracks.

In such ways the spectroscope has told us that all of the stars are composed of the same chemical elements as our earth. This is the first conclusion in our study of stellar evolution. The chemical composition of all parts of the universe, however distant, is the same.

2. The atoms of the 92 chemical elements are made up of two and only two ingredients. These fundamentals are called the protons and the electrons. The protons are unit positive electrical charges. The electrons are unit negative charges exactly equal but opposite in nature to the protons.

In a single atom of hydrogen there are one proton and one electron. In a single atom of oxygen there are 16 of each, and in heavier atoms many more. This is the way they are arranged: The protons and

[1] Lecture delivered at Columbia University, July 15, 1926.

part of the electrons form a central nucleus about which gyrate the remaining electrons at tremendous speeds, and in characteristic orbits. The nucleus is like the sun, controlling its family of planets—electrons. So we may say that astronomy begins within the atoms.

As all things are made of atoms, and all atoms are made of electric charges, we see that what we call matter, the substance of the earth, the stars, and all that in them is, is after all electricity.

Consider a hydrogen atom. It is just one proton with one electron revolving about it, comparable to the earth with its one moon. The two units of electricity attract one another very powerfully because they are so very close together. If the motion that holds them apart could be stopped, the electron would fall in upon the proton. What would result? Apparently annihilation. Similarly, all of the chemical atoms—that is, the whole universe—if deprived of all the inner atomic motions, would apparently be annihilated. In place of the universe would be a void. If the process were reversed, a void, separated into positive and negative unit electrical charges, and endowed with immense energy of motions in characteristic orbits, would become a universe. That would be the primary step in evolution itself.

3. How did that primary step take place? Science does not pretend to know.

The Hebrew scripture says: "In the beginning God created the heaven and the earth. And the earth was without form and void; and darkness was upon the face of the deep. * * * And God said, Let there be light: and there was light."

In this there is nothing which contradicts what science has disclosed.

The Zuñi Indians had also an account of creation:

Awonawilona, the Maker and Container of all, existed before the beginning of time in the darkness which knew no beginning. Then he projected his thinking into the void of night and evolved fogs of increase—mists potent with growth. He took upon himself the form and person of the Sun, the Father of men, who thus came to be, and by whose light and brightening the cloud mists became thickened with water, and thus was made the world-holding sea. By the heat of his rays there was formed thereon green scums, which increasing apace, became "The Four-fold containing Mother—earth," and the "All-containing Father—sky," parents of all that is.

4. Our study of stellar evolution can not begin at the beginning. Existing processes do not help us to form a conception of how the void became the atoms. We have to assume that the atoms in tremendous numbers came into being in some unknown way. That is our starting point.

5. The telescope with its photographic plate shows us that the vast spaces of the universe hold cloudlike matter called nebulae. Some of these clouds are bright, some dark. The star, Theta Orionis, near the base of Orion's sword is really nebulous. It is involved in the great nebula of Orion. The Pleiades stars are also surrounded by nebulosity. In fact, nearly every one of the irregular nebulae is associated with a bright star. Hubble has suggested that it is these stars which cause the nebulae to glow.

This view is the more probable because many of the nebulae do not glow. Thus in the Milky Way are many dark patches devoid of faint stars, apparently because a cloudy veil of nebulous matter lies between us and the starry background. A very striking example of this sort of thing is in the horse-head shaped blackness in the constellation of Orion. Then there is the lacelike nebula in Cygnus, which we suppose extends farther than it glows, because the fainter stars are absent on one side of it.

Thus we see that among the stars lies much cloudlike, unorganized substance which may seem to be suitable raw material to make up into stars. The spectroscope shows little complexity in the chemistry of such nebulae. Hydrogen is prominent, and some other gases whose spectra are unfamiliar. Perhaps these strange gases are really of some common variety whose unfamiliar spectra depend on an unknown means of exciting light.

6. The stars themselves show much variety. Even ordinary eyesight can tell a difference between the blue star Rigel and the red Betelgeuse in Orion; or between the white Sirius and the yellow Procyon of the two Dogs. The spectrum gives this distinction more precisely. It shows a regular gradation of complexity from the blue Rigel, with its few lines revealing the presence of the gas helium; to the white Sirius, with hydrogen lines predominant; to the yellowish Procyon, which faintly shows evidences of many metals; to the yellow sun whose light is considerably dimmed by the very numerous dark absorption lines of its many chemical elements; to the reddish Aldebaran in whose spectrum, as in the light of sun-spots, evidences of compound molecules appear; and finally to the deep red Antares, from whose rays most of the visible strength is cut off by powerful bands of absorption, due to compounds of carbon, nitrogen, and various gases.

These differences of spectrum are associated with temperature differences. Many years ago at the Harvard College Observatory, as the observers noted the spectrum peculiarities we have just spoken of, they named the various star types by an irregular sequence of letters that still prevails. The table shows the characteristic spectra and temperatures of 99 per cent of all the stars arranged after the Harvard type-letter system.

Characteristics of typical stellar spectra

Spectral class	B	A	F
Sample star	Rigel	Sirius	Procyon.
Constellation	Orion	Canis Maj	Canis Min.
Color	Blue	White	Pale yellow.
Surface temperature	16,000°	11,000°	8,000°.
Characteristics	The few Fraunhofer lines are mainly of hydrogen and helium. Oxygen, nitrogen show less conspicuously.	Hydrogen lines predominate. Helium lines disappear. Lines of metals come in faintly, especially spark lines.	Metallic lines conspicuous. Arc lines of metals appear.

Spectral class	G	K	M
Sample star	Sun	Arcturus	Betelgeuse.
Constellation		Boötes	Orion.
Color	Yellow	Reddish	Red.
Surface temperature	6,000°	3,500°	2,700°.
Characteristics	Solar type. Metallic arc lines predominate. Flaming arc lines also conspicuous.	Sun-spot type. Arc lines strong. Flame lines also conspicuous. Bands of compounds appear.	Flame lines prominent. Heavy absorption bands appear and are the conspicuous feature, indicating spectra of molecules, notably titanium oxide.

7. We must think of the brightness and distances of the stars. Nearly 2,000 years ago, in that great fifteenth chapter of St. Paul's Epistle to the Corinthians, he penned the expression, "For one star differeth from another star in glory." Very accurate measurements of this difference have now been made, and it is found that a range of more than a billion of billionsfold occurs between the brightness of the sun and that of the faintest stars which have been photographed with the largest telescope. The accompanying chart (fig. 1) shows what an enormous range it is.

Part of this difference depends on distance. We may express these tremendous distances in light-years. Light travels 6,000,000,000,000 miles per year. It takes light only eight minutes to reach us from the sun, four years from the nearest star, and thousands of years from the vast majority of them.

When we know, as we do, the distances of great numbers of the stars, it is found that the real brightness of them differs very greatly from that which is apparent. Hertzsprung and Russell discovered that when ranged in terms of real brightness the different spectrum classes behave very differently. The later work of Adams and of Jackson and Furner shows this even more in detail. Of deep red M stars there are two separate classes, one extremely bright, the other extremely faint. Of reddish K stars there are also two such classes, not quite so widely separated in brightness. The discrepancy diminishes with yellow G-type stars, nearly ceases with the yellowish F type, and is altogether absent in the white and blue stars of types A and B.

Thus we find our spectrum sequence of star peculiarities split into two. A bright series of stars exists of every spectrum class, and, besides, a second series growing fainter and fainter as we approach the red end of it.

8. It is well known that the hotter a light source, and the bigger it is, the more light it gives. But the two kinds of red stars, being the same in color, we must suppose are equally hot on the surface. Hence, one kind of them must be enormously bigger than the other. Thus, we can now go a step farther and divide our stars into the giants and the dwarfs.

Some of the red giants have been measured in diameter by the ingenious method of Doctor Michelson. It proves that they exceed 200,000,000 miles, or several hundred times the diameter of our sun, which itself is a hundred times the diameter of the earth. In fact the whole annual orbit of the earth around the sun would not extend out to the surface of Antares or of Betelgeuse if our solar system were centered in those stars.

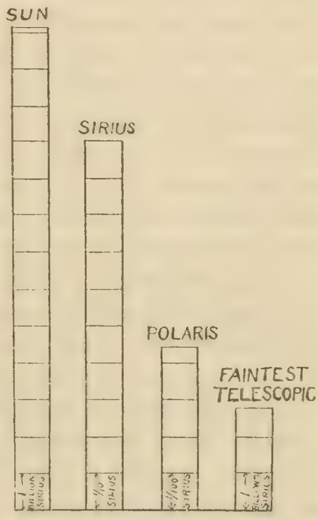

Fig. 1.—The range of brightness of the heavenly bodies

What must be the state of matter in those giant red stars? The answer: In the state of an extremely rare gas. For by applying Newton's and Kepler's famous laws of gravitation and planetary motion to the cases of the numerous double star systems that are known, it has been shown that the stars are never many times as massive as our sun. A star like Antares, which has, say, 300 times the sun's diameter, has 27,000,000 times the sun's bulk. If not more than 27 times the sun's mass, it has less than $\frac{1}{1000000}$ the sun's density. But we know that the sun is about 1,500 times more dense than air, so that Antares must be something like 1,000 times less dense than air.

9. We now begin to see a reasonable path in stellar evolution. We commence with the formless nebulae, which are of perfectly enormous bulk. Some of the stars, though they seem but points to us, are shown to be hundreds of millions of miles in diameter. But nebulae which are equally distant, since they are clearly star appendages, as in Orion and the Pleiades, extend over large areas of sky. Hence their bulk is enormously greater than that of stars, too great even to try to express. Although no doubt they are excessively rare gases, yet doubtless the nebulae would furnish material for many giant stars if compressed to the angular dimensions of a starry point as seen by us.

A nebula condensed may thus become one or many giant red stars. May not the giant gaseous red stars, by further condensing grow hotter and hotter? They would thus become in turn light red, yellow, white, and blue. Having reached the acme of their effulgence, they might gradually cool again with increasing density until they should have passed through these stages in reverse order, and might end their starlike history as red dwarfs, still hot, but now compressed so small as to give little light.

10. The gradations of spectrum, of temperature, and of density which have been traced among the stars support this view of stellar evolution. The question now comes, is it harmonious to the laws of physics as we know them? Here we have the results of the great English scientist, Professor Eddington. He finds that in accordance with the law announced many years ago by Lane, it is perfectly to be expected that a great globe of rare gas will become hotter and hotter as it shrinks, and its supply of radiation to space will keep up while its diameter shrinks, because its temperature rises. The change of spectrum, too, is well accounted for. Though the signs of the metals seem to disappear in the white and blue stars, this is only because the more violent excitation strips off from the metallic atoms certain of their orbital electrons, and causes the spectral lines to occur beyond the violet in a spectral region where the ozone of our upper atmosphere cuts off the light of all the stars. The metals still exist in the blue stars, but their signs do not reach us because our atmosphere prevents it.

But Eddington found later on that even stars as dense as our sun, that is to say denser than water, behave as if they are perfect gases. This was at first a puzzle, until it occurred to him that in a gas it is the size of the separate entities, compared to their distances apart that determines whether they have the freedom of the perfect gas. In the interior of a star, as dense and hot as our sun, the atoms are well known to be broken up into their nuclei and their electrons. These objects are some thousandfold smaller in diameter than atoms or molecules. Hence, they have complete freedom of motion in stars so dense that ordinary gases (made up of molecules instead of electrons) would not at all obey the perfect gas law.

11. This discovery for the moment threw discredit on the view that stars after reaching a certain density could no longer become hotter by contraction, and must inevitably thereafter begin to cool, and so go back down the descending branch in stellar evolution. It is now suggested that they keep on growing hotter within. Temperatures of tens and hundreds of millions of degrees occur, it is computed, inside such stars as our sun.

At these unexampled degrees of effulgence, the rays sent out are even shorter in their wave lengths than X rays, and are so powerfully absorbed that they are quite unable to penetrate from within to the star surface. Hence the supply of energy fails to quite maintain the outside temperature required to keep up the immense radiation of such a star to space. Our sun, for instance, gives out each year as much energy of radiation as four hundred thousand billion of billions of tons of anthracite coal, and it is believed that the increasing temperature of the sun's interior more and more hinders the communication of energy to supply its surface loss.

So the surfaces of the dense stars cool while they are still raging hot within, and from these cooling surfaces we receive the diminished light which gives the declining spectrum series associated with dwarf stars.

12. But how about the energy to support such enormous radiation? Surely it can not come indefinitely from shrinkage. The study of radium and uranium bearing rocks has proved that our earth in its present stage has had a duration of quite a billion years, and the fossil story shows that life was well organized quite as long ago. Shrinkage of the sun can not account for a supply of heat to warm the earth for the support of life so long as that.

As we have seen, the annihilation of an atom by the falling in of its two kinds of electricities must give up the energy of motion which the electrons possessed as an atom. It is now conceived that at the exalted temperature and tremendous pressure within the denser stars, conditions are right for the annihilation of their atoms, with liberation of their energy to support radiation.

13. To recapitulate the probable course of evolution of stars: Out of the formless nebula, whose atoms were brought into being by some means of creation which we do not possess or understand, red giant stars, far less dense than air, were formed. Under the combined influences of gravitation and radiation, these giant stars grew hotter and denser. With rising surface temperatures, their colors advanced through yellow to white and blue, attended by the familiar changes of spectra, and by a great decrease in diameter, but without much change of total brightness. Arrived at temperatures so superlative and densities so considerable, the flow of radiation from within to heat the surface is hindered by absorption owing to shortness of average wave length, so that the surfaces no longer maintain their maximum temperature or radiation. Yet the inner temperatures continue rising because the stars, though so dense, retain the characters of perfect gases. For their atoms are reduced by separation of nuclei and electrons. The process of cooling at the surface continues until the star, born a red giant, dies a red dwarf, having not only attained great density by contraction but lost much mass by annihilation.

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14. Hitherto we have considered the constitution of individual stars. We now turn to the birth of starry systems. Before the modern aids to exact telescopic work were available, it was found that nebulous patches of very definite forms are in the heavens. These are now resolved by photography into such beautiful spirals as that in the constellation of the Hunting Dogs. Others of these spirals are more or less inclined to our line of vision, and some are even seen directly on edge. Seen under these various angles of presentation, we find that all of these so-called spiral nebulae are of flattened, watchlike shape.

Curiously enough, too, our own galaxy, which contains some 30,000,000,000 stars or more, is of this flattened type, and extends out quite five times as far along the Milky Way as towards its poles.

Sir William Herschel suggested more than a century ago that the spiral nebulæ were, as he picturesquely termed them, "island universes." In other words, he suggested that they are galaxies like ours, but so distant that the largest telescopes of his time could not separately distinguish their stars.

This has now proved true. Hubble with the 100-inch telescope on Mount Wilson has succeeded in resolving some of the spiral nebulae in part into stars of exceeding faintness. By means of certain of these stars, called Cepheids, which have a peculiar type of variable brightness, he has shown that the great nebula of Andromeda and others are nearly 1,000,000 light-years distant.

Considering the similarity of shape, of general spectrum, and other points of resemblance, there is no little doubt that we, ourselves, reside not excessively far from the center of a galaxy which, to the intelligent dwellers on the Andromeda galaxy, if such there be, must seem like a great spiral nebula.

15. In all these spirals, of which there are some hundreds of thousands in the heavens, two arms depart from opposite sides of the central condensation. There are, however, other nebulous objects which present gradations of form back from the spiral to the spindle, to the ellipsoid, and finally to the sphere without hint of structure. Professor Jeans has computed the relations of masses and motions which would cause a globe of gas to elongate its equatorial radii under rotation, and pass on to the spindle shape. At a certain degree of extension, the gravitation toward the center would be nearly balanced by the centrifugal force of rotation. Then the trifling differences of attraction from different directions exercised by the other masses of the universe would cause tidal extensions to leave the parent mass at opposite ends of a diameter. Jeans goes on to show how these extensions would draw away more and more material into ropelike arms, which, as they extended, would necessarily wind into the spiral forms. He even succeeded in proving

that these arms must separate into knots of starlike dimensions, which indeed agrees with the appearance of many spiral nebulae.

Some of the arm-knots, being too massive for existence as single stars, would, as Jeans shows, form double or even quadruple star systems. This also is verified by observation. For among the stars of our galaxy at least one-third are multiple stars. His analysis seems to lead very satisfactorily toward the phenomena of stars as they have been discovered in the spiral nebulae and in our own galaxy, which may be taken as a sample of such a nebula.

16. But what of the sun's family, the planets and their moons? Are these also to be regarded as agglomerations of the arms of a small spiral nebula? Apparently not. Certain dynamical difficulties stand in the way of accepting the present arrangement of mass in the solar system as a result of such a process.

Jeans adopts a similar device to that proposed by Professors Chamberlin and Moulton of the University of Chicago, who conceived that at some ancient epoch another star came so near to our sun as to raise upon it ropelike tides. The two stars separated again in their rapid flights before our sun had been divested of much of his mass. From the ropes of matter thrown off by this tidal encounter were concentrated, it is conceived, the planets and their satellites. Some of the matter given off in the encounter remains ungathered in the meteors and minor planets, and among the curiosities of condensation are the beautiful rings of Saturn.

17. Such are the present views of the evolution of galaxies, of multiple stars and of planetary families. Though they do not pretend to explain the original creation, they harmonize, far better than I can take note of in this brief account, great numbers of the phenomena known to mathematicians, chemists, physicists, and astronomers, and indicate a gradual progress in events which may well be called stellar evolution. Although its march is far too long to be followed in the span of human life, yet the heavens present so many cases of objects in every state of progress along the majestic course, that the summation of cases may be a satisfactory substitute for the continuity of action which in finite human life we can not perceive.

18. There remain some branches of the subject yet to touch upon. One of them relates to the motions of the stars and nebulae. With the diligent employment of great telescopes and spectroscopes, the distances of several thousand stars have been determined, and their motions to or from the observer, as well as their angular motions across our line of sight have been measured. By combining all these data, we arrive at length to know the actual motions in space of great groups of stars relative to each other and to our sun. Even for the spiral nebulae these facts are observed. Stromberg has arranged it all in a great diagram.

Let us admit that the island universe theory is true, and that our galaxy of stars is one among the many galaxies represented by the spiral nebulae. What is found is this:

The various galaxies represented as spiral nebulae rush hither and yonder in all directions at speeds ranging up to several hundred miles a second. Our own galaxy is rushing from the general center of them along a way represented in direction by a line drawn toward the constellation Sagittarius, at the rate of about 200 miles per second. Its older and smaller stars are more scattered from the common direction than the younger and more massive ones, so that, for example, the diffusion of yellow G type stars much exceeds that of the blue B type stars. Our sun happens to be moving in a direction not very far from along the general direction of our whole galaxy, but at a somewhat faster rate than the average of its stars, and at the present time is nearer to the center than to the circumference of our lens-shaped system of stars.

19. Finally, we may inquire how numerous are the heavenly bodies, and whether there are limits to the extent of the entire universe. In our own galaxy it is believed that the number of the stars reaches or exceeds 30 billions. Its greater and lesser diameters may be set at perhaps 100,000 and 20,000 light-years. Of spiral nebulae which could be photographed by the greatest telescopes, there are little less than 1,000,000. Those whose distances have been measured prove to be about 1,000,000 light-years distant. Smaller ones may very likely be much farther away. Indeed, one can not set bounds to the whole universe. There may be other galaxies far beyond the faintest which our photographs reveal, and others still beyond these, indefinitely. Possibly their individual star populations may approach or exceed that of our own. We can not know that they do not. Mathematics, indeed, as Professor Moulton has shown, informs us that if space were infinite and populated with galaxies, they could not be distributed with approximate uniformity in this infinite extension as the dust particles are in a room. It would, however, be possible that if galaxies in great numbers constitute supergalaxies of enormous dimensions compared with individual galaxies, and if these supergalaxies are the units of which supergalaxies of the second order are composed, and so on in an unending sequence, each cosmic unit being made up of smaller units which are very far apart compared with their dimensions, then there will be no contradictions with observational evidence or dynamical requirements.

In contemplation of these things, one has more reason than the psalmist had to exclaim: "When I consider the heavens, the work of Thy fingers, the moon and the stars, which Thou has ordained; what is man that Thou art mindful of him and the Son of Man that Thou visitest him?"

THE PLEIADES, G. W. RITCHEY

Photographed with the 2-foot reflector of the Yerkes Observatory, 1901, October 19. Exposure, 3½ hours. Cramer Crown plate. From "The Sun," by C. G. Abbot. Published by Appleton & Co., 1911

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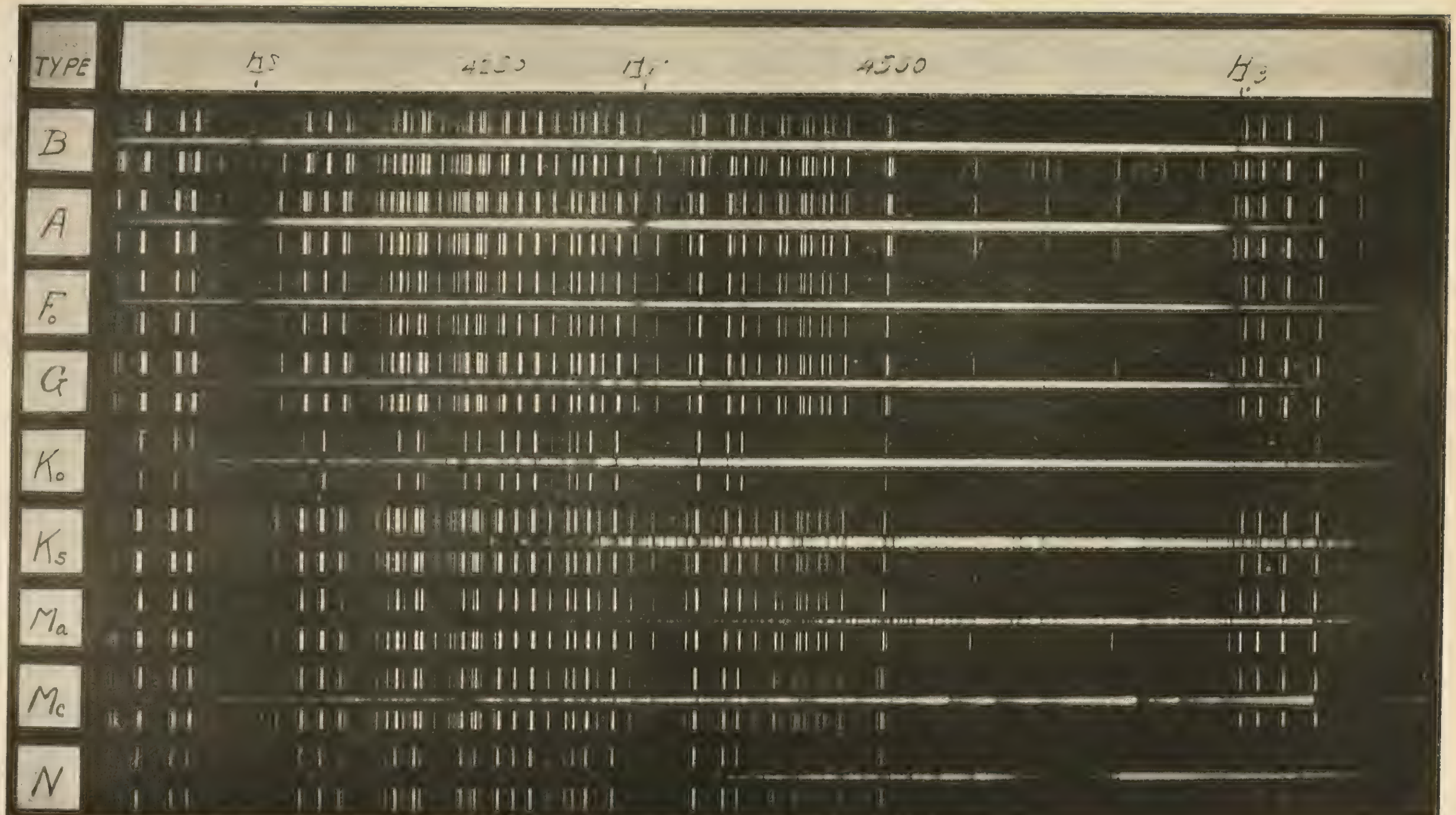
CENTER. R. A. 17h 2m. DEC. −45° 55′. GALACTIC LONGITUDE 303°. LATITUDE +3°. TAKEN 1910, MAY 6

Region around δ Normae. Bright stars: δ Normae (11,94), ι Lupi (80,1) … [illegible]



CLASSIFICATION OF STELLA SPECTRA (ADAMS)
From Harper's Magazine, October, 1926

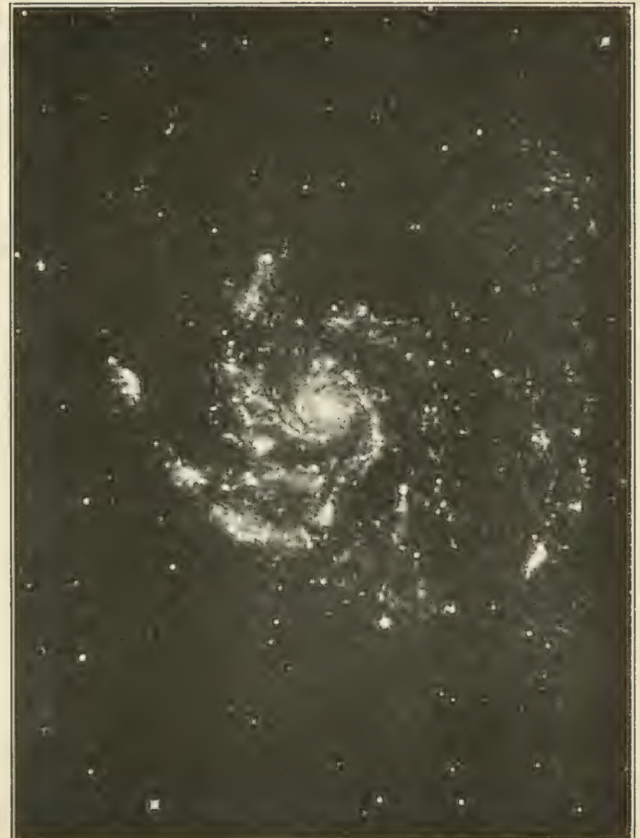
1. REGULAR SHAPED NEBULA (N. G. C. 3115)

2. REGULAR SHAPED NEBULA (N. G. C. 5866) WITH BAND OF DARK MATTER ON EQUATOR

1. REGULAR SHAPED NEBULA (N. G. C. 4594) WITH RING OF DARK MATTER SURROUNDING EQUATOR

2. SPIRAL NEBULA (N. G. C. 891) SEEN EDGE ON

1. Spiral Nebula in Canes Venatici (M. 51)



2. Spiral Nebula in Ursa Major (M. 101)

EXCURSIONS ON THE PLANETS[1]

By LUCIEN RUDAUX

[With 10 plates][2]

May we some day be asked to leave this modest planetary globe upon whose surface we now pass our lives? We will not stop to discuss the pros and cons of such an eventuality but suppose the question has been answered affirmatively. In other words, some dweller on our earth is to set foot upon other worlds. Upon such a voyage will the reader be conducted. To simplify matters we will abstain from any scientific speculations as to the actual itinerary of such a voyage. Let us disdain all ordinary methods of journeying, too slow for our purpose, because of the immense distances to be traversed. We will suppose ourselves—as our imagination can allow us—transplanted in the twinkling of an eye to the various neighboring worlds—the moon and the planets of the solar system, the "earths of the heavens," as they have been expressively called by Camille Flammarion.

Can we, by any chance, describe the scenes we will see except as pure phantasies? Yes. Within certain limits, we can approach the subject and reply positively to some of the questions which will be asked in the contemplation of the heavens. If, despite the perfection of the methods of research in modern astronomy, there yet remain many unsolved problems relating to an intimate knowledge of the celestial worlds, nevertheless we do have at present precise data which make possible a visualization of the general physical conditions on each of them. That we may keep on ground where we are surest of not going astray, we will try to indicate simply the essential differences in the aspects of nature which meet the eye of the human voyager.

Let us start on the moon. We know that its surface is broken by thousands of rings, or craters, of various depths, numerous mountains, and vast plains improperly called seas. This general view is so well known that we need not dwell upon it. But we must consider how all this would appear to a voyager landing upon the

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[1] Translated by permission from La Nature, June 19, 1926.
[2] Halftone reproductions of drawings by the author.

ground—that is, what manner of landscape would greet his wondering eye.

The very accurate data which astronomers possess as to the structure of the lunar terrain greatly facilitates this problem. For geometry enables us to put easily into actual perspective all the details which the telescope allows us to see in relief under an oblique illumination. Remember, in passing, that the shadows are sharply delineated and that they may be seen to elongate as the sun rises or sets for different regions of the lunar surface. This enables us to calculate exactly the heights of the various parts of this surface.

It is astonishing, despite these exact data, what phantastic representations have been drawn of the landscapes of this lunar world. Numerous astronomical treatises have represented them as embellished with mountains and peaks made of jagged sugar loafs, at the feet of which are heaped numerous small vatlike formations having the appearance of volcanic molehills. Actually the lunar mountains have profiles comparable in their steepness to our own terrestrial mountains. The great majority of the circular formations are of such size that we would be unable to see their whole extent in a single glance. It would be necessary to turn around in order to see their circular walls which would appear like a long chain of more or less irregular mountains. For some of them, if we were at their center, their ramparts would be so far distant as to be invisible, lost below our horizon. We must further remember that on the moon, because of the greater curvature of its globe, relative to the stature of man, the horizon is closer, and therefore objects disappear behind it at a shorter range. Only those craters which are very small and numerous and whose diameters are of the order of a kilometer may be wholly seen from one place. We should in no way compare them with the ordinary volcano whose crater is a cavity at the top of an elevated cone. The lunar craters, despite this name with which they are often designated, are comparable to excavations whose bottom levels are very much below the surrounding lunar surface above which the exterior surrounding walls rise very little.

As to the extended gray plains, erroneously called seas, their great smooth surfaces must present a remarkably monotonous aspect broken here and there by immense fissures whose gigantic proportions have no parallel upon our earth.

We can reproduce the contour of any given region on the moon since we have comparatively precise measures. Though such views can not lay claim to an absolute fidelity, they are probably nearly true. They contain a certain dose of imagination indispensable to fill the gaps in our knowledge of the minuter details. They, however, can show us in an expressive fashion the general character of these extra-terrestrial regions.

But it is not the contour, the general outline of these moonscapes, which strikes the human eye with astonishment; it is the atmospheric conditions. We know that this globe, if not totally without an atmosphere, at least possesses none which we can detect. Consequently, since there is no air to scatter the light coming from the sun, this orb of day is enthroned in a black sky, dotted with stars as if at night. Moreover, a harsh light marks every detail, near or distant, with the same dry and insistent sharpness. How different is this view from those on our earth where the different distances merge harmoniously in blending vapors. It is surely in this manner that the eye will be most surprised, even though it is the eye of the most rabid impressionistic artist. Let the eye be that of an astronomer and his marvelling will be without end. Here our atmosphere interposes a serious obstacle to his contemplation of the heavens; it obstructs greatly the light coming from the stars, troubles their images, and even limits their visibility. It is, indeed, a real veil placed before his eyes. Upon the moon this veil is absent and the heavens shine in striking majesty. If the eyes are not dazzled by the blinding rays coming without hindrance directly from the sun, the unfathomable space will appear riddled with stars, more countless than on the earth, and these myriads of stars will show no scintillation. What a wonderful richness and what facility for observation would be the lot of the fortunate astronomer inhabiting the moon. Further, because of this same lack of an atmosphere, the rising and setting of the sun would offer appearances entirely unknown on the earth. At sunrise there would first appear the radiant glory of the sun's corona; next those gigantic rose-colored flames, the protuberances, will rise above the horizon. On the earth these phenomena are visible to the unaided eye only during the short duration of a solar eclipse. Stretching far upwards, like a great extension of the corona, will be seen the immense spindle-shaped zodiacal light, a phenomenon about which our ideas are still somewhat confused because of the difficulties in the way of its observation from the earth.

This grand spectacle, of which Plate 1 is a very unsatisfactory replica, we can leisurely admire. For the rotation of the moon takes the same length of time as its revolutions about the earth—for which reason she always turns the same face toward us. This rotation time is twenty-seven times less rapid than that of the earth. The apparent movement of the heavens is of course slowed down in the same proportion and the stars will appear to rise and set with a majestic slowness. Though the sky itself seems almost motionless, there is one celestial body which will appear to be at rest—our own earth. This is really not quite true, since, because of the unequal movement of the moon in its eccentric orbit, the terrestrial globe appears to oscillate about a mean position. The sun and the stars appear to file slowly back of it, while all the time we can see it rotating upon its own axis and changing phase, like our moon, with the varying position of the sun from which it receives its illumination. The position in the sky where the earth will be seen changes with the position of the observer. From the central region of the lunar disk visible from the earth, it is enthroned in the lunar zenith. At the periphery, it will be seen on the horizon. (Pls. 3 and 4.) In each position, it will have an aspect thirteen times greater than that of our moon. At the time it is full it will shine with intense brilliancy.

Let us now leave this strange world, so near to us—only 384,000 kilometers (239,000 miles) distant. It is the excursion outside of the earth about which we can foretell the most. The facts we possess about the other planets of the solar system are fewer, and to avoid pure phantasy we must limit ourselves to more general considerations. Let us remember that with regard to the worlds which we are to consider, though the facts relative to the appearances in the sky are exact, coming from mathematical deductions of measures, further than that we can offer only details which seem reasonable. We can not, for instance, say: Behold a landscape of the planet Mars! but, rather, a landscape which is theoretically possible on the planet Mars; or, better yet, what we conceive should be certain landscapes upon that planet.

The "fixed stars" are so distant that their relative positions appear the same from whatever planet they are observed. Therefore, for each of these worlds the starry firmament would be the same as ours. However, from each one the other planets are seen with differing brightness, there are different moons, and, finally, the sun appears of very different size (pl. 5).

Thus from Mercury, the planet closest to the sun, this central star appears enormous, in such proportions as Plate 5 indicates. Further, this great size varies notably because the orbit of Mercury is very eccentric. The apparent diameter of Mercury's sun indicated (relative to that seen from the earth) is that when Mercury is in perihelion; that is, when it is nearest to the sun. What manner of landscape is lighted by this colossal furnace the heat of which we are certainly not so constituted as to be able to bear, especially since it stays immovable in the sky? For Mercury revolves about the sun, always turning the same side toward it. In order to enjoy the freshness of night we would have to travel around into the opposite hemisphere.

Our knowledge about this planet is insignificant. Probably its surface has high mountains, but we can not estimate the importance of its atmosphere. Let us not delay upon this inhospitable world, because of the great heat of the sun, but travel to Venus, farther off from the sun. Seen from Mercury, Venus at certain times would appear a truly blinding star.

Again we have reached a planet about which we know very little. It appears from without of a brilliant whiteness, but we can detect no detail upon it probably because its thick cloudy atmosphere hides its soil from our eyes. Some astronomers believe that this atmosphere is very rich in water vapor, others that it contains none! At any rate the density of its atmosphere is very great, almost double that of ours. Upon the surface of Venus, covered with this dense atmosphere, diffusing the intense light from the enormous sun as seen from there, a sort of luminous and troubled fog must singularly limit the range of vision, doubtless preventing the enjoyment of any extended landscape. What are these landscapes? In lieu of anything better, let us suppose there exists here a surface with some land but much water. Through the dense atmosphere, the stars are either only slightly or not at all visible. If the sun can be observed at setting, the phenomena of refraction will be noted as on the earth but much more in evidence, modifying strangely the appearance of the solar disk. (Pl. 6, fig. 2.)

Farther away than the earth from the sun, upon the planet Mars, we should feel more at home. Day and night are scarcely longer than on the earth. Through an atmosphere very similar to ours although less dense, the stars will appear in splendor, enriched with two small moons. The smaller of these not only will appear to move with great speed but in an opposite direction from the apparent movement of the stars; indeed it revolves about Mars faster than the latter rotates upon its axis. At certain epochs, either in the morning or evening, the earth will be visible as morning or evening star, respectively, brilliant in the dawn or evening dusk, the latter of short duration because of the rarity of the Martian atmosphere. The sky will appear darker during the daytime and the sun, a third smaller than from the earth, will illumine less brilliantly the doubtless more monotonous landscape. The most reliable observations indicate a ground with very little relief, probably almost everywhere level, cut here and there with immense swamps. Incontestably in every respect we should feel the most at home on this planet.

But let us pursue our journey toward the giant planets. Upon them—Jupiter, Saturn, Uranus, and Neptune—we would no longer find ourselves upon solid ground, at least in the literal sense of the word. For it is very probable that these worlds are yet fluid, at any rate in a condition which would not admit of a solid surface. It would be impossible to find a landing place. Because of this circumstance, we will suppose ourselves changed into immaterial beings though still retaining our organs of sight. If Jupiter should possess

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a surface of any kind, it would appear of great extent to us because of the colossal dimensions of its globe. Would we be able to see the heavens through the thick and dense atmosphere whose storminess we can observe from our earth? Let us suppose so, and then we would see the sun as a very small disk shining with light twenty-five times fainter than as seen from the earth. That would be very meager for a sky so heavily clouded. Jupiter's globe turns upon its axis once in nine hours and fifty minutes. The succession of day and night is therefore very rapid; only five hours elapse between the rising and setting of the diminutive appearing sun which passes rapidly across its sky.

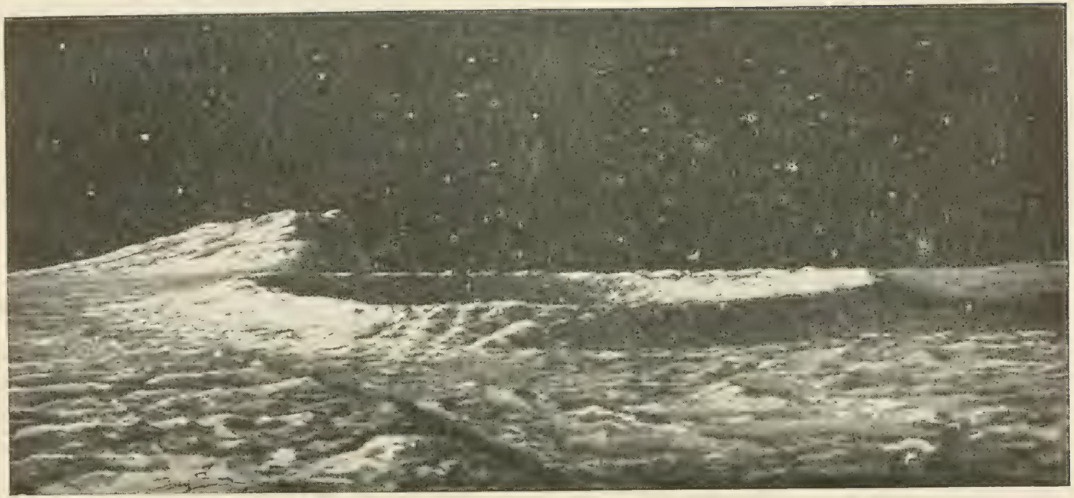
Jupiter has nine moons but only five are visually of any importance nor can all be seen at the same time. Their apparent size, reckoned from their actual size and distance from Jupiter, shows them to be comparable to our moon. They are of greatly diminished brightness since the sun illumines them much less intensely.

Suppose we now quit Jupiter to stop a moment, say, upon the nearest of its moons. From it the appearance of Jupiter will be immense because of the nearness of the giant globe as seen from this first satellite. Jupiter would indeed look like a formidable moon, one hundred times greater in diameter than our own, ten thousand times greater in extent of surface.

Along with this same order of grandeur of ideas, an even more astonishing spectacle awaits the traveler who sets foot upon the satellites of Saturn, the nearest one especially. Situated in the plane of Saturn's ring, this ring would appear only as a bright bar crossing the enormous globe of Saturn, but excessively distorted in dimensions by perspective, the whole system presenting very different aspects than as seen from the earth. Add to this the eclipse of a portion of Saturn by the shadow of the rings (pl. 9), the phases of the enormous globe changing with the direction of the light from the sun, and we will still have only a partial conception of the views that would be presented to our eyes. If it were possible to land upon Saturn—and here the same doubt arises as in the case of Jupiter—the sky would have an aspect equally strange. From different points of the globe, this sky, dotted with numerous moons, would be traversed by the luminous ring in varied aspects. At the Equator it would appear as a luminous thread passing through the zenith from one horizon to the other. At higher and higher latitudes toward the poles, it would appear as an arch, deformed somewhat by perspective, and according to the season, which here are terrestrial years long, it would be cut by the shadow of Saturn itself. And further, depending upon the relative diameter of Saturn and the annular system and because of the marked polar flattening of the former, beyond latitudes 65° 11′, north or south, this marvelous celestial arch would cease to be visible so that the polar inhabitants of Saturn must be completely ignorant of its existence.

We are now very far away from the sun which will appear in the sky of Saturn only as a small disk ten times smaller in diameter and shining with one hundred times less light. For us earth dwellers that would be a melancholy illumination. But what would we say if there were possibilities of going yet farther off toward the planets Uranus and Neptune, where our sun would be reduced in grandeur to the appearance of a bright star shining with respectively four hundred and nine hundred times less light than we receive on the earth.

SUNRISE UPON THE MOON: SEEN FROM A PLACE SITUATED AT THE EQUATOR: THE CENTRAL REGIONS ARE ILLUMINATED BY THE EARTH SITUATED IN THE ZENITH



TYPICAL OF A SMALL LUNAR CRATER

THE EARTH AND ITS PHASES SEEN FROM THE SOUTHERN POLAR REGIONS OF THE MOON. ALTHOUGH THE EARTH APPEARS AT REST IN THE SKY, THE SUN MOVES ALONG HORIZONTALLY BENEATH THE HORIZON, HID BY THE MOUNTAIN WHOSE SUMMITS ARE ILLUMINATED BY IT

a. Epoch of "new earth"; our globe, surrounded by the brilliantly illuminated ring of its atmosphere, is projected upon the corona and upon the zodiacal light

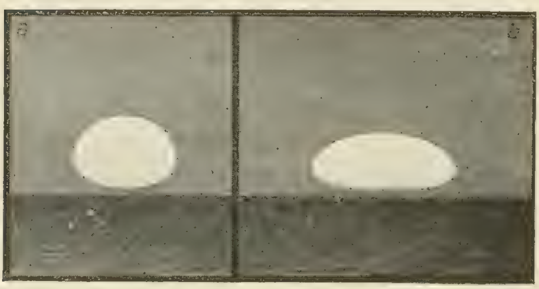
b. Epoch of the first quarter

THE EARTH AND ITS PHASES SEEN FROM THE SOUTHERN POLAR REGIONS OF THE MOON

c. Epoch of the "full earth"
d. Epoch of the last quarter

THE VARIATION IN THE APPARENT SIZE OF THE SUN AS SEEN FROM THE VARIOUS PLANETS OF THE SOLAR SYSTEM

1. THE PROBABLE CHARACTER OF THE SURFACE OF VENUS

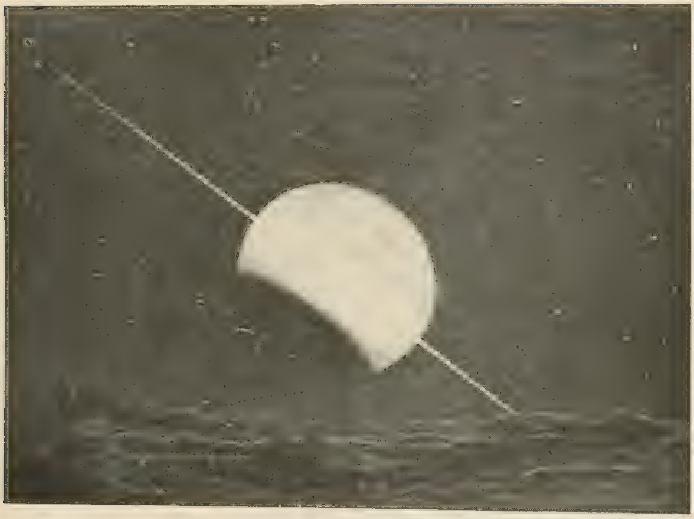


2. THE SOLAR DISK DEFORMED BY ATMOSPHERIC REFRACTION: (A) UPON THE EARTH; (B) UPON VENUS

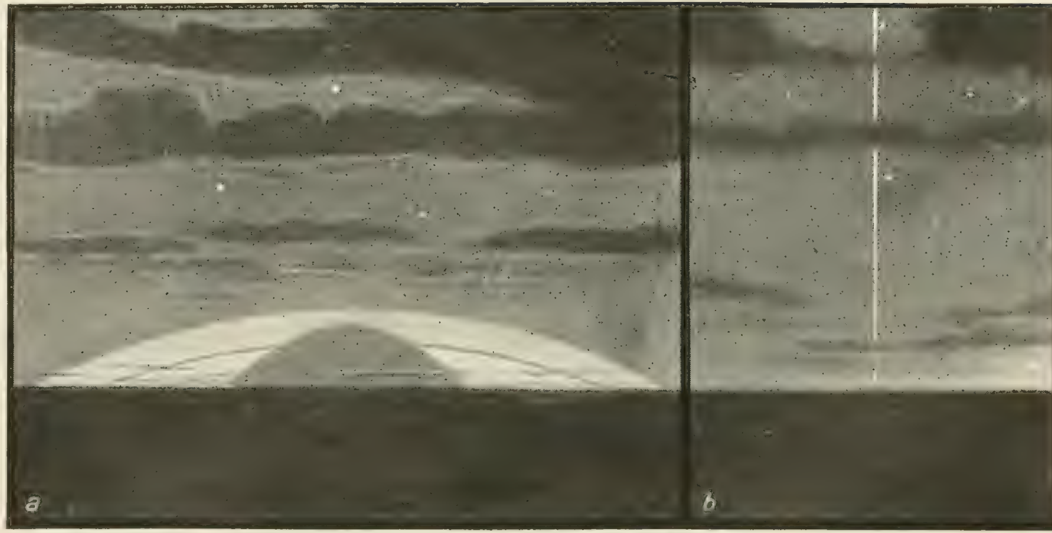
THE PROBABLE CHARACTER OF A LANDSCAPE UPON THE PLANET MARS SEEN IN THE DUSK OF EVENING. ITS TWO SMALL MOONS AND THE EARTH, LIKE AN EVENING STAR, SHINE IN ITS SKY

1. THE COMPARATIVE DIAMETERS OF OUR MOON AND THE SATELLITES OF MARS

2. THE MOONS OF JUPITER



THE PLANET SATURN SEEN FROM ITS FIRST SATELLITE



HOW THE RING OF SATURN IS SEEN FROM DIFFERENT PARTS OF ITS GLOBE: (A) SEEN FROM A HIGH LATITUDE; (B) FROM THE EQUATOR

HIGH FREQUENCY RAYS OF COSMIC ORIGIN [1]

By R. A. Millikan

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INTRODUCTION BY C. G. ABBOT

The paper of Professor Millikan which follows may be compared with the work of Röntgen, published in the Smithsonian Report of 1897. Some years after his discovery of X rays, it was proved that, like light and Hertzian or radio rays, they consist of ether vibrations of the transverse type. X rays, however, lie in the range of wave lengths from fifty to five thousand times shorter than those which produce the sensation of yellow light in the eye.

Now comes Professor Millikan with the most definite proof thus far obtained of a new type of rays also of the nature, as he thinks, of transversely vibrating waves, but whose wave lengths are of the order of two thousand times less than those of the shortest wave X rays.

Röntgen's X rays could penetrate flesh and thereby became a powerful aid in surgery and medicine. They could also penetrate many metals opaque to ordinary light. But the X rays are stopped by rather thin sheets of lead, so that X-ray photographers are accustomed to protect their sensitive plates by lead wrappers. Röntgen, however, distinguished between different degrees of penetration in the rays he was able to produce. He introduced (one does not exactly know why) the term " hard " to designate more penetrating and " soft " to designate less penetrating X rays. After the measurements of X-ray wave lengths had been accomplished, some years later, the " hard " rays were found to differ in being shorter wave lengths than " soft " ones.

It is not surprising then that rays of two thousand times less wave length should be very " hard." Professor Millikan, indeed, finds that these new rays will penetrate the equivalent of 6 feet of lead, the most impenetrable of common metals for ordinary X rays.

Still more noteworthy is the fact that the new rays do not appear to be engendered on this earth, but rather to fly about in every direction through the universe beyond our atmosphere. It is suggested by Professor Millikan that they arise from the destruction of transmutation of atoms in those fiery laboratories, the stars. Such features make the subject of the new rays one of extraordinary interest and perhaps of great developmental possibilities.

Readers will be interested to recognize in these new rays a very great addition to the gamut of the spectrum described so well by the late Prof. E. F. Nichols in his paper in the Smithsonian Report for 1923. Our friends will also take pleasure in the thought that the Smithsonian Institution, by its support of the work of Langley in the infra-red, of Shumann in the ultra-violet, and by its articles in which the progress of knowledge of the extension

[1] Reprinted by permission from the Proceedings of the National Academy of Sciences, vol. 12, No. 1, January, 1926. Read before the Academy Nov. 9, 1925.

of the spectrum is described from time to time, has played a worthy part in the enormous development to which the following paper by Professor Millikan is so notable a continuation.

It was as early as 1903 that the British physicists, McLennan and Burton [2] and Rutherford and Cooke [3] noticed that the rate of leakage of an electric charge from an electroscope within an air-tight metal chamber could be reduced as much as 30 per cent by inclosing the chamber within a completely encircling metal shield or box with walls several centimeters thick. This meant that the loss of charge of the inclosed electroscope was not due to imperfectly insulating supports, but must rather be due to some highly penetrating rays, like the gamma rays of radium, which could pass through metal walls as much as a centimeter thick and ionize the gas inside.

In view of this property of passing through relatively thick metal walls in measurable quantity, the radiation thus investigated was called the "penetrating radiation" of the atmosphere, and was at first quite naturally attributed to radioactive materials in the earth or air, and this is in fact the origin of the greater part of it. But in 1910 and 1911 it was found that it did not decrease as rapidly with altitude as it should upon this hypothesis. The first significant report upon this point was made by the Swiss physicist, Gockel,[4] who took an inclosed electroscope up in a balloon with him to a height of 13,000 feet and reported that he found the "penetrating radiation" about as large at this altitude as at the earth's surface, and this despite the fact that according to Eve's [5] calculation it ought to have fallen to half its surface value in going up 250 feet.

In 1911, 1912, 1913, and 1914 two physicists, Hess,[6] a Swiss, and Kolhörster,[7] a German, repeated these balloon measurements of Gockel's, the latter going to a height of 9 kilometers, or 5.6 miles, and reported that they found this radiation decreasing a trifle for the first mile or so and then increasing until it reached a value at 9 kilometers, according to Kolhörster's measurements, eight times as great as at the surface. This seemed to indicate that the penetrating rays came from outside the earth, and were, therefore, of some sort of cosmic origin. If so it was computed [8] that in order to fit the Hess and Kolhörster data the rays had to have an absorption coefficient of 0.57 per meter of water and an ionizing power within a closed vessel sent to the top of our atmosphere of at least 500 ions per cubic centimeter per second in place of the 10 or 12 ions found

[2] McLennan and Burton, Physic. Rev., 16, 184, 1903.
[3] Rutherford and Cooke, ibid., 16, 183, 1903.
[4] Gockel, Physik Zeit., 11, 280, 1910.
[5] Eve, Phil. Mag., 21, 26, 1911.
[6] Hess, Physik Zeit., 12, 998, 1911, and 13, 1084, 1912.
[7] Kolhörster, ibid., 14, 1153, 1913, and D. Physik Ges., July 30, 1914.
[8] E. v. Schweidler, Elster u. Geitel Fest schrift, p. 415, 1915.

in ordinary electroscopes at the surface. The war put a stop the world over to further studies of this sort, but as soon as we could get the proper instruments built after the war in the newly equipped Norman Bridge Laboratory of Physics, I. S. Bowen and myself went to Kelly Field, near San Antonio, Tex., as with four little recording electroscopes which we succeeded in the spring of 1922 in sending up in sounding balloons to almost twice the heights which had previously been attained. The highest flight reached the altitude of 15.5 kilometers, or nearly 10 miles.

These instruments were interesting in that, though they were built of steel to hold 300 cubic centimeters of air at 150 pounds pressure, and were provided each with a recording barometer, thermometer, and electroscope, also with two different sets of moving photographic films and the necessary driving mechanism, the total weight of the whole instrument was yet but 190 grams, or about 7 ounces. The altitudes were determined not only from the now well-established law of ascent of balloons, but also by direct, two theodolite observations which Maj. William R. Blair of the United States Signal Corps kindly sent Lieutenant McNeil to Kelly Field for the express purpose of making for us.

In these experiments we expected, if the results previously reported were correct, to find very large rates of discharge; for our instruments went up to such heights that 88 per cent of the atmosphere had been left beneath them, and only 12 per cent was left to cut down, by its absorption, the intensity of the hypothetical rays entering from outside. In other words, our electroscopes should have been exposed to radiations approaching in intensity those existing at the very top of our atmosphere. We actually failed to find anything like the computed rates of discharge. Our experiments were in agreement with those of the European observers in that our electroscopes showed a somewhat higher rate of discharge at high altitudes than at the surface, but at the same time they proved conclusively that a radiation of the assumed properties did not exist, our observed rates of discharge being not more than one-fourth the computed amounts.

Since the origin of the "penetrating rays" was still uncertain, Dr. Russell Otis and myself in the summer of 1923 went to the top of Pike's Peak for the sake of making absorption experiments upon this radiation at the highest altitude to which we could carry large quantities of absorbing materials. For if the rays were not of cosmic origin they did not need to be more penetrating than are the gamma rays from radioactive materials, while if they were of cosmic origin the sounding balloon experiments of Bowen and myself had shown that they must be very much harder (more penetrating) than any-body had thus far assumed. What was needed was absorption experiments to determine just what sort of rays they actually were.

We carried 300 pounds of lead and a 6 by 6 by 6 foot tank of water to the top of the peak and obtained as the net result of these absorption experiments the definite proof that the rays found at the top of Pike's Peak were predominantly of the hardness of ordinary gamma rays, and further that they were very largely, if not entirely, of local origin, since local conditions, such as a heavy snow storm and blizzard, which occurred while we were there, varied their intensity nearly as much inside a screen of 4.8 centimeters of lead as outside. Kolhörster had by this time, after the brief publication of our Kelly Field data, and as a result, also, of new experiments made subsequently to them in crevasses and holes in glaciers in the Alps, reduced his estimated absorption coefficients [9] from 0.57 to 0.25, a change he regards as within the limits of his experimental uncertainties, but a change which made the assumed rays so hard as to be no longer irreconcilable with our sounding balloon observations. But we found that our Pike's Peak observations were not yet compatible with his now (1923) assumed characteristics of rays of cosmic origin, viz., rays which produce 2 ions per second per cubic centimeter at the earth's surface, and have a coefficient of 0.25 per meter of water. For while in going from the altitude of Pasadena to that of Pike's Peak the number of ions observed with the unshielded electroscope increased from 11.6 to 22.2, an increase of 10.6 ions, the number of ions observed through the shield of 4.8 centimeters of lead increased but from 9.37 to 11.6, an increase of only 2.23 ions. But radiation of the characteristics assumed above would have caused by itself, inside our lead screen, an increase of 3.34 ions, even if none of the large increase in radiation shown by the unshielded observations got through the lead shield—a supposition which we believed to be contrary to fact. In a word, our Pike's Peak observations showed that if rays of cosmic origin existed at all they must be of different characteristics from any as yet suggested, and they further showed most interestingly that a very copious soft radiation of unknown origin existed at the altitude of Pike's Peak.

Accordingly, Mr. Harvey Cameron and myself planned some new experiments for the summer of 1925 which were designed:

(1) To settle definitely the question of the existence or nonexistence of a small, very penetrating radiation of cosmic origin—a radiation so hard as to be uninfluenced by, and hence unobservable with the aid of, such screens as we had taken to Pike's Peak—and,

(2) To throw light on the cause of the variation with altitude of the radiation of gamma-ray hardness which our absorption experi-

[9] Kolhörster, Sitz.-Ber. Preuss. Akad. Wiss., 34, 366, 23.

ments on Pike's Peak showed to be more than twice as copious there as at Pasadena.

The only possible absorbing material obtainable in the immense quantities needed, and of homogeneous and nonradioactive constitution, were the waters of very deep snow-fed lakes—snow-fed because the results of underwater experiments which we had previously carried on near Pasadena had been vitiated by our discovery that the waters were appreciably radioactive. We felt that there was much uncertainty as to how much this cause might have affected the European observations in and about glaciers. Further, our Pike's Peak experiments had demonstrated that if any of the penetrating rays were of cosmic origin the ionization due to them in our electroscope at sea level had to be much less than the 2 ions, assumed above, out of the 11.6 observed, the experimental error being, say, half an ion. No crucial tests could, therefore, possibly be made unless we could find very deep, nonradioactive lakes at very high altitudes where cosmic rays, if they existed, had two or three times the ionizing effect to be expected from them at sea level. We needed at least three ions due to cosmic rays, to vary with absorbing materials, if we were to obtain unambiguous evidence.

We chose for the first experiments Muir Lake (11,800 feet high), just under the brow of Mount Whitney, the highest peak in the United States, a beautiful snow-fed lake hundreds of feet deep and some 2,000 feet in diameter. Here we worked for the last 10 days in August, sinking our electroscopes to various depths down to 67 feet. Our experiments brought to light altogether unambiguously a radiation of such extraordinary penetrating power that the electroscope readings kept decreasing down to a depth of 50 feet below the surface. The atmosphere above the lake was equivalent in absorbing power to 23 feet of water, so that here were rays so penetrating that, if they came from outside the atmosphere, they had the power of passing through 50+23=73 feet of water, or the equivalent of 6 feet of lead, before being completely absorbed. The most penetrating X rays that we produce in our hospitals can not go through half an inch of lead. Here were rays at least a hundred times more penetrating than these, and having an absorption coefficient but one twenty-fifth, instead of "about one-tenth of that of the hardest known gamma rays." [9]

How unambiguous was the experimental evidence may be seen from the fact that with the aid of a new electroscope of high sensitivity the change in ions per cubic centimeter per second in going from the surface of Muir Lake to the depth of 15 meters (50 feet)

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[9] Kolhörster, Sitz.-Ber. Preuss. Akad. Wiss., 34, 366, 23.

was from 13.9 ions to 3.8 ions, or a decrease to about a fourth value. The largest decrease below a surface reading reported by Kolhörster due to sinking electroscopes in water [9] was 2.1 ions, or a decrease of perhaps 20 per cent, so that we have here obtained an altogether new precision of measurement and unambiguity of evidence.

To obtain definite evidence as to whether these very hard rays were of cosmic origin, coming in wholly from above and using the atmosphere merely as an absorbing blanket, we next went to another very deep snow-fed lake, Lake Arrowhead in the San Bernardino Mountains, 300 miles farther south and 6,700 feet lower in altitude, where the Arrowhead Development Co. kindly put all their facilities at our disposal. The atmosphere between the two altitudes has an absorbing power equivalent to about 6 feet of water. Within the limits of observational error, every reading in Arrowhead Lake corresponded to a reading 6 feet farther down in Muir Lake, thus showing that the rays do come in definitely from above, and that their origin is entirely outside the layer of atmosphere between the levels of the two lakes.

Analysis of our absorption curves shows that the rays are not homogeneous but are hardened as they go through the atmosphere, just as X rays are hardened by being filtered through a lead screen. Our hardest observed rays have an absorption coefficient of 0.18 per meter of water and the softest which get down to Muir Lake a coefficient of 0.3 per meter. The sounding balloon experiments of Bowen and myself make it improbable that they become very much softer than this at the top of the atmosphere, since otherwise we should have obtained larger readings in our very high flight.

Observations carried on day and night for four consecutive days on Pike's Peak at an altitude of 14,100 feet, and for two consecutive days on Mount Whitney at an altitude of 13,500 feet reveal no preferential direction in the heavens from which the rays come. Within the limits of our uncertainty of measurements, then, these rays shoot through space equally in all directions.

When absorption coefficients are reduced to wave length by a formula [10] of probable, though not yet certain, validity our hardest observed rays have the wave length 0.00038 Å, and those of longer wave length go up to nearly twice this value, i. e., we find a spectrum about an octave in width in a frequency region about two thousand times higher than that of the mean X ray (1 Å), or as far above X rays as X rays are above light. The shortest wave length just computed corresponds to a frequency ten million times higher than that of visible light.

When these extraordinary high-frequency rays strike the earth, according to the now well-established Compton effect, they should

[10] N. Ahmad, Proc. Roy. Soc., A109, 206, 1925.

be transformed partially into soft rays of just about the hardness of the soft rays which we have actually observed on Pike's Peak and Mount Whitney. The reason these soft rays were more plentiful on the mountain peaks than at Pasadena would then be found simply in the fact that there are about three times as many of the hard rays to be transformed at the altitudes of the peaks as at that of Pasadena. This seems to be the solution of the second of our summer's problems.

We can draw some fairly reliable conclusions of a general sort as to the origin of these very penetrating and very high-frequency rays. The most penetrating rays that we have known anything about thus far, the gamma rays of radium and thorium, are produced only by nuclear transformations within atoms. In other words, they are produced by the change of one atom over into another atom, or by the creation of a new type of atom. It is scarcely possible, then, to avoid the conclusion that these still more penetrating rays which we have here been studying are produced similarly by nuclear transformations of some sort. But these transformations must be enormously more energetic than are those taking place in any radioactive changes that we know anything about. For, according to our present knowledge, the frequency of any emitted ray is proportional to the energy of the subatomic change giving birth to it. We can scarcely avoid the conclusion, then, that nuclear changes having an energy value perhaps fifty times as great as the energy changes involved in observed radioactive processes are taking place all through space, and that signals of these changes are being sent to us in these high frequency rays.

The energy of the nuclear change that corresponds to the formation of helium out of hydrogen is known, and from it we have computed the corresponding frequency and found it to correspond closely to the highest frequency rays which we have observed this summer. The computed frequencies of these cosmic rays also correspond closely to the energy involved in the simple capture of an electron by a positive nucleus. Thus, the highest speed β ray emitted by thorium leaves its mother atom with a speed which is equivalent to the energy acquired by the fall of an electron through 7,540,000 volts.[11] This electron in order to get out of the mother atom was obliged to move against the pull upon it of the positive nucleus, and in this act it gained a potential energy the equivalent of a fall through 4,400,000 volts.[12] If this same electron had reversed its path and plunged into the nucleus it should have generated in so doing a 12,000,000-volt ray (7,540,000+4,400,000). The cosmic rays

[11] Report of Committee on X Rays and Radioactivity of National Research Council, 1925, p. 92.

[12] Report of Committee on X Rays and Radioactivity of National Research Council, 1925, p. 68.

with which we have been dealing have frequencies which make them the equivalent of from 12 to 30 million volt rays. It is not improbable that the capture of an electron by the nucleus of a light atom involves a higher energy than its capture by a heavy one, so that such captures as are here discussed constitute, perhaps, the most plausible hypothesis as to the origin of these rays.

Is it possible to imagine such a phenomenon going on all through space? The difficulty is not so insuperable, in view of the transparency even of large amounts of matter for these hard rays combined with Hubbell's recent proof [13] at the Mount Wilson Observatory that some of the spiral nebulae are at least 1,000,000 light-years away. The centers at which these nuclear changes are taking place would then only have to occur at extraordinarily widely scattered intervals to produce the intensity of the radiation observed at Muir Lake.

The only alternative hypothesis to that above presented of high-frequency rays transvering space in all directions, might seem to be to assume that the observed rays are generated in the upper layers of the atmosphere by electrons shooting through space in all directions with practically the speed of light. This hypothesis might help some in interpreting the mysterious fact of the maintenance of the earth's negative charge, but it meets with insuperable obstacles, I think, in explaining quantitatively the variation with altitude of the ionization in closed vessels. In any case, in its most important aspect, this hypothesis is very much like the one presented above, for it, too, fills space with rays of one sort or another traveling in all directions with the speed of light. From some such conception as this there now seems to be no escape. And yet it is a conception which is almost too powerful a stimulus to the imagination. Professor MacMillan of Chicago will wish to see in it evidence for the condensation into matter out somewhere in space of the light and heat continually being radiated into space by the sun and stars,[14] an altogether permissible speculation. Unfortunately the psychics will of course be explaining all kinds of telepathies with the aid of these cosmic rays. But, be that as it may, the simple experimental facts, as shown by the foregoing work, are:

(1) That these extraordinary penetrating rays exist;

(2) That their mass absorption coefficient may be as high as 0.18 per meter of water;

(3) That they are not homogeneous, but are distributed through a spectral region far up above X-ray frequencies—probably one thousand times the mean frequencies of X rays;

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[13] Hubbell, Pop. Astron., 33, pp. 252–255, 1925.

[14] MacMillan, Science, 62, 122, 1925.

(4) That these hard rays stimulate, upon striking matter, softer rays of about the hardness predicted by the theory of the Compton effect;

(5) That these rays come into the earth with equal intensity day and night and at all hours of the day or night, and with practically the same intensity in all directions.

Mr. I. S. Bowen, Dr. Russell Otis, Mr. G. Harvey Cameron and myself, all of whom have participated in this investigation and have received invaluable aid from the instrument maker, Mr. Julius Pearson, will publish full details of this work elsewhere.

THE PRESENT STATUS OF RADIO ATMOSPHERIC DISTURBANCES [1]

By L. W. Austin

Laboratory for Special Radio Transmission Research [2]

Our knowledge concerning atmospheric disturbances is still very meager. The observed facts may be catalogued as follows: (1) In general, atmospherics are stronger at the longer wave lengths. (2) Except for the effects of local storms, they are nearly always stronger in the afternoon and night, while for the higher frequencies this increase in strength is confined usually to the night alone. (3) They are stronger in summer than in winter, (4) in the south than in the north, and (5) on the land than on the ocean. (6) A large proportion of them appear to be directive; that is, to come from definite regions, or centers, as mountain ranges, rain areas, or thunderstorms. It is also reasonably certain that (7) at least most of the long-wave disturbances travel along the earth with a practically vertical wave front,[3] like the signals; (8) that a considerable portion are oscillatory in character, though a certain portion are nonoscillatory and give rise to shock oscillations in the antenna at all wave lengths; and (9) that disturbances sometimes occur simultaneously at stations thousands of miles apart.[4]

The origin of the ordinary rumbling disturbances (grinders) has been the subject of many conjectures. Eccles [5] believed at one time that he had found the source of this type of disturbance, as far as England was concerned, in distant thunderstorms, especially in Western Africa. DeGroot [6] has suggested that the grinders are due to the bombardment of the upper atmosphere by electrons from the sun or charged cosmic dust. The idea that this type of disturbance

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[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, D. C., Apr. 30, 1925. Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce. Reprinted by permission from Journal of the Washington Academy of Sciences, vol. 16, No. 2, Jan. 19, 1926.

[2] Conducted jointly by the Bureau of Standards and the American Section of the International Union of Scientific Radio Telegraphy.

[3] Jour. Wash. Acad. Sci., 11: 101. 1921.

[4] M. Baumler, Jahrb. d. Drahtlosen Teleg., 19: 325. 1922. This matter of simultaneous crashes needs further investigation since a certain number of such coincidences may evidently occur by chance.

[5] Electrician (London), 69: 75. 1912.

[6] Proc. I. R. E., 5: 75. 1917.

comes in some way from above has also been held by Weagant.[7] Mosler,[8] while ascribing the disturbances to thunderstorms, concluded in contradiction to the ideas of Eccles, that thunderstorms could give rise to atmospherics only over a radius of about 60 miles. This limitation in distance was very probably due to insensitive apparatus. A very systematic study of thunderstorms and atmospherics, undertaken by the British Meteorological Office and the Admiralty, has apparently settled the fact that thunderstorms can be located with modern apparatus up to about 1,500 miles.[9]

There is still much difference of opinion as to the proportion of atmospherics which is due to thunderstorms. Professor Appleton, at a symposium[10] on atmospheric ionization and radiotelegraphy, November 28, 1924, expressed the opinion that practically all atmospheric disturbances might be produced by thunderstorms somewhere in the world.

It is undoubtedly true that thunderstorms produce many atmospherics, but it is not by any means certain that the lightning flashes themselves are always the actual sources. There is a widely prevailing idea among radio operators that the lightning flash often produces only a harmless click in the telephone receivers. I have made some observations during thunderstorms, using a coupled circuit with rectifying vacuum tube and galvanometer, which indicated that lightning flashes, even within 3 or 4 miles, were not as powerful in their effects on the receiving apparatus as many of the disturbances which occurred when no flashes were apparent. This comparatively feeble effect of the flashes is difficult to understand if the current rise at the beginning of the flash is as steep as is often assumed but would be understandable if the lightning discharge curves were of the form and duration of the atmospheric disturbance curves observed by Appleton and Watt (figs. 1–5). On the other hand, it is quite possible that the small deflections from the lightning flashes were due to a paralysis of the detector tube, a phenomenon which often occurs when the tube is exposed to very high electromotive forces. It must, therefore, be concluded that the connection between lightning and atmospherics is still not clear, and valuable work can be done by anyone who will watch the lightning and listen to the atmospheric crashes from thunderstorms in the neighborhood.[11]

At the London Physical Society symposium already mentioned, Prof. C. T. R. Wilson discussed the probability of there being dis-

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[7] Proc. I. R. E., 7: 207. 1919.

[8] Elektrot. Zeits., 1134. 1912.

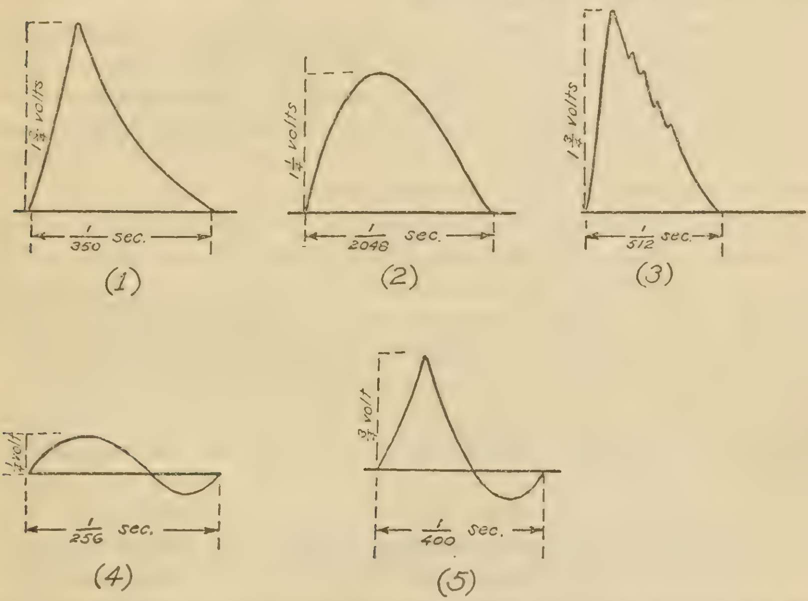
[9] World Power, 3: 20. 1925.

[10] Proc. Phys. Soc., London, 37: 2D–50D (appendix). 1925.

[11] It appears that for wave lengths below 1,000 meters, when thunderstorms are within a few miles, the visible discharges produce most of the strong disturbance crashes.

charges of thunderclouds to the upper conducting region of the atmosphere. His calculations indicated that thunderclouds of common electric moment might very readily discharge to a conducting layer at a height of 60 or 80 kilometers, since the electric force required to produce discharge decreases even more rapidly with the height than the electric force of the thundercloud. Discharges of this kind, probably nonluminous, may possibly furnish the explanation of the strong atmospherics heard from thunderclouds when no flashes are visible.

Mr. Watson Watt, in analyzing the records of European[12] direction-finding stations, concluded that in only about 35 per cent of



FIGS. 1, 2, 3, 4, and 5.—Atmospheric disturbance curves observed by Appleton and Watt

the cases could thunderstorms be identified as the sources of atmospheric disturbances, though in about 75 per cent of the cases the indentified sources were rain areas of some kind.

Captain Bureau[13] of the French Meteorological Office has recently published papers in which he shows that many of the atmospheric disturbances in France are closely connected with the advance of meteorological cold fronts and that the atmospherics are accentuated when these air movements come in contact with mountain ranges.

For the determination of the direction from which atmospheric disturbances come, Mr. Watt[14] has invented an automatic recording

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[12] Nature, 110: 680. 1922.

[13] C-R. Acad. Sci., 176: 556 and 1623. 1924: L'Onde Electrique, 3: 385. 1924.

[14] Proc. Roy. Soc., A, 102: 460. 1923. Phil. Mag., 45: 1010. 1923.

apparatus in which a radiocompass coil, tuned to about 30,000 meters, is rotated slowly and continuously by clockwork, the atmospheric crashes being recorded on a drum attached to the coil.

It should be said in this connection that it has been very common in Europe to estimate the strength of atmospherics by the number of disturbances occurring in a given time. This method, of course, would hardly seem to be applicable to our Washington summer conditions, or to the conditions during the disturbance season in the tropics where often in the afternoons and evenings the noise in the telephones forms an almost continuous rumbling through which no signal can be heard unless it is strong enough to rise above the background of disturbing sounds.

If, indeed, there is a physical difference between the atmospherics, crashes, grinders, etc., it is not at all certain that what is being measured in Europe by the counting method is the same thing that is being measured in America, either by direct estimates of the average disturbance strength, or by measuring the strength of signal which can be read through the disturbances.

On the Atlantic and Pacific coasts of the United States, except for occasional local thunderstorms, very little certain connection has been noticed between the direction of the atmospheric disturbances and rain areas. On the Atlantic coast, the main disturbances seem to come roughly from the Southwest, but it seems uncertain whether the sources are in the Allegheny Mountains or much farther removed, perhaps in Yucatan. Experiments reported by the Navy Department in New Orleans have indicated the more southerly origin.

Unfortunately, very few triangulation experiments have been made in America for fixing the exact positions of sources of atmospherics. In most cases, therefore, the direction is all that is known.

Observations made at Madison, Wisconsin, by Professor Terry of the University of Wisconsin, covering the last two years, show conditions in the Middle West which are similar to those described by the continental European observers; that is, there is no single prevailing direction of the atmospherics, but a more or less definite connection with thunderstorms and other rain areas. This absence of any prevailing southerly source of atmospherics in the central portion of the country casts doubt on the Mexican origin of those observed in the Atlantic coast region, since the distance from Yucatan to Madison, Wisconsin, is about the same as from Yucatan to Washington.

On the Pacific coast of the United States it is pretty well established that at least at San Francisco and San Diego the sources of disturbances are largely local, lying in the mountain ranges not far from the coast. These centers seem to be permanently fixed, resulting in very constant directional conditions.

It seems to be pretty well settled, in all parts of the world where observations have been made, that there is a very definite connection between the intensity of the disturbances and the position of the sun. In the Northern Hemisphere during the winter when the sun is far in the south, the disturbances are generally moderate even as far south as Panama, within 9° of the equator. But as the sun comes north in the spring, there is often a rapid and, sometimes, very sudden increase in strength, and it is reported that stations close to the Equator experience two disturbance maxima, corresponding to the two periods when the sun is nearly overhead.

In addition to the study of the sources of the disturbances, the question of their wave form is of much importance. Messrs. Watt and Appleton [15] in England, working under the Radio Research Board, have made some investigations of this problem, making use of the cathode-ray oscillograph (Braun tube). In their work the atmospheric disturbance, after being received on an aperiodic antenna and amplified by an aperiodic resistance-coupled amplifier, was impressed on one pair of plates of the oscillograph, while a source of 60-cycle current was connected to the other pair of plates for the purpose of drawing out the spot of light into a line on the fluorescent screen. The resulting movement of the spot of light could not be photographed, but could be observed and sketched with some accuracy. Five typical curves are shown in the figures. Most of these appear to be aperiodic, though some are feebly oscillatory.

In Figure 3 it is seen that there are minute oscillations superposed on the main curve. It will be noted that the period of main oscillation is, in all cases, of audio frequency; and Eckersley [16] has pointed out recently that the relatively prolonged impulses of Watt and Appleton can not account for the observed intensity of the atmospherics, ordinarily experienced in radio reception. He suggests that possibly the ripples, such as are shown in Figure 3, may be the actual atmospheric waves. Mr. Watt in the symposium cited accepts this view and adds that more recent experiments in Egypt and elsewhere in the Tropics show that there the fine ripple structure is much more common and of much greater amplitude than in England. Professor Appleton, on the other hand, holds that the low-frequency wave forms shown in the figures are capable of producing the observed disturbances at all wave lengths by shock excitation.

In conclusion, the differences of opinion mentioned in this paper show that there is still much to be done before the sources of the disturbances are identified with certainty. While many of the at-

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[15] Proc. Roy. Soc., A, 103: 84. 1923.
[16] Electrician (London), 93: 150. 1924.

mospherics undoubtedly come from thunderstorms, many appear to come from regions where no such storms are occurring. It is also believed that even in thunderstorms some of the heaviest disturbances do not come from the lightning itself, but the nature of these nonluminous sources of such great power is still a matter of conjecture.

COLD LIGHT [1]

By E. Newton Harvey, Ph. D.
Professor of Physiology, Princeton University

Man may well pride himself upon the development of heat, light, and electricity. Modern comfort is dependent on them. Few would welcome their disappearance despite the present tendency to decry the complexity of a mechanical age. But let us not forget that living creatures have long possessed methods of producing heat, light, and electricity quite different from those of the furnace, the lamp, or the dynamo.

Mammals and birds maintain their body temperature continually above that of their surroundings. They possess eternal fires and efficient thermoregulation, which makes them independent of cold. Fireflies and other luminous animals have flashed their lights for countless ages, while electric fish can generate currents strong enough to ring a bell or light an incandescent lamp.

We speak of the production of light by living things as bioluminescence, and few subjects touch as diverse fields of inquiry or interest as many investigators. It appeals to the morphologist, the physiologist, the chemist, the physicist, the philosopher, and the illuminating engineer. Those who have seen the brilliant flashes of innumerable fireflies, filling the fields on a midsummer night, or the sea a vivid sheet of flame when disturbed by some passing ship, can not but marvel at the display. Slow is the imagination which will not inquire how and why this light is emitted, or whether we may not some day successfully develop a "cold light," modeled on nature's plan.

It is possible in the space at my disposal to state only the general facts of bioluminescence and discuss some recent experiments bearing on the physical chemistry of the process. While fireflies have been known for centuries to all people, it is about 50 years since we have recognized the cause of certain other phosphorescences of living things. The glowing of dead fish or the glowing of meat in refrigerators or the glowing of wood were definitely proved to be due to living organisms in 1875 when it was shown that these luminescences were of plant or animal origin.

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[1] Reprinted by permission from Princeton Alumni Weekly, Vol. XXVI, No. 33, June 2, 1926. Appeared also in Scientia, May, 1927.

In 1810 a paper was presented to the Royal Society of London by a man named McCartney, setting forth the causes of the light or phosphorescence of the sea. He goes over some of the older theories which had been advanced to account for the phenomenon. Some had thought that the light was due to "putrefaction," because it had been known that dead matter might become luminous. Others thought that the light of the sea was electric, because it was excited by "friction." Others thought that it was "phosphoric," that the element phosphorus was present in the sea, which phosphoresced as it does on a match. Others thought that the sea imbibed light which it afterwards gave off, much as will a phosphorescent mineral like calcium sulphide.

Finally McCartney decided that the phosphorescence of the sea was due to animals living in it, and this is the correct explanation. Every phosphorescence of the sea is due to one or another form, usually microscopic, but many visible to the naked eye. I think few people realize how many luminescent organisms there are. If we examine the different groups of animals, we find that at least 40 different orders contain one or more forms producing light, and at least two groups of plants are luminescent. The two plants which produce light are the fungi and the bacteria. All the phosphorescence of wood is due to fungi, and all the phosphorescence of dead meat or fish in refrigerators, and other dead matter is due to bacteria. These luminous bacteria are very widespread and grow readily on an appropriate culture medium.

Not only bacteria and fungi, but sponges, jellyfish, comb jellies, hydroids, sea pens, minute organisms in the water known as dinoflagellates and radiolaria, many kinds of marine worms and earthworms, centipedes, brittle stars, several mollusks, many kinds of shrimp and crabs, and many kinds of cuttlefish or squid as well as true fish produce light. The number of luminescent species runs into the tens of thousands.

In some squid (*Watasenia*) the ends of the tentacles contain luminous organs, and as the squid swims through the water, it waves these tentacles around and flashes them much as the firefly does. This form is found in Japan and is called "hotaru ika," or firefly squid.

Another kind of squid (*Heteroteuthis*) from the Italian coast, throws out luminous secretion into the sea water. It lives in the depths of the sea, in perpetual darkness. The luminous secretion is manufactured in a gland corresponding to the ink sac that in surface squid produces the ink. According to the direction of evolution this gland has produced the blackest known fluid in cuttlefish, or a fluid not only transparent but one shining with its own light in *Heteroteuthis*. It is startling enough to see a cuttlefish surround itself with a black mass of ink; imagine one's surprise at the discharge of a cloud of "fire" that glows in the sea water for some time. What is the use of this remarkable power? Perhaps to frighten or blind predacious animals while the squid makes good its escape. It is not known with certainty.

Many fish produce a light of their own, apart from the light of luminous bacteria growing on the dead fish. The living fish contain organs which in themselves are light-producing, especially forms living in the deep sea. These organs are arranged in rows on the sides or bottom of the fish, giving it the appearance of a ship with all its port holes illuminated. Sometimes the organ is dangled on the end of a long stalk projecting from the head of the fish, a Diogenes of the deep in search of an honest meal.

Some of these luminous organs are exceedingly interesting from a structural standpoint because they are veritable lanterns. They have been carefully studied by Prof. Ulric Dahlgren '94, who has contributed much to our knowledge of the histology of luminous animals. In many ways they resemble the eye because they have a lens, except that the lens in the case of the luminous organ is used for directing the light, whereas in the eye it is used for receiving the light and converging it on to the retina. The more complicated of these luminous organs have not only a lens, they have also a layer of cells which contain a shiny material, and this shiny material makes the layer act as a reflector, so that when the light is produced in the middle of the organ, that which comes back against the reflector is shot forward and out through the lens, and all the light is directed and concentrated in a beam. Not only does the organ have reflectors, it has also opaque screens, in order to protect the tissues of the animals from any light which may pass out the side and possibly injure cells around the luminous organ. Light—strong light, at least—is destructive to living tissue, and where we have an organ in the animal producing a light of its own, we have, practically, a very strong light, and we find in most cases the organs or tissues protected by some kind of a screen.

There may also be present color screens, which allow only certain wave lengths to pass, and so give the light a definite color. These have been described in luminous cuttlefish from the depths of the ocean. One species has at least three colored luminous organs—a blue, a violet, and a reddish organ. An insect from South America has not only white luminous organs, but also red ones, and these red lights, so it is said, are very conveniently situated at the tail of the insect, and the white lights at the head. It is know locally as the "automobile bug."

Two luminous fishes found in the Dutch East Indies, in the Banda Sea, are of great interest because they have developed a luminous organ designed for the support of luminous bacteria. The organ is large, just under the eye, and the bacteria are of a special kind which will not grow on ordinary culture media or on the outside of the fish. They are spoken of as symbiotic luminous bacteria and present only another case of a mutual benefit partnership between two different organisms. The fish have the benefit of the light while the bacteria are supplied with free board and lodging. A very rich system of blood capillaries brings food and oxygen so necessary for the luminescence of these bacteria. It is characteristic of luminous bacteria that their light is shining day and night continually, as long as they are alive, while other luminous forms only light when they are stimulated. We observe this in the phosphorescence of the sea, which only occurs when the water is agitated by wind or the ship's propeller or movement of oars. Consequently these fish have had to develop a screen to cut off the light, and we find a fold of black pigmented skin, like an eyelid, that can be drawn up over the luminous organ and so obscure its light. Hence the name of the fish, *Photoblepharon*, or "light eyelid." The fishermen of Banda cut off these luminous organs, remove the screen, and impale them on hooks for bait. The light will shine steadily for a night's fishing. But *Photoblepharon* itself swims about in the sea turning its great luminous organ on and off like many another fish that manufactures its own light material without relying on the kind assistance of luminous bacteria. Only a careful microscopic examination reveals the true nature of the luminescence of *Photoblepharon*.

One can not be too careful in investigating the light production of a new form. I remember once while collecting luminous beetles in Cuba I was astonished to find a luminous frog. As fish are the highest creatures which can produce light, a frog with luminous organs would be a rare find indeed. My hopes were short-lived, however, for closer examination revealed that the animal had just finished a hearty meal of fireflies, whose light was shining through the belly with considerable intensity.

Some cases of luminosity are on record in connection with man himself. Before the days of aseptic and antiseptic surgery, wounds frequently became infected with luminous bacteria and glowed at night. The surgeons of that time believed that luminous wounds were more apt to heal properly than nonluminous ones. Perhaps there is some truth in this view. Luminous bacteria are harmless nonpathogenic forms and it is possible that such forms might crowd out pathogenic bacteria striving to gain the ascendency on the wound.

In the older literature there is a case of luminous sweat and several cases of human urine, luminous when voided. If these observations are really true, and so far as I know they have not been confirmed in recent times, we may be dealing with luminous bacteria or there may be secreted some easily oxidizable substance that luminesces during its oxidation. Several such bodies are known in organic chemistry.

To the student of evolution, luminous animals offer a great field, but a field in which relatively little is known. Almost everyone is interested in the use of luminescence to the luminous animals, and unfortunately we can say in only a very few cases what the use of the light is. Who, for instance, would venture to suggest the use of light to a luminous bacterium, an organism which is perhaps one twenty-five-thousandth of an inch in diameter and which has not the nervous reactions of a higher form; or the use of the light to an animal which occurs living at the surface of the sea, and which also has no nervous system, a one-cell form, blown hither and thither by the wind?

Apparently, in such cases as this, we must believe that the light is merely fortuitous, that it accompanies merely some of the organic chemical changes which go on in the animal. It is a chance phenomenon. On the other hand, it would seem likely that deep sea fishes and squid—and it is chiefly these forms which have the lantern, complicated in structure—must use their light as a searchlight for seeing things in a region where we know light does not penetrate.

On the other hand, a great many species are known which do not live continually in dark places and many luminous forms do not move around at all, the sea pens, for instance. They are almost all luminous, a colony of animals that live in the mud or sand at the bottom of the sea at a depth of perhaps 50 feet where there is plenty of light. As they do not move about from one place to another it has been suggested that they may use the light as a warning. If a predacious fish comes along, the minute the sea pen is disturbed by the fish, the light is flashed on. That warns the fish and scares him away. But this is a mere conjecture and I think no one has seen it take place. It has been thought also that animal light may be used as a lure, that certain forms use their lights to attract other forms on which they prey. Whether that is true or not, is also a conjecture.

Finally, it certainly seems that in some forms the light is used to attract the opposite sex in mating. That is the case with the firefly. Each species of firefly has a light which shines in a certain definite way, and if one is an expert, he can go into the field and point out the different species of fireflies by the interval between flashes and the time of the flashes. The male and female of each species are brought together by signaling in that way.

The chemical nature of animal luminescence is the subject I have studied most closely. Whenever I mention that I am interested in luminescence, I am always asked one question—whether the light is

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phosphorus or not. It is easy to answer in the negative, that the light has nothing to do with the element phosphorus, which is too poisonous to be found in living cells. On the other hand, the light has a very great resemblance to the luminescence of phosphorus. In the first place, it is an oxidation, and if we remove the oxygen from any luminous animal, the light will disappear completely, and if we again readmit oxygen, the light will return. This is a very interesting experiment, and a very old one. In fact, it is one of the first experiments that was ever made on luminous forms, by Robert Boyle, in 1667.

Boyle at that time was experimenting with his air pump, and, among other things, he placed a little piece of "shining wood" or phosphorescent wood under the receiver of his air pump. He found that when he exhausted the air, the light disappeared, and when he readmitted air, the light returned. Of course, he did not know that it was oxygen in the air which was responsible for the effect, but nevertheless I think we can credit him with the discovery that the luminescence of living things requires the presence of free oxygen.

The second chemical fact is also rather an old one. It was discovered by Spallanzani, an Italian, in 1794, that all luminescence required water, and he showed that he could take any luminescent animal, and dry it and the light would disappear, but that if he kept this dried material and at some later time moistened it again, the light would reappear. So, like the experiment with oxygen, we have another perfectly reversible process, showing that luminous animals require water in order to luminesce.

This experiment also shows that luminescence is not a function of living cells in the same sense that the contraction of a muscle or propagation of a nerve impulse is a function of living cells. If a muscle is dried quickly, its form or constituents are not changed, but if put in water again, although it will look like the original muscle, no contraction will result on stimulation. The muscle has lost its contracting power by drying, and a nerve also loses its conducting power after drying. Therefore, we have in these tissues loss of a living function, but we do not observe loss of the power of luminescence on drying the luminescent organ of an animal.

Since water and oxygen are necessary, it is likely that some material produced by the cells of the animal is oxidized, and this material is called, to use a general term, the photogen, but to use a more specific term, it is called luciferin.

In fact, not only one material, but two materials are found to be necessary in order to get light, in addition to water and oxygen. This is the third discovery in connection with the chemistry of luminescence, made by a Frenchman, Dubois, in 1887. He found that a luminous extract of an animal could be separated into two parts, one containing luciferin, which will oxidize with the production of light, and the other part containing a catalyst or enzyme which accelerates the oxidation of luciferin. The two substances could be separated by a difference in their properties, luciferase being destroyed on heating, while luciferin was not. We can obtain the two substances in solution in water, and they can be precipitated by various reagents. They can be purified and experimented with like any other bodies, although we do not yet know what is their exact structure. Chemically, luciferin is probably to be placed among the proteins, among the simplest members of the proteins, the peptones or proteoses; luciferase is related to the albumins.

The question as to whether we shall ever be able to reproduce living light becomes the question whether we shall ever be able to synthesize the proteins. Personally I think that will come in the future. We now synthesize fats, sugars, and some of the polypeptids, which are simple proteins. It is only a matter of time for synthesis of the more complicated compounds of which luciferin is a member.

Finally we may ask what happens when luciferin is oxidized. Does it go to carbon dioxide like other foodstuffs in our body? Sugar and fat are oxidized to water and carbon dioxide. Can we place the luminescent oxidation in the same category? I think we can not. Experiment has shown that no carbon dioxide is produced from the luminescence of an animal, and I believe the change that does occur is a very simple change. Although the reaction can be only partially written we can at least name the material which is oxidized, and for convenience I have called this oxidation product, oxy-luciferin, a similar nomenclature to the one which is used for the red pigment of blood. The red pigment of our blood, hemoglobin, when shaken with air, becomes oxy-hemoglobin. If we place oxy-hemoglobin under an air pump, and exhaust all the air, it returns to reduced hemoglobin or hemoglobin proper. This process is reversible and will go either one way or the other, depending upon the amount of oxygen present.

Luciferin behaves in a somewhat similar way. We can allow the luciferin to become completely oxidized and then by proper methods reduce the oxy-luciferin again and recover our luciferin. The methods for doing this are not quite so simple as the method for reducing oxy-hemoglobin, for one can not put it under an air pump and get reduction, but there are many other means of reducing oxy-luciferin, and I think this occurs in the luminous animal. When a firefly flashes, it oxidizes the luciferin to oxy-luciferin. When it is resting, in the dark between the flashes, the oxy-luciferin is reduced back to luciferin, and the firefly is ready for another flash.

I do not wish to say that all the luciferin in the firefly becomes oxidized in one flash, but part of it does, and in the time between flashes, part is reduced. A reversible process occurs, and you will note that this is an extraordinary process from the chemical standpoint. Here is an animal with a lamp which burns an oil, and after that oil has been burned, the oil is reformed, and it is ready to be reburned. We have the process of oxidation and reduction simply going back and forth according to the amount of oxygen which is present. Not only from the physical but from the chemical standpoint the firefly is highly economical. Like the Phœnix of old, luciferin is recreated from its ashes to pass through the cycle of another life.

It is possible to devise a lamp in which luciferin is burned continuously over and over again. In one region luciferin is oxidized to oxy-luciferin with luminescence; in another the oxy-luciferin is reduced to luciferin again. To be sure the light is weak, and practical difficulties appear in the "poisoning" of necessary catalysts, but the principle remains. Perhaps we may look to an application of this principle for the future development of new means of illumination.

Apparently mysterious and often unusual in color, the light of living creatures is not essentially different from that of any ordinary light, except in its mode of production. We express this difference when we say that animal light is "cold light" or a luminescence. Electric light is a "hot light" or an incandescence. Every substance, no matter of what material, of any color or texture, whether it burns or not, emits light when its temperature is raised above a certain point (about 525° C). The first light at this low temperature is red, then yellow appears at a higher temperature, then white light at the 5,000° of our sun. The higher the temperature the brighter the light. This means of producing light is so universal and so easy that it is no wonder we have adopted it. Practically every illuminant in use to-day is patterned after the sun and stars. We heat an incandescent lamp filament to the highest temperature possible without volatilizing the filament. It is not possible to attain the temperature of the sun, but 2,000° is attained, and a high percentage of the electrical energy which heats the filament is radiated. Unfortunately most of this radiation is heat, and only about 2 per cent is visible light. If the 98 per cent useless radiation could be eliminated, a 2-horsepower engine might run the dynamo to supply our lights that now require 100 horsepower. Incandescence is a wasteful way of producing light because it is impossible to separate the heat radiation from the visible light radiation.

Luminescence, or cold light, on the other hand, consists of nothing but visible light. The spectrum of a firefly lies wholly in the visible region with no infra-red or ultra-violet. As far as radiation goes it is all light or 100 per cent efficient, and this is the basis for the statement that fireflies are so efficient.

Most persons do not realize that this radiant luminous efficiency tells us nothing regarding the efficiency of a firefly as a light producing machine. When the most efficient incandescent lamp, a tungsten nitrogen-filled Mazda, glows, coal is being burned in some power house. Every ton of coal represents so much energy, but of this energy only one-half of 1 per cent, a well-known figure, appears as visible light.

To compare a luminous animal with a commercial light we must ask what fraction of the energy of its fuel (food) appears as light. No one has determined this for the firefly, and the investigation would present special difficulties because the firefly flashes, and flashing lights can not be measured easily. We are forced to fall back on luminous bacteria which emit a steady light, despite the fact that they are the smallest luminescent creatures. I have studied such a bacterium, a cylindrical rod measuring 1.1μ wide[2] and 2.2μ long, with a volume of 0.000,000,000,017 cubic centimeter.

Perhaps I may be pardoned if the technical details of such an efficiency determination are briefly outlined. Visible light is a form of energy and can be evaluated in a common energy unit—the calorie.[3] We must measure the light produced by a single bacterium and express this in calories per second. Food represents the source of an organism's energy, the energy input, and when burned liberates a maximum amount of energy, also measured in calories. We must measure the food utilized by the bacterium and express the energy input in calories per second. Then, light emitted in calories divided by food oxidized in calories, gives us the over-all efficiency of a bacterium.

The light measurements themselves present no particular difficulties. We can make an emulsion of luminous bacteria in sea water, many billions of them, count the number of bacteria per cubic centimeter, measure the amount of light emitted by 1 cubic centimeter, measure the absorption of light by bacteria in front of others, and calculate the amount of light in lumens which each bacterium would emit in all directions, provided there were no absorption. As one candle emits 4π lumens, the candle power of the smallest light in the world is easily obtained.

The general scheme of investigating the energy input is as follows: Metabolism experiments in animals show that for a liter of oxygen consumed a certain number of gram-calories is produced by oxidation of the foodstuffs. A gram of tallow oxidized by a guinea pig liberates the same amount of heat and consumes the same amount of oxygen during combustion to CO_2 and H_2O, as if it had been burned

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[2] $1\mu = 0.001$ millimeter=one twenty-five-thousandth of an inch.

[3] The light of the bacteria is actually measured in light units. One lumen=0.0015 watt or 0.00036 calorie.

in a candle. This was one of Lavoisier's great contributions to science. A bacterium could obtain no more energy in burning its foodstuffs than a guinea pig or any other organism.

Knowing the oxygen consumption of an animal and its food, we can calculate its heat production, and this "method of indirect calorimetry" gives results in surprising agreement with direct measurement of heat production in a calorimeter. Applying this method to luminous bacteria, which were fed upon 60 per cent glycerin and 40 per cent peptone, each liter of oxygen consumed should produce 4,840 gram-calories or 3.4 gram-calories per milligram of oxygen consumed. We have only to measure the oxygen consumed by the bacteria to find how much energy is supplied by the food during luminescence.

Converting energy from milligrams of oxygen utilized and lumens of light emitted into the same units, calories, the over-all efficiency of a bacterium turns out to be 0.16 per cent. This tells us the percentage of the energy necessary to run a bacterium which appears as light. It does not give us a true picture of the efficiency of the light-producing reaction, for much of the oxygen consumed is used by bacteria for processes which have nothing to do with luminescence. It can be shown by other experiments that certainly only one-sixth of the oxygen is used in luminescence, and probably much less than this. Using the figure, one-sixth, brings the efficiency of the bacterium to nearly 1 per cent, a figure twice as great as that for over-all efficiency of the best incandescent lamp.

While the extravagant claims for total efficiency of luminous animals are not confirmed by my investigations, nevertheless the value, which I regard as a minimum value, is sufficiently high to warrant further inquiry into the process by which animal light is produced. We usually find that living creatures have developed very economical ways of doing things, and one would like to know what the total efficiency of luminous animals, far brighter than luminous bacteria, might be, if we could separate completely the light-producing process from the other energy-consuming processes of the animal.

Such creatures as I have described offer problems of fascinating interest. The chief appeal is to the intellect, a study in pure science, in a field whose boundaries touch biology, physics, and chemistry. Advance will be made when the ever-widening waves of knowledge in each science meet and reinforce each other. Cooperation between the sciences is sure to bring more and more fruitful discoveries. I have endeavored to point out some of the interlocking connections in the field of light. Princeton is fortunate in having research on this important subject well under way in five fundamental sciences and a future program which we hope may be carried out with an adequate endowment for pure scientific research.

SCIENTIFIC WORK OF THE "MAUD" EXPEDITION, 1922–1925 [1]

By H. U. Sverdrup, *in charge of the scientific work of the expedition*

Capt. Roald Amundsen's ship *Maud* left Norway in July, 1918, with the intention of following the Siberian coast to the vicinity of the New Siberian Islands, penetrating into the drift ice, and, if possible, being carried across the Arctic Sea to the vicinity of Spitzbergen. However, on account of unfavorable ice conditions, it was necessary for the expedition to winter three times on the Siberian coast and, in 1921, to go to Seattle for repairs and replenishment of provisions.

The *Maud* left Seattle again on June 3, 1922, in order to resume her task in the Arctic. The main object was, as previously, to make scientific observations of interest in various branches of geophysics. We could not expect to contribute to the geographical knowledge of the Arctic region, because it was improbable that the drift should carry us across the great unknown area within the Arctic Sea. To Captain Amundsen, however, the exploration of this unknown area had always been a fascinating task. Therefore, after having organized and equipped the drift expedition in the best way possible, he resolved to leave the ship and try to fly across the Arctic Sea. Accordingly, he left us at Point Hope, Alaska, and went with a trading schooner to Point Barrow.

I shall not here enter upon his first unsuccessful attempts, nor dwell upon his and Mr. Ellsworth's marvelous achievement during the past summer. Captain Amundsen and Mr. Ellsworth have not yet reached their goal; however, they are, as you know, planning a flight with a dirigible airship from Spitzbergen to Alaska during the summer of 1926.

Captain Amundsen left us on July 28, 1922, and the *Maud* headed toward the west under the command of Capt. Oscar Wisting. We met the ice a short distance from Point Hope but succeeded in penetrating to Herald Island, where we were closed in by the ice on August 8, 1922. The drift of the *Maud* is plotted in Figure 1, where the routes of earlier expeditions in this region are also entered. For one year we drifted toward the west-northwest in a

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[1] Address delivered Dec. 1, 1925, at The Carnegie Institution of Washington, Washington, D. C. Reprinted by permission from the Scientific Monthly, May, 1926, Vol. XXII, pp. 400–410.

zigzag course, depending mainly upon the wind and were, at the beginning of September, 1923, in latitude 76° 17′ north, being east of De Long Islands. We hoped to drift on the northern side of these islands and perhaps cross to Spitzbergen along a route more north-

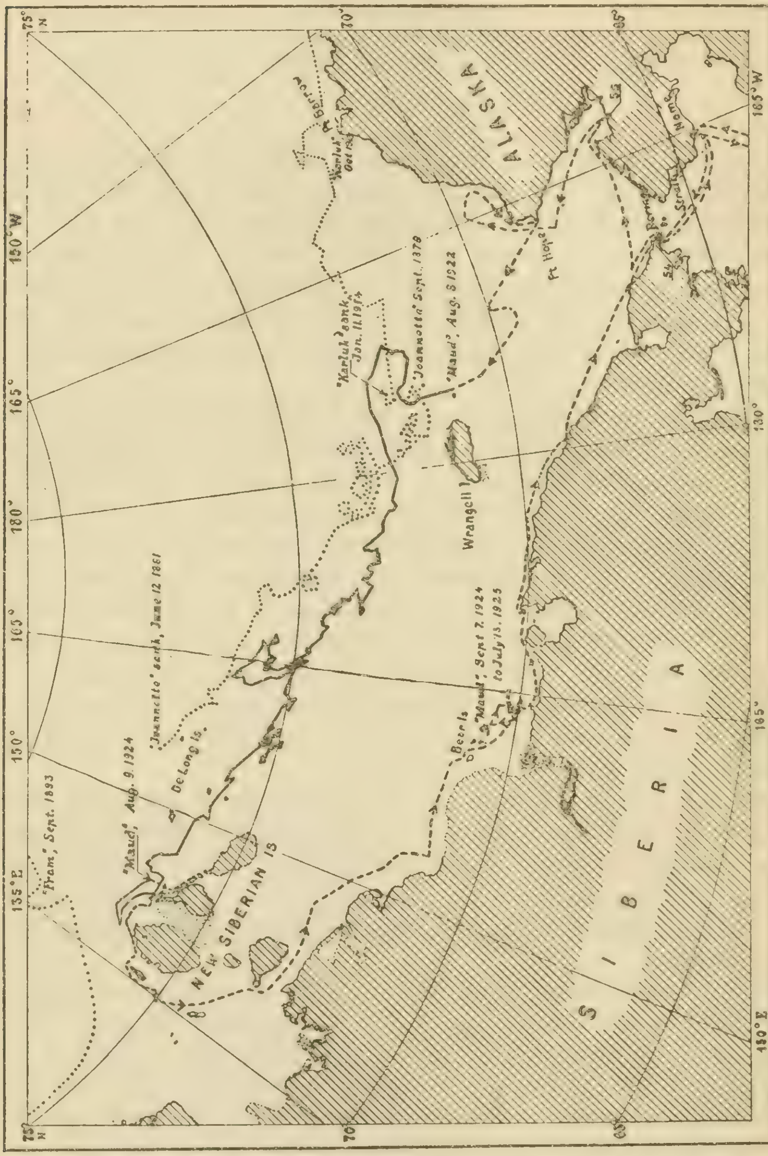


Fig. 1.—Map showing the route of the *Maud* 1922–1925
- - - - - *Maud* moving under own power
—— The drift of the *Maud*
.... Routes of the *Fram*, the *Jeanette*, and the *Karluk*

erly than the one taken by the *Fram* during the famous drift of Doctor Nansen, 1893 to 1896. However, continuous northerly winds carried us 100 miles to the south. The winter of 1923–24 was spent in latitude 75° north, to the southward of De Long Islands. At the end of February, 1924, Captain Wisting received a wireless message from Captain Amundsen asking him to get out of the ice, if possible, and return to Nome in the summer of 1924. In the spring and summer we were again carried toward west-northwest. The ice opened, and on August 9 we could move under the ship's own power after having drifted helplessly for two years. However, we did not reach Nome in the summer of 1924, but were stopped by the ice at the Bear Islands, where we had to stay for 10 months. We finally reached Nome on August 22, 1925.

When leaving Point Hope, our party consisted of eight men, including a native boy from the Siberian coast who acted as cabin-boy. We lost one of our comrades from inflammation of the brain in July, 1923, after one year in the ice, and buried his body in sailor fashion by lowering it in a space between the ice-floes. During the remaining two years we saw no human beings outside of our own small party before March, 1925, when we were visited by half-breed Russians from the settlement at the Kolyma River.

During the drift and later we did not pass through any geographically unknown region. We carried an airplane, a Curtiss Oriole, with which we hoped to extend the geographical exploration to both sides of our route. The starting and landing conditions on the ice were, however, very unfavorable. Two successful trial flights were made in spite of the difficulties, but during the third flight the motor missed fire at the take-off, the pilot had to land on rough ice, and the plane was damaged beyond repair.

Our zigzag route was determined by frequent astronomic observations, generally two or three a week. In winter it was often a chilly amusement to take these observations and the observer had to dress up for the occasion, but in summer it was delightful because the temperature then was around the freezing-point. The astronomic observations were generally taken on the ice, but the instruments were never left there. They were always carried on board after the observations, because the ice might at any time break up and the instruments might be damaged or lost.

The astronomic observations, of course, had to be taken from the very beginning of the drift in order to follow our route step by step. Simultaneously with these, the observations of the magnetic elements were made. These observations had to be taken on the ice at such a distance from the ship that the disturbing influence of the magnetic iron masses on board was eliminated. The *Maud* was far from being nonmagnetic. The first observations were taken without any other shelter than the protection against the wind which a large ice-hummock might give. Later, when our surroundings became more solid, we built an ice house which we used to call the "crystal palace." The ice house was equipped with electric lights and a nonmagnetic stove which, in winter, brought the temperature up to about −10° F. The magnetic and other observations were taken in this house during the first winter, 1922–23.

The magnetic instruments were loaned to the expedition by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, which had paid special attention to make them suitable for use in the Arctic. The greatest improvement was that all metal parts which had to be touched by the fingers were covered with celluloid caps. If metal is touched at low temperatures by a cold finger, the result is frequently a white, frozen spot on the finger, but the celluloid caps could be handled without great inconvenience. The magnetic needles, however, could not be provided with celluloid protection, and they had to be handled with uncovered hands. They often left a white line which, later, when the observer returned to a heated room, turned black and caused "toothache" in the finger. All of us had blackened finger tips in the winter.

Our crystal palace did not survive the Arctic summer; it melted in June, and in summer we had to take the observations in a tent. This observing tent was used during the entire winter of 1923–24 because a new crystal palace, which had been built in October, 1923, disappeared when the ice broke to pieces around the ship at the end of the month, and because our surroundings later were constantly changing. Our tent undertook several independent expeditions as the ice broke between the ship and the tent and the parts on both sides of the crack were displaced in relation to each other. On one occasion we thought the tent was lost. The ice broke on Thursday afternoon, and the tent rapidly disappeared out of sight between hummocks and pressure ridges. Searching parties were out looking for it on Friday and Saturday, but without success. On Sunday Mr. Hansen, the mate, and I took a walk, following a lane which recently had been covered with young ice on which walking was easy. We thought we were going in the opposite direction to the one in which the tent was supposed to be, but about 2 miles from the ship we saw human tracks on an old ice-floe and an inspection soon revealed that we had encountered an old acquaintance, which previously had been located close to the ship. Looking around, we saw the tent standing there unharmed; we took it down and carried it back to the ship in triumph.

Continuous records of the magnetic elements could not be obtained on the drift ice because the ice fields were always moving, turning, and twisting, making a permanent orientation impossible. The conditions were different during the winter of 1924–25, when we were frozen in close to the coast on motionless ice. There we used a large tent for ordinary magnetic observations and installed an instrument for photographic registration of the declination in a light-tight case within the smaller tent previously used.

I shall not enter upon the results of our magnetic observations during the drift, but wish to mention the character of the diurnal variation of the magnetic declination as recorded during the winter of 1924–25. The most remarkable feature is the small range of the diurnal variation in the middle of the winter and the rapid increase of this range in the spring. It is to be hoped that our records, combined with previous results, may furnish sufficient data for the application of corrections for diurnal variation to the declinations observed on or near the Siberian coast.

The records may also be of value in the study of magnetic storms. There is a close relation between the occurrence of magnetic storms and the occurrence of the aurora borealis. We always had to keep night watches. We used to stay up for two hours each, and the watchman was instructed to make frequent notes regarding the form, amount, and intensity of the aurora. We succeeded in taking several pictures of brilliant displays, using cameras developed by Professor Störmer, of Oslo.

The atmospheric-electric observations in the winter of 1922–23, which were confined to observations of the potential gradient, were also taken in the ice house.

In 1922 the Department of Terrestrial Magnetism had drawn our especial attention to the value of observations of the diurnal variation of the gradient over the Arctic Sea. One of the most interesting results of the atmospheric electric work carried out on board the *Carnegie* during 1915 to 1921 was that this variation follows universal time over the oceans, the maximum value being reached simultaneously over all the oceans. Our special task was to ascertain whether this law for the variation was valid over the Polar Sea as well.

During the first winter the diurnal variation of the potential gradient was followed by eye observations through 24 hours, but we found that we naturally would save time and materially increase the amount of data if we could record the gradient continuously. I, therefore, asked our aviator, Mr. Dahl, who is a genius as an instrument designer and maker, to construct a recording electrometer. The instrument itself did not present any difficulties, but these arose when a perfect electrostatic insulation was to be insured. Amber is generally used for insulation, but we had no supply of amber. The difficulty was finally overcome by my sacrificing a perfectly good amber pipestem.

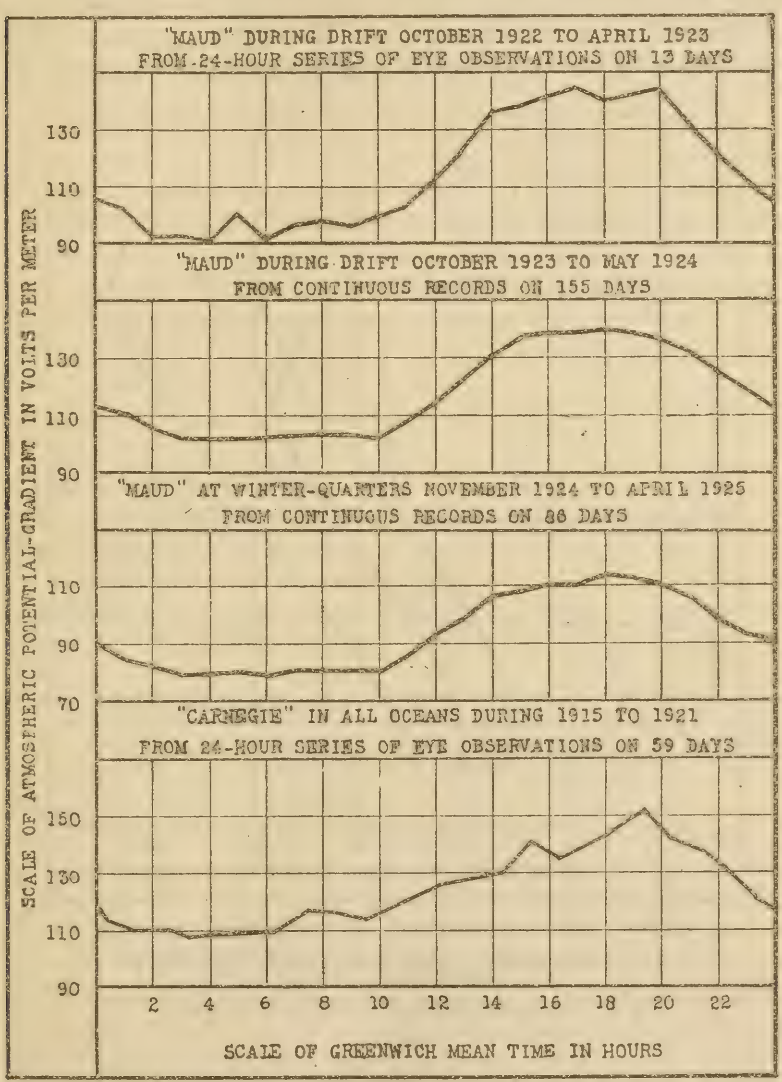
Our recording electrometer was placed in an unheated room on deck and became, therefore, covered with frost on the outside, but this circumstance did not influence the efficiency of the instrument. The records gave however, only relative values of the gradient. In order to reduce them to absolute values, simultaneous eye observations were carried out from time to time on smooth ice at a sufficient distance from the ship. As a matter of precaution in case a polar bear should be too curious, the observer was always armed when he had to go some distance from the ship. I may mention that the observers were never disturbed.

We were unable to secure any observations during the summer because a satisfactory insulation could not be maintained on account of the dampness of the air. Our records are, therefore, limited to the cold months, October to April. When referred to universal time, the records for this season are in excellent agreement with the results obtained on the *Carnegie*. These are represented by the lower curve in Figure 2, while the three upper curves represent our preliminary results during the three winters. Our observations from the Polar Sea thus confirm the important conclusions regarding the universal character of the diurnal variation of the potential gradient drawn from the observations carried out on the *Carnegie* during cruises over all oceans.

The greatest value of the gradient occurs at 18^h Greenwich mean time, which is approximately the time when the sun is in the meridian of the magnetic poles of the earth. This fact indicates a close relationship between the magnetic and electric fields of the earth, but the character of this relationship has yet to be explained.

Meteorological observations were taken regularly six times daily during the three years, and for the entire period continuous records of the barometric pressure, the temperature and humidity of the air, the direction and velocity of the wind, and the duration of sunshine are available. Our meteorological screen was placed on the roof covering the deck, while a snow gauge for measuring the amount of precipitation was placed on the ice. Special studies of the humidity of the air at low temperatures and of the formation of frost were carried out by the assistant scientist, Mr. Malmgren, who devised and, assisted by Mr. Dahl, constructed a special instrument for recording the frost formation. Special studies of the daily variation of the temperature of the air were also carried out, but I can not enter upon a discussion of the results of these investigations nor of the results of the general meteorological observations. Instead I shall turn to our upper-air observations.

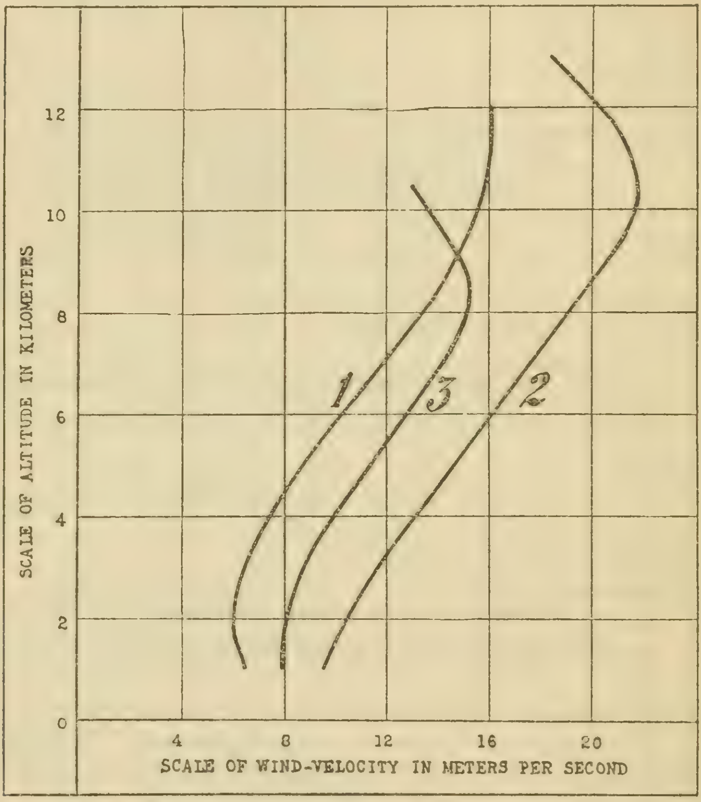
The direction and velocity of the wind aloft was determined by means of pilot balloons, 552 of which were released. These wind observations indirectly give interesting information regarding the average temperature distribution at great altitudes. In Figure 3 average wind velocities in the free atmosphere are represented by three curves, (1) representing the velocities over the North Atlantic trade-wind region, (2) over middle Europe, and (3) over the part of the Arctic which we have traversed. I wish to draw your attention to the wind maximum which the last two curves show at great



DIURNAL VARIATION OF THE POTENTIAL GRADIENT OF THE ATMOSPHERE

FIG. 2

altitudes. This maximum is known to occur at an important boundary surface of the atmosphere, which has been called the "ceiling of the troposphere." Below the maximum, within the region called the troposphere, the temperature decreases with altitude, but above the maximum, within the stratosphere, it remains constant. These curves show that the ceiling of the troposphere above the North Atlantic trade wind lies higher than 12 kilometers; in fact, it is found at an altitude of 16 kilometers. In the southern part of this country the corresponding altitude is 12.5 kilometers, in the northern 11 kilometers, in middle Europe 10.5 kilometers, and over the part of the Arctic we have traversed it is only 8.5 kilometers. Our results



AVERAGE WIND - VELOCITY AS A FUNCTION OF ALTITUDE

1 — NORTH ATLANTIC TRADE-WIND REGION, LATITUDE 23°
2 — MEAN EUROPE, LATITUDE 52°
3 — ARCTIC SEA NORTH OF SIBERIA, LATITUDE 75°

FIG. 3

confirm the conclusion that the distance to the ceiling of the troposphere decreases toward the pole.

Direct observations of the temperature of the free air are available from the lowest part of the atmosphere and have been obtained by means of self-recording instruments lifted by kites. The instruments were tested in the laboratory of the *Maud* from time to time. The big kite reel for letting out and hauling in the kites was placed on deck. The wire could be guided in any desired direction, depending upon the direction of the wind, by means of a special pulley mounted on the ice a short distance from the ship. The first pulley was fastened permanently to the ice but was lost during an ice pressure. We, therefore, mounted the second pulley on a sledge, which could be taken on board at short notice. The kites, which were most used, were loaned to the expedition by the United States Weather Bureau. They were built sturdily, but were subject to hard usage on account of the difficult conditions. They, therefore, had to be repaired frequently, both in winter and in summer. So little was left of the original kites after the three years that they had to be entered as lost.

The most interesting result from the kite ascents is, perhaps, that in winter the temperature of the air practically always is lower close to the ice than 300 meters above the ice. The mean temperatures derived from 60 ascents made during the drift in the coldest months, November to March, are represented in Figure 4. The full curve represents the conditions during the kite ascents; that is, when the average wind velocity at the ice was about 11 miles per hour. The temperature decreases with altitude in the first 136 meters, but increases higher up, first very rapidly and then more slowly. The mean temperature at the ice is —28.4° C., while at an altitude of 1,000 meters it is only —20.3° C. The dashed curve represents the corresponding temperature distribution in calm weather. This last curve may be called normal because it is of a familiar type. Even in this latitude the lowest temperatures are found close to the ground on clear and calm days in winter because the air is cooled from below by contact with the surface, which loses heat by radiation. When a wind arises, however, the air generally becomes mixed to a considerable altitude on account of the numerous eddies which are formed along the ground, and a normal decrease of temperature with altitude is more or less established. The characteristic feature encountered over the Polar Sea is evidently that this forced mixing is limited to a thin layer of air directly above the ice. Over this layer comes a marked inversion, forming a surface of discontinuity which prevents further mixing.

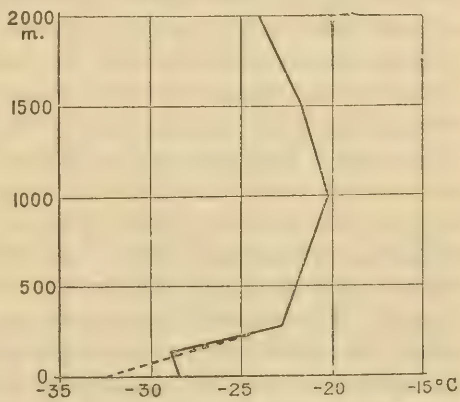


FIG. 4.—Mean temperatures, November to March
——— From kite ascents
------ On calm days

The wind observations by pilot balloons confirm this result. At the ice the observed wind velocities were always small, undoubtedly on account of the great resistance offered by the rough ice, but above the inversion, where the warmer air was sliding over the cold layer, strong winds were met.

The temperature distribution here described was always present in winter, independent of the direction from which the wind was blowing. Considering this and the uniform meteorological conditions over the Polar Sea, it seems justified to conclude that in winter the whole Polar Sea is covered by a thin layer of cold air which, to a great extent, is isolated from the atmosphere above it. Such conditions are possible on a frozen sea, which, disregarding the roughness of the ice, has the character of a vast plane. A sharp surface of discontinuity can exist over a vast plane even when the wind is blowing, but it can not exist over a mountainous continent because it would soon be broken up on account of the differences in elevation.

Since the cover of cold air is isolated from the free atmosphere above it, the temperature of this cover must depend, to a great extent, upon the temperature of the ice-surface with which it is in contact. Particularly, the lowest temperatures of the air must correspond closely to the lowest temperatures of the surface. During the six winters I have spent on or off the Siberian coast the minimum temperature always has been close to 50° below zero, F. There must be some reason why this limit is reached but not passed. The answer seems very simple. The surface of the ice, which is covered by a very thin layer of hard snow, loses heat by radiation to space at night. The temperature would sink to very low values during the long, continuous winter night if this loss were not compensated in some way. It is compensated. Heat is constantly conducted through the ice to the surface from the underlying sea water, which has a constant temperature of 29° above zero, F., the freezing point of the sea water. The amount of heat conducted to the surface increases when the temperature of the surface sinks, but the amount of heat lost by radiation decreases at the same time. Loss and gain, therefore, must equalize each other at a certain temperature, and when this limit is reached the temperature of the surface can not sink any further.

We have made extensive measurements of the heat lost by radiation and the heat conducted through the ice, and have found that loss and gain, on the average, compensate each other at about −40° F. and at about −50° F. under exceptional circumstances. The conditions seem, therefore, to be actually as simple as assumed. The minimum temperature of the air is reached when the surface receives as much heat from the sea as it loses by radiation to space.

The instrument for measuring radiation was loaned to the expedition by the Smithsonian Institution, and was used extensively for determining not only the loss of heat at night but also the amount of heat received from the sky and the sun in the daytime. For this purpose it was mounted beside the instrument for recording the duration of sunshine and was made self-recording thanks to the ingenuity of Mr. Dahl. The recorder was a very sensitive galvanometer. The pen of the galvanometer was pressed down by an arm operated by an electromagnet at intervals of four minutes.

Our computation of the amount of heat conducted through the sea ice was based on measurements of the temperature within the ice at various depths. For this purpose we used resistance thermometers, which were buried in the ice. The leads were taken into the ice house, where the readings were made during the first winter. In summer the readings were taken on the ice without any shelter. In the spring of 1924 the ice floe in which the thermometers were buried was carried away from the ship, and we had to start out in a boat in search of it in order to obtain the daily reading. The thermometers were finally lost when the ice floe upon which they were mounted was crushed, but not before a sufficient number of observations had been obtained.

Our knowledge of the physical properties of the sea ice was materially increased by experimental studies which Mr. Malmgren undertook under very trying conditions. His results show that the newly frozen sea ice, which contains a great quantity of salt, really consists of pure ice with inclosures of brine. With any change in temperature, part of the brine is transformed primarily into pure ice, or vice versa. The expansion or contraction of the ice and its specific heat depend, to a great extent, upon the intensity of this process. The problem can be treated mathematically, and there is an excellent agreement between the computed and experimental results.

In summer, when the temperature of the ice approaches the melting point, the inclosures of brine increase so much that the ice becomes porous, the brine trickles down through, and the upper part of the ice, which previously was too salty for drinking purposes, becomes absolutely fresh.

Our daily soundings showed that during the whole time of our drift we had remained on the continental shelf; the depth varied for long periods between 20 and 30 fathoms, although the distance to the coast was 300 miles. A hole in the ice was kept open for the soundings. Once a week we determined the temperature at various depths by reversing thermometers and collected water samples for investigation of the density, salinity, and amount of oxygen of the sea water. Speed was essential when the water samples were taken in winter. After the water bottle was hauled up, it had to be detached from the wire as quickly as possible and the observer had to run headlong on board with it to prevent the contents from freezing.

The water bottles were emptied in the laboratory, where samples for the various investigations were taken to be examined. The specific gravity, for instance, was determined with a high degree of accuracy by using Nansen's hydrometer of total immersion, and the amount of chlorine from which the specific gravity could be computed independently was determined by careful titration. Systematic differences amounting to five in the fifth decimal between the computed and observed densities indicate that the composition of the sea water is altered by freezing. Chemical analyses of the samples we are bringing home may throw light on the character of these changes.

We found, furthermore, that over a large part of the shelf the density of the sea water remained constant to a depth of 20 fathoms, where a sudden increase took place. The lighter surface water was separated from the heavier bottom water by a marked surface of discontinuity, which is of the same importance to the currents in the sea as is the surface of discontinuity in the air above the ice to the air currents or winds.

We had no biologist on board, and I am therefore unable to give any account of the life in the sea. We did, however, collect samples of plankton and specimens from the bottom of the sea, which we have preserved and are bringing home for further study.

The investigation of the tidal phenomena has taken much of our time and brought interesting results. The tides were recorded continuously at Bear Islands by a tidal gauge constructed on board. On the shelf the range of tide and time of high water were determined at several stations by means of direct soundings, and the tidal currents were measured or recorded continuously. At first we used the current meter constructed by Ekman, but soon found that this delicate instrument was too difficult to handle in low temperature. The moment it was hauled up for reading it became coated with ice and had to be taken indoors and heated before it could be lowered again. We needed an instrument which could be left lowered for weeks, recording the currents under the ice electrically in the laboratory. Mr. Dahl and I succeeded in designing an instrument of this kind, which recorded direction and velocity of the currents by means of a single electric circuit, but I can not enter upon the details of construction. Two types were developed, one of which was suspended on a single wire and recorded the direction by means of a compass needle, and another which was suspended in a bifilar frame and recorded the direction relative to the orientation of this frame. The latter type was kept in operation during the major part of 14 months. By lowering it to various depths we could obtain a full knowledge of the tidal currents from the ice to the bottom. The tidal motion of the ice itself was determined directly by a simpler method.

Our main results, representing the conditions at spring tide, have been entered on the map reproduced in Figure 5. The character of the tidal currents is indicated by the ellipses. They signify that the currents are rotating, the arrow-heads on the ellipses indicating the direction of rotation, which is clockwise within the entire region. The ratio between the axes of the ellipses corresponds to the ratio between the maximum and minimum current. The direction of maximum current is indicated by an arrow, and the Greenwich lunar time of maximum current is entered. Furthermore, the Greenwich lunar time of high water and the range of the spring tide are entered at all stations where data were available. Previous observations have been utilized from Point Barrow, Pitlekai, and Bennett Island, but all others represent results obtained during the six years the *Maud* has spent in the Arctic.

By means of the data entered on this map it is possible to draw lines showing the crest of the tidal wave for certain hours of Greenwich lunar time. The heavy lines show these crests, and the corresponding hours have been entered. The wave appears to reach the shelf from the north and seems to come directly across the Polar Sea from the Atlantic side without meeting any obstruction formed by masses of land. The late Prof. R. A. Harris, of the United States Coast and Geodetic Survey, compiled and discussed in 1911 all available tidal observations from the Arctic region. He arrived at the conclusion that the tidal wave within the region here dealt with travels practically parallel to the coast, and assumed, therefore, that a great area of land or very shallow water existed within the unknown area north of Alaska and Siberia. His conception of the direction in which the wave proceeds seems, however, to be erroneous, as the tidal phenomena seem to indicate no existence of extensive land masses between Alaska and the pole.

The tidal wave on the shelf shows a number of interesting features. The currents are rotating clockwise at all stations and vary with the distance from the bottom; the rate of progress does not bear a simple relation to the depth; the range of the spring tide decreases from right to left along the wave crest, referred to an observer looking in the direction of progress, namely, from 215 centimeters close to the New Siberian Islands to 14 centimeters at Point Barrow; and the range also decreases in the direction of progress, from 18 centimeters at the middle of the shelf to 3 centimeters at Bear Islands. These

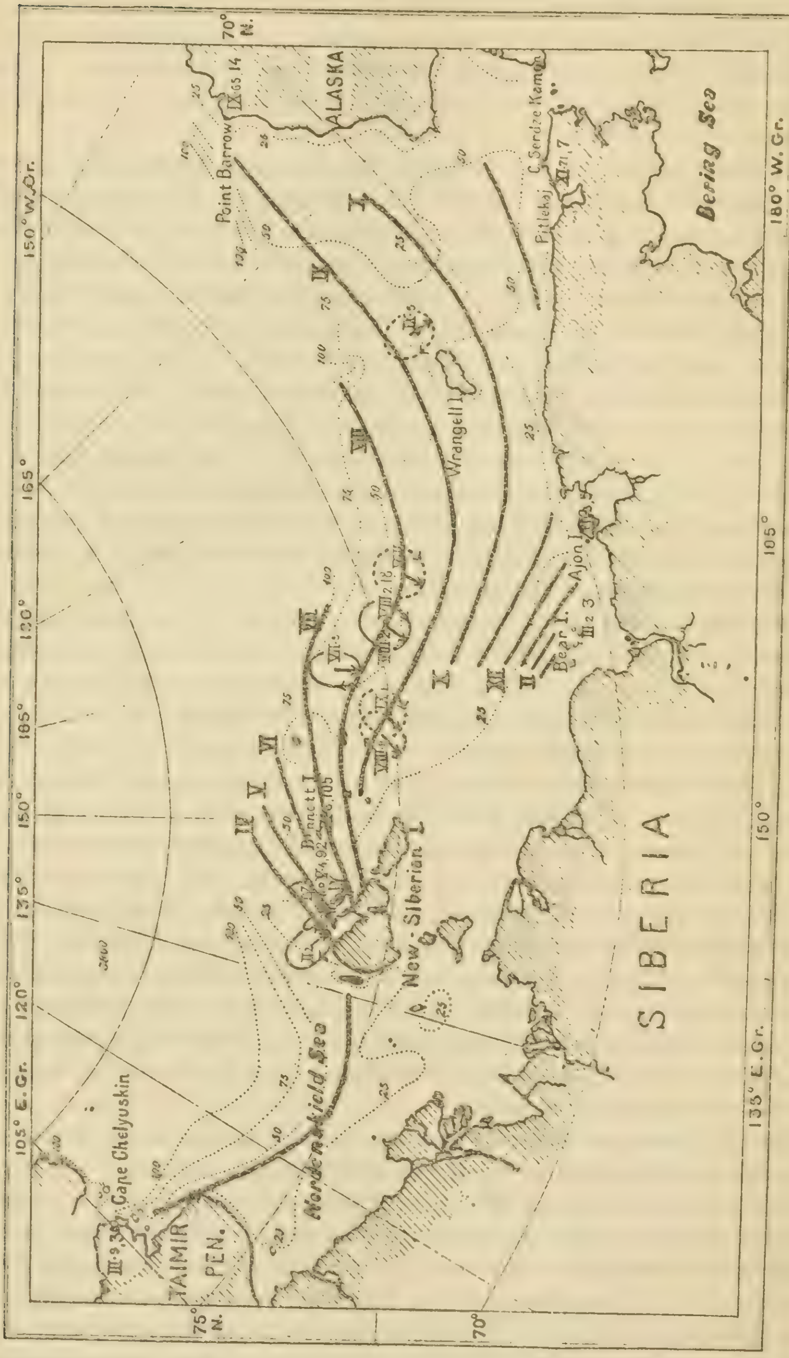


Fig. 5.—Results of tidal observations, 1918–1925

features can not be explained except by taking into account the rotation of the earth and the resistance which the tidal currents meet along the bottom and under the ice and also considering that the resistance affects the currents in great distances from the boundary surfaces on account of the eddy viscosity. The results of a theoretical investigation of the influence of the rotation of the earth and the eddy viscosity on progressive waves were in good agreement with the observed tidal phenomena on the north Siberian shelf and may, perhaps, lead to a better understanding of corresponding phenomena on other continental shelves.

As I have mentioned previously, we reached Bering Strait in August, 1925. At that time all of us were sailors. My duties were, for instance, to take care of the navigation of the ship and of the not less important cooking. Previously all of us had taken more or less part in the scientific work. Our cruise in the Arctic finally ended when the *Maud* was lying peacefully anchored off Nome three months ago.

In conclusion, I hope that to-night I have been able to show you a phase of Arctic exploration which differs from the usual geographical exploration, but is of no smaller importance. Our knowledge of the physics of the earth is incomplete so long as data from the Arctic and Antarctic regions are lacking. I hope that this expedition, which went out through the energetic and persistent efforts of Capt. Roald Amundsen, may bring results which will fill a few gaps. However, we have traversed only a small region and have left many problems unsolved. The field for future exploration is tremendous. I hope that this, which I may call physical exploration of the Arctic, will continue for a long time after the completion of the map of the Arctic region and after the discovery of the last island.

THE ROMANCE OF CARBON[1]

By Arthur D. Little

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As the chemist studies the material structure of the universe he finds it to be composed of about 90 substances of such persistent identity and character that he has come to regard them as elements. He has reason to believe that not more than 92 of these elementary substances exist and he suspects that these may, themselves, have been formed in the cosmic process by successive condensations of hydrogen and helium, the lightest and simplest of them all. He finds that the atoms of which these elements are composed are not the hard, round, indivisible little particles which he had long assumed them to be, but that they are instead complex systems of electrical charges, vibrant with intensest energy and relatively very far apart.

There is, therefore, for each of the elements an astronomy of its own, as awe inspiring in its order and minuteness and as far removed from the plane of our existence as that of the stars themselves. Each of the elements, also, has its own story of absorbing interest. There is helium, first discovered by the spectroscope in the atmosphere of the sun and now extracted from natural gas to carry airships above the clouds; radium, which in the beginning made its presence known by the image of a key upon a photographic plate and thereafter revolutionized our ideas of matter and supplied a new and powerful aid to therapy; gold, which since the dawn of history has furnished the motive for fierce endeavor, intrigue, exploration, crime, and wars. But these, and many others, are stories for another time. Our present theme is the romance of the element carbon, a fragment from a single chapter in the great romance of chemistry.

ATMOSPHERIC DUST

In considering carbon one is immediately struck by the protean aspects of its occurrences. To that ubiquitous individual, the man in the automobile, carbon presents itself as a nuisance in his engine

[1] Presented before the 71st meeting of the American Chemical Society, Tulsa, Okla., Apr. 5 to 9, 1926. Reprinted by permission from Industrial and Engineering Chemistry, vol. 18, No. 5, p. 444. May, 1926.

cylinders, while, because of carbon in his smoky exhaust, the motorist himself is often regarded as a nuisance by the pedestrian. The householder thinks of carbon in terms of coal and sees the wood in his fireplace transformed to charcoal. There was no romance in carbon to the London chimney sweep of a century ago, when little boys of five or six were sold for seven years for 30 shillings and forced up chimneys by their masters with slight regard for the danger of burning or suffocation. To these boys carbon became a personal matter, for many went unwashed for years. Even to-day the soot deposit over London amounts to 260 tons per square mile per year, and in many of our American cities the figure is undoubtedly as high. Three days after a recent storm the surface snow taken from an average square yard in front of our Cambridge laboratory yielded 2.85 grams of soot and cinder, the equivalent of 9¾ tons per square mile. In such amount and form carbon becomes a menace to health and property, a thing of loathing to a careful housewife, and a powerful incentive to the purchase of stock in laundry companies.

The burning of coal is a principal cause of atmospheric dust, and over a city like London or Paris the number of dust particles per cubic centimeter of air may exceed 100,000, while over the oceans the air may hold only a few hundred per cubic centimeter. But the dust is not without its compensations, for to it we must ascribe the blue of the sky, much of the glory of the sunset, and, in large measure, the gentle precipitation of rain.

CHARCOAL

It was probably in the form of charcoal that man first became acquainted with carbon as he stirred in his cave the dying embers of his wood fires. With the soot from burning fat he drew pictures on his cave walls of the animals he knew, and very fresh and vivid some of these pictures still remain. Such great masters as Dürer, Holbein, and Michelangelo have since enriched the world by famous charcoal drawings, and soot has served as a vehicle for the communication of thought in the exquisite calligraphy of China as it serves to-day in printer's ink. Manuscripts of Herculaneum written in carbonaceous ink appear unchanged after 1,800 years. Fortunately for our own standing with posterity, the fabric of our newspapers is far less durable than the ink it bears.

Before it was displaced by coal there was a very general use of charcoal as a cleanly domestic and industrial fuel, but its chief employment was in metallurgy and particularly in the smelting of iron. The reputation of charcoal iron still endures and is especially associated with that from Sweden. In England, timber for charcoal became scarce by the sixteenth century, and in 1740 coke, another form of carbon, was introduced and saved the declining iron industry. It is curious, however, to note how long it took to make the simple change. In 1619 Dudley, an English ironmaster, first substituted coal or coke, it is not certainly known which, for charcoal and continued his efforts through many vicissitudes for more than 40 years, only to end in commercial failure. Not until Abraham Darby, about 1730, renewed the attempt was success achieved and the modern iron industry initiated. Twenty-six years later Darby declared his furnace to be "at the top pinnacle of prosperity, making 22 tons [of iron] a week." Prosperity, like other things, is relative. The United States, in 1925, had an estimated production of over 50,000,000 tons of coke, most of which was consumed in smelting iron ore.

It was between two charcoal points that Sir Humphrey Davy, in 1821, first produced the electric arc, and carbon in denser form has since played a conspicuous and essential part in the development of the electrical industries. It still serves as the terminals in the arc lamp and, until displaced by the tungsten filament, was for many years the source of light in the incandescent lamp. Of it are composed the electrodes of batteries and of the great electric furnaces employed in the production of brass, aluminum, electric steel, and ferrous alloys. Grains of carbon form the variable resistance through which speech is transmitted in the telephone, and back of all the bewildering opulence of word and sound that comes to us by radio are similar grains of carbon in the microphone. In the photophone, which marvelously transmits speech along a beam of light, such refinement of delicacy was required in the contacts that they were made of carbonized dandelion down.

Charcoal, by reason of its porous structure, presents an enormous internal area, which may, in case of specially prepared or activated charcoal, be as great as 20,000 square yards, or about four acres, for a cubic inch of the material. As a result, it exhibits in very high degree the phenomena of surface attraction or adsorption, by which it is able to condense gases and vapors within its pores or to remove and hold coloring matters from liquids filtered through it. It has consequently long been employed as a decolorizing agent and in the form of bone black for refining sugar, while the more intimate knowledge of its properties forced upon us by the exigencies of the war has extended its use into far more important fields. The dire necessity of devising means for the protection of troops against attack by poison gas forced the chemists of the Allies to an intensive study of the factors conditioning the adsorptive power of charcoal for use in the canisters of gas masks. It was presently determined that dense materials like nut shells yielded a superior charcoal, and peach stones and coconut shells became overnight munitions of the first importance. The porosity and adsorptive power of charcoal from such sources was further greatly increased by secondary or so-called activating treatments, and charcoals were finally produced of such efficiency that very high vacua are obtainable by their use. They may condense within their pores several hundred times their own volume of ammonia and lesser, though still large, amounts of the poison gases used in warfare. A good activated charcoal will, for example, absorb three-quarters of its weight of chloropicrin and will, in less than 0.03 second, reduce a concentration of 7,000 parts per million to less than one-half part in a rapidly moving stream of air.

Such phenomena obviously mean that the adsorbed gases are held within the charcoal by the force of surface attraction under pressures equivalent to many tons per square inch and that they are in many cases condensed to liquid films.

At the close of the war these properties of activated charcoal were immediately utilized by Colonel Burrell and others in the now well-known charcoal process for the extraction of gasoline from natural gas at the casing head, by which many million cubic feet of gas are now stripped daily, the adsorbed gasoline being recovered by heating the charcoal.

GRAPHITE

Graphite, so familiar to us all in the business end of a lead pencil, is another form of carbon for which many uses have been found. It occurs in nature, the best coming from Ceylon, where it is found in large, lustrous flakes, and it is artificially produced in quantity by heating coke or anthracite coal to high temperature in the electric furnace. It is several times as dense as charcoal and is a good conductor of electricity. As it is infusible and very inert chemically it is largely used for crucibles, and as it is also very smooth and soft it is commonly employed in facing molds in foundries and as a lubricant for heavy machinery. It lends its luster to the kitchen stove.

DIAMONDS

In the form of soot, carbon is black, amorphous, and synonymous with dirt and grime; as coke and charcoal, it is dull, porous, and readily combustible; as graphite, it is dense, lustrous, and so soft that it leaves a mark on paper. It is opaque in all these forms. But carbon in society has quite a different aspect from carbon in its working clothes. There it is the diamond, transparent, sparkling, brilliant with flashing color, and so intensely hard as to be well named in Greek 'Αδάμας, the invincible. Confusion of this Greek name with the Latin *adamare*, to love, may account for the frequency with which diamonds are offered at the shrine of Venus. In Sanskrit the diamond is vajra, the thunderbolt, a designation not without appropriate significance, for diamonds of small size are often found in meteorites.

Whereas graphite is a good conductor, the diamond has about the same electrical resistance as glass. Its refractive index, upon which, with proper cutting, its brilliancy depends, is far higher than that of glass, and the diamond is transparent to X rays, whereas paste is opaque. Some diamonds, at least, are luminous in a dark room after exposure to sunlight, and Sir William Crookes has shown that the diamond may acquire and retain indefinitely the property of radioactivity. A diamond which he embedded for some months in radium bromide became olive green and so highly radioactive that it was luminous in the dark after nine years. The same distinguished chemist ascertained that after exposure in a vacuum tube to a high-tension electrical discharge diamonds phosphoresce in various colors. Most South African diamonds shine with bluish light, while those from other localities emit bright blue, apricot, red, orange, or yellowish green.

Owing to the anomalous fact that the boiling point of carbon at atmospheric pressure is below its melting point, carbon volatilizes at about 3,600° C. without melting. Sir William Crookes has, therefore, calculated that under a pressure of only 17 atmospheres carbon would liquefy at a temperature of 4,130° C. and on cooling crystallize out as diamond. The process is not patented and is commended to any who may be contemplating a diamond wedding.

Many curious associations and beliefs have grown up around the diamond. In the Middle Ages it was thought to afford protection from plague and pestilence; to warn its wearer of the presence of poison by turning dark; and by some subtle homeopathy to be an antidote for poisons, though in itself a deadly one. It insured victory to its possessor, banished ghosts and dispelled the devil; brought friends and riches, and deferred old age. Though diamonds are expensive, one seldom gets so much for his money, and, in view of these accruing benefits, it is difficult to understand why it is fashionable in Siam to wear your diamonds on Fridays only.

Diamonds occur in nature in the so-called "blue clay" of volcanic pipes and are believed to have been formed by the slow crystallization of carbon from iron or molten rock through the combined action of high temperature and great pressure. The theory finds support in the results obtained by Moissan, who produced diamonds, though very small ones, by raising molten iron to very high temperature in the electric furnace, introducing carbon within the molten mass, and flooding the furnace with water. The sudden external cooling of the metal subjected the interior to enormous pressure while it was still extremely hot. When the iron was finally dissolved by acid the diamonds were found. Some years later another Frenchman, Lemoine by name, turned Moissan's discoveries to more practical account in the perpetration of the famous diamond swindle, by means of which he mulcted Sir Julius Wernher of 1,671,000 francs. Sir Julius was, presumably, not seriously inconvenienced thereby, in view of his great holdings in the South African diamond mines, from which most diamonds are now derived. The initial discovery in these fields was made in 1867 by Dr. W. G. Atherstone, who identified as diamond a pebble obtained from a child on a farm on the banks of the Orange River.

The diamond has played its part in history, and seldom creditably. You will recall at once the complicated affair of the diamond necklace, in which, shortly before the French Revolution, Marie Antoinette, Cardinal Rohan, Cagliostro, and many lesser personages were involved. Great names are associated with all the largest stones. The famous Sancy diamond of 53 carats passed successively through the hands of Charles the Bold, de Saucy, Queen Elizabeth, Henrietta Maria, Cardinal Mazurin, Louis XIV, only to be stolen during the French Revolution. It was later owned by a king of Spain, Prince Demidoff of Russia, and an Indian prince.

The Orloff diamond, which weighed 194 carats, was stolen by a French sailor from the eye of an idol in a Brahman temple. From him it was again stolen by a ship's captain, who murdered him. It was at last bought by Prince Orloff for £90,000 and by him presented to Catherine the Great of Russia.

The sale of the Victoria diamond to the Nizam of Hyderabad for £400,000 is an impressive instance of form value. The diamond weighed 180 carats, or 576 grains, or one-tenth of a troy pound. The sales price of this particular piece of carbon was therefore at the rate of £4,000,000 sterling, or $20,000,000 per pound troy.

The Premier mine in the Transvaal has yielded much the largest diamond ever found, a gigantic stone weighing 3,025 carats. It was known as the Cullinan diamond and was bought by the Transvaal Government for presentation to King Edward. Even that was eclipsed by the diamond throne which Buddhists believe to have stood near the Tree of Knowledge, beneath which Buddha received his revelation. The throne was 100 feet in circumference and made of a single diamond. Unfortunately, it seems to have been lost.

But the diamond condescends to lend itself to the humbler purposes of mankind. The impure crystals and fragments known as bort and the inferior carbonado, or black diamond, are used to point the diamond rock drills so essential to the progress of great engineering works. Thus, without carbon so employed, the route to San Francisco might still be around the Horn.

COMBUSTION AND OXIDES OF CARBON

The making of fire was perhaps the greatest achievement of the human race, and, though there has been no posthumous award of medals to Prometheus, the phenomena of combustion include some of the most fundamental chemical changes with which we are acquainted. All of the ordinary forms of combustion, upon which we depend for light and heat, involve the burning of carbon or of compounds of carbon and hydrogen. Even the diamond may be burned in oxygen, and the product of its combustion is carbon dioxide, differing in no respect from the CO_2 produced when charcoal is burned in air. When hydrocarbons burn the ultimate products of combustion are carbon dioxide and water.

During all the long centuries which preceded the Welsbach mantle and the tungsten filament practically all artificial light was derived from incandescent carbon. It glowed in the firelight within the caves which sheltered the Neanderthal man and later in the smoky flare of pine-knot torches, rude oil lamps, and rushlights. In the flickering flames of many candles it lent brilliance to the courtly fêtes of Versailles, and the Argand burner, the gas flame, and the carbon filament have brought light into our own homes. There is an almost unthinkable complexity to flame within which molecular systems are disrupted as their vibrating atoms rush, with the discharge of ions and electrons, to form new systems while radiating energy as heat and light. Since light has always been regarded as the symbol of joy and life-giving power, it is not surprising that fire was sacred and adorable in primitive religions. The Parsees adore fire as the visible expression of Ahura-Mazda. The Brahmans worship it as that "which knowest all things." In the Jewish Holy of Holies was a "cloud of light" symbolical of the presence of Yahweh. Jewish synagogues have their eternal lamps as the Greeks and Romans had their perpetual and sacred fires. In Christianity fire and light have always been conceived as symbols of the divine nature and presence. Human history and literature teem with their romantic associations. What pictures are called to mind by the mere mention of vestal fires in the temples, of watch fires on the hill, of camp fires in the forest or in the field with troops. The driftwood fire depicts the wreck of stranded ships that missed the gleam of the beacon which brought others safely to port. Candles and altar fires, the pillar of smoke, and the burning bush have their deep religious significance.

The extinction of lights marks the end of the ceremony of excommunication, while the symbol of reconciliation is the handing to the penitent of a lighted candle. Both life and love are symbolized as flame, and the fire on the hearth and the light in the window are synonymous with home.

There is thus little cause to wonder that centuries ago the fire worshippers from India and elsewhere in the East journeyed to Baku and there built temples where hydrocarbon gases issued from the ground. The ruins of the temples in which their priests tended the eternal flames exist to our own times.

When air is passed upward through a deep bed of incandescent coke as in the manufacture of producer gas, or when an automobile is running on too rich a mixture, or otherwise when the supply of air is insufficient for complete combustion, carbon monoxide is formed. It is utilized in metallurgy as a reducing or smelting agent of the utmost value and constitutes a large proportion of the important fuel, water gas, made by blowing steam through red-hot coke. Like carbon dioxide, the product of the complete combustion of carbon, it is a colorless and odorless gas, but, unlike the dioxide, it is intensely poisonous. It combines with the hemoglobin of the blood, thereby checking the absorption of oxygen in the lungs, and death is due to asphyxia from want of oxygen. The affinity of hemoglobin for carbon monoxide is three hundred times that which it has for oxygen, and one volume of the monoxide in eight hundred of air is fatal in 30 minutes. Much higher concentrations may be more quickly reached when an automobile engine is running in a closed garage.

Carbon dioxide, the gas once brilliant in the sparkle of champagne and now more dully effervescent in vanilla sodas, plays a part of extraordinary interest and importance in the economy of nature. It is poured into the atmosphere in vast quantities from volcanoes and in great amounts from burning coal and forest fires. It is also formed by oxidation of organic matter in the soil, and according to Geoffrey Martin, one acre of good garden land in summer evolves more than 6 tons of carbon dioxide. As Faraday first showed, the gas is readily reduced by cold and pressure to the liquid form, and by rapid evaporation of the liquid it may be converted into a snowlike solid, the "dry ice" now sometimes displayed in restaurateurs' windows beside a discouraged thermometer. It is produced industrially, for liquefaction and distribution, from flue gases; by the burning of limestone, and as a by-product of alcoholic fermentations.

Animals exhale carbon dioxide as the result of the oxidation in the lungs of organic wastes in the blood stream. It is normally present to the extent of about 4.5 per cent in human breath, and in a long life a man may exhale more than 20 tons of the gas. For the conduct of the processes which result in its production nature provides the average man with a lung area of about 100 square yards, or enough for a tennis court. The accumulation of carbon dioxide in the blood provides the normal stimulus to respiration.

Pure air contains about 0.03 per cent of carbon dioxide. In crowded halls the proportion may rise to 0.5 per cent. Since under ordinary atmospheric conditions the gas dissolves in water about volume for volume, it is constantly being washed down and slowly attacks the silicated rocks with formation of calcium and magnesium carbonates, by which soft waters are rendered hard and much trouble is caused by boiler scale. Ultimately such waters find their way to the sea, where marine animals, the chambered nautilus, the coral polyp, the oyster, the humble clam, and, most important of all, the minute foraminifera fix the calcium carbonate in their shells. If you rub down to a thin paste with water a piece of chalk you will find upon microscopical examination that it is composed almost entirely of the tiny shells of foraminifera. Such are the chalk beds of England, which, often more than 1,000 feet in thickness, extend across the island for 280 miles and at the coast line rise in those white cliffs to which England owes her name of Albion. But the chalk bed stretches far beyond the coast of England, over much of France, through Denmark and Central Europe, south to Africa, and even into Central Asia. Chalk and limestone are carbon compounds, and the overwhelming evidence is that, wherever found, they are the product of aquatic life in regions once submerged.

CARBONATES

The Latin word for a coin was *nummus*, and, for a reason which will presently appear, it gives its name to the nummulitic limestones, which extend over vast areas of North America and, in a band often 1,800 miles in breadth and of enormous thickness, from the Atlantic shores of Europe and Africa through western Asia to northern India and China. Of it the pyramids were builded, and from a knoll-like outcropping was fashioned that other memorial of antiquity, the Great Sphinx, before which even the centuries seem to pause.

This variety of limestone has been formed by the slow accretion in marine deposits of innumerable billions of the shells of foraminifera of the genus *Nummulites*, which is characterized by shells of extraordinary complexity of structure and a disk or coinlike form.

But limestone has been formed by other agencies, and its formation is still proceeding on a grand scale through the activities of the coral polyp in many of the warmer waters of the globe. Two and a half million square miles of ocean bottom are covered by coral mud and sands. The gigantic structures of the coral islands and the barrier reefs, of which one extends for 1,000 miles along the Australian coast, are the work of tiny bits of animated jelly, which abstract carbonate of lime from the sea water and so deposit it that it reproduces their own radiated structure. All the structural works of man fade into nothingness when compared with the results of the life activities of the minute foraminifera and the coral polyp. Höyborn calculates that the limestones and dolomites contain twenty-five thousand times the amount of carbon dioxide now present in the air. And chalk is still forming over 50,000,000 miles of ocean bottom.

In its metamorphosed form of marble, limestone exhibits the widest possible range of texture, color, and degree of purity. In it the greatest sculptors have found a medium for their best expression, and of it were built the exquisite lacelike fabric of the Taj Mahal and the structures which were the glory of Greece and Rome. The pearl, which in all ages has been associated with beauty and with riches, is in reality no more than a brilliant sarcophagus of carbonate of lime formed around an intruding parasite by the pearl oyster. There are, nevertheless, as Browning says:

> "Two points in the adventure of the diver—
> One, when a beggar he prepares to plunge;
> One, when a prince he rises with his pearl."

Like all carbonates, the pearl dissolves in weak acids with evolution of carbon dioxide. When, therefore, Cleopatra dissolved the pearl in vinegar she prepared the most expensive carbonated drink that history records.

CLIMATIC INFLUENCE OF CARBON DIOXIDE

Despite the minute proportion of carbon dioxide in the atmosphere its climatic influence is of extraordinary importance. The blanket which keeps the earth warm is composed wholly of carbon dioxide and water vapor, which absorb the heat that would otherwise be radiated from the earth. According to Arrhenius the removal of all carbon dioxide from the atmosphere would cause the temperature of the earth's surface to drop 37° F. The quantity of water vapor would, therefore, so diminish as to cause an almost equal drop, and the whole earth would be bound in Arctic ice. Thus an increased and uncompensated fixation of carbon dioxide by the rocks would bring on a new glacial period, whereas a slight augmentation of its proportion in the atmosphere would restore the tropical climate and the exuberant vegetation of the Carboniferous Age. Fortunately, there is now maintained a delicate balance in the carbon cycle in nature. The ocean is estimated to contain forty times as much carbon dioxide as the atmosphere, and, as equilibrium is disturbed by the fixation of carbon dioxide by the rocks and plants, a compensating portion of the ocean reserve passes into the air.

PLACE IN ORGANIC CHEMISTRY

Carbon is the central element of the organic kingdom. It is closely related to life and to energy. Most of the energy for the world's work in machine or animal or man is derived from the oxidation of carbon. Plants absorb carbon dioxide from the air to an estimated yearly amount of 13,000,000,000 tons and, under the stimulus of sunlight, fix the carbon in their structure in such compounds as cellulose, starch, and sugar. All vegetable and indirectly all animal life owes its existence, therefore, to the sun's rays acting upon the carbon dioxide in the atmosphere. The initial step in this fixation of carbon is probably the transformation of carbon dioxide to formaldehyde through reaction with oxygen and hydrogen, the elements of water. As the result of this reaction plants exhale oxygen, whereas animals in a reverse process, as we have seen, exhale carbon dioxide. Bailey has recently synthesized glucose by subjecting formaldehyde to the light of a mercury arc lamp.

In comparison with all the other elements carbon is strikingly notable for the enormous number of its compounds. The known compounds of all the elements other than carbon are only about 25,000, whereas the compounds of carbon reach the astonishing total of 200,000. This is due in large measure to the peculiar fact that the atoms of carbon exercise a powerful attraction for each other, by reason of which carbon compounds are built up which may contain many carbon atoms linked together in straight or branched chains, or in one or several rings, or in more complex configurations which include both chains and rings of carbon atoms in association with those of other elements. Hydrogen is thus associated in the great majority of carbon compounds, which very often also contain oxygen.

The amazing complexity of structure that carbon compounds may attain is indicated by the fact that compounds are known which have more than 200 carbon atoms in a single molecule, beside which a diagram of the solar system appears too simple to talk about.

Organic chemistry, which is the chemistry of the compounds of carbon, is further complicated by the fact that many carbon compounds contain the same elements in the same proportions, but differ from one another in their properties. Thus 86 compounds of the formula $C_{10}H_{12}O_3$ are known, and Cayley has calculated that 802 of the formula $C_{13}H_{28}$ are possible. Obviously, then, the properties of carbon compounds must depend not only upon the kind and numbers of atoms composing them, but also upon the manner of arrangement of these atoms within the structure of the molecule. Long-continued intensive study of the reactions of carbon

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compounds has enabled chemists to determine the structural arrangement of a large proportion of them and even, in very many cases, to build up or synthesize the compounds themselves from simpler substances or even from their elements. Among such notable triumphs are the synthesis of the vegetable coloring matters, indigo and alizarin; the long list of coal-tar compounds, including hundreds of brilliant dyes and many powerful drugs; high explosives; and the remarkable product known as bakelite.

Fortunately for the student, organic chemistry is characterized by the frequency with which the carbon compounds occur in series of closely related members and in groups or families exhibiting marked resemblances in structure and more or less alike in properties. Among such series, for example, are the paraffin and olefin hydrocarbons, and among such groups we find the cyclic hydrocarbons as benzene; the alcohols, ethers, and acids; the carbohydrates, like starch, cellulose, and the sugars; and so on. The student is assisted also by the frequency with which groups of carbon and associated atoms enter into combination as entities, called radicals, and so become familiar to him as structural units. Those who insist upon a speaking acquaintance with each of the carbon compounds are referred to the 4,700 pages of Richter's Lexicon, the Who's Who of carbon chemistry.

Some faint conception of the industrial importance of the carbon compounds may be gained by casual reference to a few of the industries that are directly based upon them. They will be found to comprehend the major portion of the invested capital, the annual turnover, and the workers of the nation. First of all is agriculture with its ramifications into prepared foods, canning, and packing. Closely related thereto are lumbering, naval stores, paper and textiles, and the special industries based on individual agricultural products as rubber and sugar. Of lesser importance, though only by comparison, are explosives, celluloid, artificial silk, solvents, dyes, and the thousands of other synthetic products of the laboratory. Of supreme significance are, of course, the fuels, coal and coke, natural and artificial gas, and finally, petroleum, which not only provides light and heat and flexible power, but supplies the lubricants without which the wheels of industry could not turn. Upon the reducing power of carbon fuels are based the steel and other metallurgical industries, and without the energy of their combustion we should have no steam-power plants, locomotives, motor cars, or ocean liners. Even the internal-combustion engines of the ox team and the jinrikisha would be stalled.

SOURCE OF ENERGY

The economic position of a nation is determined in large measure by the supplies of energy available to its people, and their social progress is similarly conditioned by the extent to which the price of energy permits its broad and general utilization and so increases manifold the effectiveness of the human factor in production. Cheap energy, efficiently used, is the formula for high wages and low prices.

Most of the energy upon which civilization depends to-day is derived from carbon and the compounds of carbon and hydrogen. In use, their potential energy is always first transformed into heat energy. The burning of 12 grams of carbon to carbon dioxide liberates 97,000 calories, and the combustion of 4 grams of hydrogen sets free 136,600. Since coal consists essentially of carbon with variable amounts of volatile hydrocarbons, while petroleum is a complex mixture of hydrocarbons, our reserves of coal and oil constitute vast reservoirs of potential energy. One pound of coal burned delivers heat sufficient to raise the temperature of 7 tons of water 1° F., an amount of energy that would lift a ton more than 1,500 feet. The same amount of petroleum burned would develop nearly 30 per cent more heat. Cheap coal and abundant petroleum must, therefore, be counted among the greatest material assets of a nation, and the United States has been bounteously supplied with both. It contains about 50 per cent of the world's reserves of coal, and despite the long drain upon our petroleum resources, we are still supplying 70 per cent of the world's production.

COAL

All the vast quantity of coal contained in the world and the still more vast amount of lignite originally came from carbon dioxide once present in the atmosphere. Long years ago, under the influence of sunlight, the plants constituting the rank and exuberant vegetation of the Carboniferous Period withdrew carbon dioxide from the air and built the carbon into their structure just as plants everywhere are doing to-day. A spruce tree weighing 1,000 pounds when dry has derived less than 3 pounds of mineral matter from the soil, but it contains more than 500 pounds of carbon combined with oxygen and hydrogen, the elements of water. In the warmth and humidity of the Coal Period, when the proportion of carbon dioxide in the atmosphere was perhaps greater than at present, trees unlike living conifers, but more resembling the ginkgo, grew luxuriantly with great ferns, giant club mosses, and gigantic horsetails. Ferns with fronds 10 to 20 feet long so deluged their surroundings with their spores that some coals seem to be almost wholly made of the spore cases. More than 2,500 species of fossil plants have left their record in the coal measures for us to read to-day. As these plants crowded each other in the swamps and died, fermentation and decomposition set in with gradual elimination of much of their substance as marsh gas and carbon dioxide, but with the proportion of carbon in the residue constantly rising. As the land sank or rivers rose, clays and sand were deposited upon this residue, which gradually was compacted into coal. It is thus possible to trace a perfect gradation from wood or peat, through brown coal and lignite to bituminous coal, and finally to anthracite and graphite.

As the result of successive depressions and uplifts of the land, the strata in every coal field are repeated many times. There may be as many as 100 coal seams, varying in thickness from a fraction of an inch to 40 feet or more, and separated by much thicker strata of limestone, iron ore, sandstone, and shale. In Nova Scotia the rock system comprising the coal measures is 13,000 feet in thickness, and in Pennsylvania and West Virginia it is 4,000 feet or more.

In the intervals between coal strikes we mine in this country about 600,000,000 tons of coal a year, a quantity which Charles P. Steinmetz calculated was sufficient, if used as a building material, to construct a wall, like the Chinese wall, entirely around the United States, while with the chemical energy contained in the next year's coal we could lift this whole stupendous structure into space to a height of 200 miles. There are so many other uses for coal, however, that neither operation seems worth while at present prices.

The production and distribution of coal in the United States is a business of such vast proportions and complexity that the mere maintenance of human relations within the industry involves problems so acute and difficult as to lead to frequently recurring crises, like the recent anthracite strike, in which, for 165 days, the miners received no wages, while the operators incurred enormous losses and the public got along as best it could. The basic difficulty in the whole coal situation is perhaps the fact that the mine capacity of the country is 40 per cent greater than the demand. With the many mines and far too many miners it is difficult to insure prosperity and employment to all.

The problems of the coal consumer are of corresponding magnitude, although perhaps less acute. His initial problem is to secure an adequate and regular supply of fuel at the lowest reasonable price, and his secondary concern is to utilize that fuel to the best advantage. Under present conditions the first is largely beyond his control, while as regards the second he commonly fails from lack of knowledge or from willful disregard of the requirements of good practice. The proportion of carbon dioxide in the flue gases of a boiler plant is a good index of its efficiency of operation. It varies from 5 per cent in small inefficient plants to 15 per cent or more in large plants operated at high efficiency. Under such conditions there is a saving of 60 per cent in the fuel cost of heat energy in the large plant. This and similar considerations constitute the argument for superpower systems.

In its consideration of the fuel problem the general public is chiefly influenced by two factors—the cost of fuel and the smoke nuisance. The exasperations due to both are doubtless familiar to all. Within a few weeks anthracite, in small lots, has sold in New York for as much as $48 a ton, while for years many of our cities have been immersed in a Stygian atmosphere, depressing as viewed, unhealthful when breathed, and defiling to all with which it comes in contact. In Pittsburgh the soot deposit per square mile varies, according to the Mellon Institute, from 600 to 2,000 tons per year. One jumps to the conclusion that this is wholly due to outpourings from industrial plants, but in Chicago it was found that 57 per cent of the nuisance was caused by domestic fires and the furnaces in apartment houses.

There have been many proposals for the relief of these deplorable conditions, and those that are of promise involve the initial processing of coal with the recovery of by-products and delivery to the consumer of a smokeless fuel, which may be coke or gas or an artificial anthracite. The whole fuel situation is, in fact, in a state of flux, and revolutionary developments are impending. Nowhere is this trend more evident than in the gas industry.

GAS

Gas has been well described as cleanly, smokeless, sootless, dustless, ashless, instantaneous, flexible, controllable. It is in all these respects an ideal fuel as millions of householders and thousands of industrialists in the districts fortunate in the possession of natural gas well know. Gas as fuel possesses form value—the ability to serve—in very high degree. It is, therefore, not surprising that its development has been consistent and progressive since William Murdock first lighted his Redruth home by gas in 1779. The first gas company in the United States was organized in 1816 to light the streets of Baltimore, but within the last five years the use of gas in Baltimore has been greater than in the preceding century. In the country as a whole the production of manufactured gas has doubled within the last ten years, and to-day the invested capital in the gas industry approximates $4,000,000,000 and its annual production exceeds 400,000,000,000 cubic feet. Imposing as these figures are, the industrial use of gas has just begun, and the inevitable house heating by gas has hardly started. Having learned to cook by gas, we shall presently extend its use to the gas-fired refrigerator.

Some 4,400 American cities and towns are now served by gas, but many others are still without it. They will before long be served by supergas plants designed for long-distance transmission. Already manufactured gas is being delivered 60 miles from its point of production. We have heard much of superpower plants at the coal mines, but their sponsors commonly ignore the fact that the enormous quantities of condenser water required for such plants are very rarely available at any mine. Supergas plants, on the contrary, require very little water, but may, nevertheless, distribute potential heat energy over wide areas.

As long ago as 1881 Sir William Siemens said:

> I am bold enough to go so far as to say that raw coal should not be used as fuel for any purpose whatsoever and that the first step toward the judicious and economic production of heat is the gas retort or the gas producer in which coal is converted either entirely into gas or into gas and coke.

Very recently, as the result of much research in France and Germany, an entirely new field has been opened to the gas companies through the production, from water gas, of methyl alcohol and gasoline. It has been a serious and not wholly undeserved blow to the distillers of wood in this country, who have not yet learned that the price of progress is research. It promises, none the less, ultimately to afford the gas companies a means of equalizing the present spread between their summer and winter load and the broader gap confronting them as their activities are extended to include house heating.

PETROLEUM PRODUCTS

While the origin of the coals and lignites must be regarded as established beyond question, there is another series of carbon products, secondary only to them in importance, the beginnings of which are still the subject of some controversy. Concerning this series Le Conte says:

> Collected in fissures beneath the earth, or issuing from its surface we find a series of products, some solid like asphalt, some tarry as bitumen, some liquid as petroleum, some volatile as rock naphtha, and some gaseous. There is little doubt that all are of organic origin.

The genesis of the petroleum series is, nevertheless, still attributed by some to the formation and reactions of carbides within the earth's crust, but the weight of evidence certainly favors the assumption that the hydrocarbons of the petroleum series are the product of the decomposition of plant or animal remains and most probably the latter.

Bitumen, asphalt, and jet were undoubtedly the members of the petroleum series first recognized and used by man. Jet beads are found among the deposits in the paleolithic caves of Belgium and Switzerland. The Greeks prized jet as an amulet protecting its wearer against the perils of the sea, and in the eighteenth century Whitby jet, found in the neighborhood of Whitby Abbey, in England, was a fashionable, though somber ornament.

ASPHALT

Asphalt and bitumen are complex mixtures of compounds of carbon and hydrogen, in which the carbon content commonly ranges from 85 to 95 per cent. They occur in so-called lakes, deposits, and fissures in many parts of the world. One of the largest of these asphalt lakes is found in the island of Trinidad, and one of the most interesting is located in Los Angeles County, Calif. The Trinidad lake has an area of 115 acres and is 135 feet deep at the center. It has been the source of much of the asphalt used in road making, roofing, sheathing paper, and asphalt shingles. The California lake has been a pitfall and a sepulcher for thousands of prehistoric animals and a mine of richest treasures for the geologist. Here mammoths were entangled like flies on sticky paper, and the saber-toothed tiger, seeking water in the pools of its treacherous, dust-covered surface, or springing upon his ensnared prey was himself enmeshed to leave his bones commingled with those of myriads of other victims.

In Utah there is a notable deposit of high-grade asphalt known commercially as Gilsonite. It occurs in veins often as much as 18 feet in width, extending, in some cases, for 8 miles, and the deposit is estimated to contain more than 30,000,000 tons of the material.

In Egypt, at one time, the terms for "asphalt" and "mummy" were synonymous owing to the practice of the Egyptians of preserving the bodies of the dead by wrapping them in asphalt-coated cloths. Thousands of years ago the Persians carved vases and animals in asphalt and set the eyes in statues with it. There was, near Babylon, a great asphalt lake, and the bricks of the walls and palaces raised by Semiramis and the kings of Babylon were bonded with asphalt cement. An inscription of about 600 B. C. records that Nabopolassar, the father of Nebuchadnezzar, "made a road glistening with asphalt and burnt brick," which we may assume to be the earliest asphalted block pavement.

NATURAL GAS

At the other extreme of the petroleum series and commonly associated with petroleum, we find natural gas which has been termed "nature's bonus to America"—a bonus so generous that our 1924 production amounted to 1,142,000,000,000 cubic feet, or 2.7 times the output of manufactured gas in 1925.

The intrinsic value of natural gas as an asset to the Nation, its unique form value as a fuel in steel works and other great industrial plants, its cheapness and convenience as a source of light and heat in more than 2,000,000 American homes, and finally its remarkable potentialities as a raw material for synthetic products would have led a more provident and perhaps deserving people than ourselves to organize its development upon a basis both careful and farsighted. Instead, its exploitation has been characterized by a reckless and appalling waste at the wells, in transit, and in use. Even the leakage after the meter has averaged 19,000 cubic feet per year, per house. Much of this waste may be attributed to lack of coordination between the gas and petroleum industries and much more to the economic and legal structure, which permits the first driller of a well to appropriate the gas belonging to his neighbors unless they themselves immediately sink wells.

The gas is held, under pressures which may exceed 1,000 pounds to the square inch, in the porous rock strata underlying the field. It varies widely in composition in different localities, but that from a given field is usually quite constant in character. Though it may contain the lighter members of the paraffin series in very different proportions, it usually consists chiefly of methane and carries about 75 per cent of carbon, or 37.5 pounds per 1,000 cubic feet. Much carbon black for printer's ink and other purposes is made from natural gas by methods of incomplete combustion which yield only about 1.3 pounds of black per 1,000 cubic feet burned. The fuel value of the gas is usually somewhat over 1,000 B. t. u. per cubic foot, so that 15 cubic feet carry the heat equivalent of a pound of good coal.

From the low-pressure gas associated with petroleum it is possible to recover, by compression or absorption in oil or charcoal, varying amounts of a light gasoline of especial value for blending purposes. The yields in some cases may be as high as 5 gallons per 1,000 cubic feet of gas, but are commonly much lower. The total amount so produced in 1925 is estimated to be about 30,000,000 barrels, or about 11.5 per cent of our consumption. Of all the States, Oklahoma has contributed much the largest proportion of this natural gasoline.

Of even greater interest for the future are the possibilities of producing from natural gas by synthetic methods alcohols, esters, glycols, and other organic compounds in great variety, as well as motor fuels of new types.

DEVELOPMENT OF PETROLEUM INDUSTRY

There are still many stately homes in New Bedford and other New England towns to bear witness to the prosperity which the whaling industry once enjoyed. The perils which attended the long voyages of its hardy crews and sturdy ships were incurred in a search for carbon compounds for lighting and lubrication. The romance of its adventures as recorded in "Moby Dick" and the "Cruise of the Cachalot" has since, however, been far exceeded by the greater romance of petroleum. Where a kill of the whaler might yield 80 barrels of oil, the wildcatter now brings in a discovery gusher producing thousands of barrels a day, and the world rushes in to share his fortune.

Petroleum has been known from the earliest times and was, to some slight extent, used even by the ancients. Baku, famous in antiquity for its sacred fires, is now more famous for its forests of derricks pumping oil. Here was struck the Droojba fountain, from which 2,000,000 gallons of oil a day spouted in a stem, 18 inches in diameter, to a height of 300 feet, with a roar which was heard for miles. Can any other industry offer such a spectacle or one presenting such potentialities of sudden wealth?

The great Roman architect, Vitruvius, writing in the time of Augustus, says:

> (Some waters) flow through such greasy veins of soil that they are overspread with oil when they burst out as springs: For example, at Soli, a town in Cilicia, the river named Liparis, in which swimmers or bathers get anointed merely by the water. Likewise there is a lake in Ethiopia which anoints people who swim in it, and one in India which emits a great quantity of oil when the sky is clear. At Carthage is a spring that has oil swimming on its surface and smelling like sawdust from citrus wood, with which oil sheep are anointed.

The real romance of petroleum began, however, in America on August 28, 1859, when the Drake well came into production near Titusville, Pa. It was further stimulated by the classic report of Prof. B. Silliman on the economic value of rock oil, in which, with marvelous prescience, he forecast most of the industrial applications of petroleum.

The Drake well went down only 69 feet and yielded less than 30 barrels a day. It led, however, to such feverish exploitation of the Oil Creek district that before 1863 the number of wells exceeded 350. Some of these had records, for a time at least, of 1,000 to 3,000 barrels daily, and the market was so flooded with oil that 10,000,000 gallons are estimated to have run to waste in the absence of purchasers. To-day we are producing more than 700,000,000 barrels from about 300,000 wells, the deepest of which is down more than 7,500 feet.

In the porous strata of the oil sands, and beneath a protective cap of impervious rock, the oil and gas accumulate under pressure from the water below and move upward to the highest point which the conformation of the cap permits. The well penetrates this cap and brings in the initial gusher. The burden of the industry is, nevertheless, carried by the modest, dependable 25 or 50 barrel well, which stays on the job all the time.

The compelling demands of our complex civilization have led the oil industry to assume economic obligations so tremendous as scarcely to permit of their appraisal. Its lubricants have become a vital necessity wherever a wheel is turned. Billions of gallons of its kerosene bring light to isolated homes and are now beginning to drive tractors on the farm. Even the empty Standard Oil tins serve many score of useful purposes in the domestic economy of China and throughout the East. The tank wagon distributing fuel oil has become, in many American cities, more familiar than the coal cart, and we cook our food with water gas enriched with oil gas.

In the Diesel engine the heavier petroleum products develop power of extraordinary cheapness, which is widely utilized in industry. Diesel engines now drive submarines and freighters, and the Diesel locomotive is demonstrating its economy on branch railroad lines.

It is indeed in its relation to transportation that the dependence of modern civilization upon petroleum is most strikingly apparent. Oil has replaced coal in the latest ocean liners and generally throughout the navies of the world, while gasoline supplies the energy for a circumfluent system of transportation which clogs our city streets and crowds our highways. It has even enabled transportation to assume a three-dimensional phase, which has carried man into the air and endowed him with vast new potentialities for good and evil.

In 1898 there were only four automobiles in the country, and one of these was in a circus. Another was used for exhibition purposes, and the two remaining were objects of curious interest as mechanical freaks. To-day there are 20,000,000 automotive vehicles on our roads. Taking cars and trucks together, they are estimated to consume an average of 10 barrels each of gasoline a year.

Our fathers might well have asked, "By what conceivable industrial and financial structures can such vast responsibilities be met?" That they are met in a truly remarkable way is due to the fact that the petroleum industry has boldly directed its own course in production, transportation, and distribution, undeterred by precedent or established usages. It is, throughout, and most distinctively, an American industry which has developed its own methods; its particular and often vivid types, as the wildcatter and the driller; its own forceful and creative personalities.

The United States petroleum industry has produced more than 8,500,000,000 barrels of oil. It is still contributing 70 per cent of the world's production, and there remain an estimated 9,000,000,000 barrels in reserve. The price of its raw material is subject to such range and violence of fluctuation as would put most manufacturers out of business, but the tank wagon is always on the route. Behind it is the second largest American industry and an investment of more than $9,000,000,000.

No mere figures can, however, convey an adequate impression of the vast extent and permeating ramifications of the petroleum industry. One must picture, if he can, the wildcatter with the spirit and optimistic courage of the pioneer; the driller, doggedly persistent and with a presidential economy of speech; the wild excitement of a discovery gusher; vast storage basins, which may hold 3,000,000 barrels in a single concrete reservoir; tank farms, like strangely ordered villages; pipe lines of a length far exceeding that of all the railways in any country in the world except our own; tankers on every sea; the endless procession of tank cars to and from more than 500 refineries, some of which are cities in themselves; thousands of cracking units and gasoline-recovery plants; the tank wagons on every road and innumerable filling stations. Yet the refineries often receive no more per pound for gasoline than one pays for cordwood in Boston and little more than Bostonians pay for anthracite.

An ample oil supply assures such benefits to industry and is so vitally essential in time of war that a somewhat menacing economic nationalism is developing around petroleum. We can, therefore, continue only at our peril the uncoordinated wastefulness which has always characterized our own production. As many have pointed out, this is chiefly due to the defective legal structure under which all owners in a field are now forced by the first driller to raise their oil or lose it to him. The remedy may well be in a Federal law compelling the development of the field as a unit, as Henry L. Doherty has recently urged before the Federal Oil Conservation Board.

There are still amazing opportunities for economies in oil refining, as by the general introduction of modern fractionating equipment and the improved processing of lubricating oils. Moreover a new phase, of great significance, now confronts the industry, for petroleum is about to take its place as a raw material of the first importance in the synthesis of organic chemical compounds. It is to-day the source of numerous alcohols and their derivatives and may soon provide the cheapest base for the synthesis of rubber.

Research has nowhere been more prolific in results of benefit to industry and to mankind than when applied to the chemistry of the compounds of carbon, and much of this fundamental research has been conducted by American chemists.

THE CAUSE OF EARTHQUAKES, ESPECIALLY THOSE OF THE EASTERN UNITED STATES [1]

By William Herbert Hobbs

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[1] Reprinted by permission from papers of the Michigan Academy of Science, Arts, and Letters, Vol. V, 1925.

PART I. GENERAL

EARLY EARTHQUAKE THEORY

Scriptural doctrine.—The Bible lands were among those racked by earthquake, and the explanation offered in the Bible was one common at the time, namely, that God was displeased with his creatures and was visiting punishment upon them. The imagery of the Old Testament reflects this feeling. "Thou hast made the earth to tremble; Thou hast broken it; heal the breaches thereof for it shaketh," is the description in the sixtieth Psalm. In the one hundred and fourteenth Psalm we read, "Tremble, thou earth, at the presence of the Lord, at the presence of the God of Jacob; which turneth the rock into a standing water, the flint into a fountain of waters," the fountains of water being a characteristic phenomenon of all earthquakes; and there follows the inevitable, "O God, * * * Thou hast been displeased: O turn Thyself to us again."

Aristotelian view.—The Greek philosophers were familiar with the earthquakes of the Mediterranean region, and the view of Aristotle, indorsed as it was by the geographer Strabo, has come down to us, and with some slight modification it has survived in a quite modern theory which, until within a score of years, was regarded as standard doctrine. Aristotle conceived earthquakes to be brought about by air imprisoned within subterranean cavities, and by its struggles to escape this air caused a shaking of the ground. Regions where there were many caves, such as Achaea, Euboea, and Sicily, were, as Aristotle well knew, especially subject to earthquakes.

The Aristotelian idea was well expressed by Shakespeare, who makes Hotspur say to the boastful Glendower:

> O, then the earth shook to see the heavens on fire,
> And not in fear of your nativity.
> Diseased nature oftentimes breaks forth
> In strange eruptions; oft the teeming earth
> Is with a kind of colic pinched and vexed
> By the imprisoning of unruly wind
> Within her womb; which, for enlargement striving,
> Shakes the old beldam earth, and topples down
> Steeples and moss-grown towers.

The suggested connection of earthquakes with volcanoes in this passage from Henry IV has been common, as is clear from the almost hopeless confusion in most of the early writings which deal with earthquakes and volcanoes.

Von Humboldt's idea of safety valves.—Alexander von Humboldt made the correct observation that although there were earthquakes usually connected with the eruptions of volcanoes, such earthquakes were by comparison with the devastating earthquakes of history relatively weak and insignificant. He conceived the volcanoes to be.

therefore, a sort of safety valve for pent up gas imprisoned within the earth, which following the Aristotelian view, he believed to be the cause of earthquakes.

Modern dress of Aristotle's doctrine, Mallet, 1862.—The ancient view that earthquakes originate within a cavity or focus wherein gases are confined, was given a modern dress as a scientific theory by an Irishman, Robert Mallet, who had invented a new type of mortar and had also made investigations upon the life of guns. These studies had brought him much renown and had been of the greatest service to the Allies during the Crimean War of 1854–55. When, therefore, in 1857 an earthquake devastated the kingdom of Naples, Mallet applied to the Royal Society for a grant of money for the purpose of making a study of this earthquake. Apparently under the impression that an expert upon explosives was by his training best qualified to study an earthquake, the society readily granted his request, and the results of his study were later published in two massive volumes bearing the title, "The Neapolitan Earthquake of 1857." When Mallet undertook this study the science of physics had recently been much advanced by the Dutch physicist Huygens, who had introduced a new method for following the progress of harmonic disturbances traveling through media such as light through glass or sound through air. Mallet adapted this scientific method to a study of the progress of earthquakes through the outer layers of the earth, and he further supplied technical names which have been widely employed even since his theory has been discredited. The supposed cavity or focus within which the shocks were supposed to originate, Mallet called the "centrum," and the point upon the earth's surface directly above it he named the "epicentrum," at which point the shocks were believed to arrive first and to be of the greatest intensity. This scientific dress applied to Aristotle's theory accounted for its retention by scientists as orthodox doctrine for another 50 years, or until early in the twentieth century.

THE UNIQUE FAULT THEORY

Japanese earthquake of 1891, Kotô, 1893.—Scientists are now well agreed that gases imprisoned within the earth are not the cause of the devastating earthquakes, though they may perhaps in part explain the relatively insignificant shocks which occur in connection with eruptions of certain volcanoes. Students of earthquakes are also in accord in believing that earthquake shocks are in some way connected with the formation of breaks and resulting displacements of the rocks at and near the surface of the earth. This change of viewpoint has come about from studies of earthquakes which have occurred within the last third of a century.

The great earthquake of 1891 in the Neo Valley of Japan was the first to supply striking photographs of changes produced at such times in the surface of the earth, and these photographs came quite generally into the hands of scientists.[2] Though they produced a profound impression they did not immediately discredit the centrum theory. The pictures showed that for many miles across the country a fracture of the ground appeared at the time of the earthquake, and that along this fracture the land upon one side had been raised relatively to that upon the other by as much as 18 feet at one place; while at other places though neither side had been raised or lowered in reference to the other, the two sides of the displacement had slipped past each other in opposite directions along the surface of the ground a distance of the same order of magnitude as that shown by the vertical displacement. It did not admit of doubt that these scissorlike movements on the ground, whether up or down or along the surface, had been sudden and violent and had, moreover, been connected with the jolting movements to which the term earthquake had been applied.[3]

Hindustan earthquake of 1897, Oldham, 1899.—Six years later occurred the great Assam (Hindustan) earthquake which was also carefully studied.[4] In this case though a small part only of the affected area was examined, there were found no less than three fracture displacements (faults), and the maximum vertical displacement measured was about 35 feet. The likelihood is that a number of other faults were produced at the surface, though the localities were not visited by any representatives of the scientific personnel of the Indian Survey. Stress was, however, laid upon one plane only of fracture and displacement, and this was believed by Oldham to be a thrust on a plane of low angle to the horizon.

THE THEORY OF MOUNTAIN GROWTH, DE MONTESSUS, 1906

Two earthquake girdles.—The late Count de Montessus de Ballore published in 1906 the results of an exhaustive study of the distribution of earthquakes, as a result of which he reached this conclusion:

> The earth's crust quakes almost in equal amounts and almost entirely along two straight zones which lie along two great circles (in the geometric sense) which make an angle with each other of about 67°—the Mediterranean or Alps-Caucasus-Himalaya circle (53.54 per cent of the earthquakes), and the

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[2] John Milne and W. K. Burton, professors in the Imperial University, "The great earthquake in Japan, 1891," 30 photogravures, plates, and map with descriptions. Lane, Crawford & Co., Yokohama (no date).

[3] B. Kotô, "On the cause of the great earthquake in central Japan, 1891," Journ. College Sci. Imp. Univ., Tokyo, vol. 5, 1893, pp. 295–355, pls. 28–35.

[4] R. D. Oldham, "Report on the great earthquake of 12th June, 1897," Mem. Geol. Surv. India, Calcutta, vol. 29, 1899, pp. 379, pls. 42, maps.

circum-Pacific or Andes-Japan-Malay circle (41.08 per cent of the quakes). These two zones correspond with the two most important lines of relief of the terrestial surface. (Fig. 1.)

Seismic Areas (de Montessus)

Geosynclines of Mesozoic Era

Coasts visited by Seismic Sea Waves (Rudolph)

FIG. 1.—Map by De Montessus to show the earthquake girdles, but reduced to the Mollweide projection

Mesozoic geosynclines.—Dr. de Montessus further concluded:

The zones, the seismic regions, coincide exactly with the geosynclines of the Secondary epoch.

The geosynclines—the most mobile bands of the earth's surface—where the sediments have been deposited in the greatest thickness, have been energetically folded, dislocated and elevated in the Tertiary epoch, at the time of the formation of the principal existing mountain chains, including within themselves, with two or three doubtful exceptions, nearly all the seismic regions, which in consequence characterize them.

The folded architecture of the geosynclines is unstable, in contrast to the tabular architecture of the continental areas, and this has with much probability been true of all the geological epochs.[5]

We have here, then, a very clear statement that the earth's two zones of earthquake of the present time, including together as they do 94.62 per cent of all recorded earthquakes upon the land areas, are the zones within which the thickest lenses of sediments were deposited during the Mesozoic era, and where also, beginning in late Cretaceous or Tertiary time, ranges of mountains have been in process of erection. It is further pointed out that this zone of folding is much dislocated.

ADJUSTMENTS WITHIN A FAULT MOSAIC AS COROLLARY TO MOUNTAIN GROWTHS

Tarr and Martin, 1906.—In 1899 Thoroddsen printed in the "Icelandic Language" an account of the earthquakes which occurred in Southern Iceland in 1896, and in which five separate earthquakes had shaken in succession each of five contiguous earth blocks.[6] In 1906 Tarr and Martin[7] clearly demonstrated that the earthquake of 1899 along the base of Mount St. Elias was a renewal of mountain growth along the shore of the Yakutat Bay in which large vertical adjustments measured in ten's of feet took place between the large blocks within a fault mosaic, and that movements of smaller magnitude occurred between smaller blocks which were parts of the larger and composite ones. This study is therefore one of the most important and satisfactory that has ever been made of a great earthquake.

Hobbs, 1907.—In 1905 the writer carried out a comprehensive study of the great Calabrian earthquake of that year with the result of showing that even where actual faults are not disclosed by escarpments or other displacements at the surface of the ground, their course may be followed often in great numbers as seismotectonic lines—lines of heavy shock.[8] These lines, as the examination

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[5] F. de Montessus de Ballore, "Les Tremblements de Terre," Géographie Séismologique, Colin, Paris, 1906, pp. 24–25.

[6] A German abstract of Th. Thoroddsen's paper appeared in vol. 47 (1901) of Petermann's Mitteilungen.

[7] R. S. Tarr and L. Martin, "Recent changes of level in the Yakutat Bay Region, Alaska," Bull. Geol. Soc. Am., vol. 17, May, 1906, pp. 29–64, pls. 12–23.

[8] William Herbert Hobbs, "On some principles of seismic geology, with an introduction by Edward Suess," Gerlands Beiträge zur Geophysik, Leipzig, vol. 8, 1907, pp. 217–292, pl. 1, and 10 figs. "The geotectonic and geodynamic aspects of Calabria and northeastern Sicily, a study in orientation, with an introduction by the Count de Montessus de Ballore," ibid., pp. 293–362, 10 pls. and 3 figs.

of earlier earthquakes within this much-racked province clearly showed, have been repeatedly the seats of movement. In the same year the writer pointed out in a discussion of seismic sea waves that these indicate a deepening of trenches on the sea floor at the time of such waves, when the neighboring coasts are usually elevated. To cite:

> Such depressions of the deeps and uplifts of the neighboring shores probably stand in some sort of balance, and both alike call for an initial recession of the water from all near-lying shores toward the area of depression at that instant when the movement occurs. Such a mass of water as would pile up over the depressed area of the sea floor as a result of the inrush of water from all sides, should be later spread in all directions and roll in to inundate the shores.[9]

At the time it was written this explanation seemed to call for mass movements upon the floor of the sea too large for ready acceptance by geologists, and the view appeared to find little support. Sixteen years later, nothing daunted, the writer had the temerity to state his belief that "the floor of the ocean has undergone sudden changes of elevation measured not in tens of feet, as have the zones of unrest upon the continents, but rather in hundreds and even thousands of feet."[10] Within a few months came the great Japanese earthquake in connection with which there occurred a seismic sea wave, an elevated coast, and a sudden adjustment of the floor of Sagami Bay off the coast. The volume of the area dropped measured some 50 cubic kilometers and the amount of the drop measured over large areas 50 fathoms or more (300 feet).[11]

Willard D. Johnson, 1907–1910.—In the early spring of 1907 at the writer's suggestion Mr. Willard D. Johnson undertook a field study of the scene of the Owens Valley earthquake of 1872. This occurred within a desert region of California in which the dislocations had suffered little change in aspect within the subsequent 38 years. For the first time in history an accurate map was prepared of a fault network which had suffered a mosaic-like adjustment at the time of an earthquake.[12]

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[9] W. H. Hobbs, "Earthquakes, an introduction to seismic geology," Appleton, 1907, Ch. XV, especially pp. 253–254.

[10] "The rate of movement in vertical earth adjustments connected with the growth of mountains," Proc. Am. Phil. Soc., vol. 62, 1923, p. 70.

[11] A. Imamura, "Preliminary note on the great earthquake of southeastern Japan on September 1, 1923," Seismological Notes, No. 6, Imp. Earthq. Invest. Comm., Tokyo, July, 1924, p. 16, pl. 4. T. Kato, "Preliminary notes on the Kwantô earthquake in Japan, September 1, 1923," Journ. Geol. Soc. Tokyo, vol. 30, No. 361, p. 8. K. Suda, "On the great Japanese earthquake of September 1, 1923," Mem. Imp. Marine Observatory, vol. 2, 1922–1924. A. Imamura, "The great Kwantô (southeast Japan) earthquake on September 1, 1923," Repts. Imp. Earthquake Invest. Comm., Tokyo, 1925. Takuji Ogawa, "On the great earthquake in Central Japan," Journ. Geol., vol. 3, pp. 1–11, map; reprinted in Kotô Commemoration Volume, Tokyo, 1925.

[12] W. H. Hobbs, "The earthquake of 1872 in the Owens Valley, California," Gerlands Beiträge zur Geophysik, vol. 10, Leipzig, 1910, pp. 351–384, Pls. X–XXIII. (Read before the Association of American Geographers at Chicago, December, 1907.)

Seismic world map, 1915.—The map of the unstable regions of the earth's outer shell which had been issued by De Montessus in 1906, reveals two narrow great circle girdles. (See p. 261, fig. 1.) The introduction of instrumental methods with use of the modern seismograph has enabled seismologists to extend their studies to the floor of the oceans. The seismological committee of the British Association published in 1916 a comprehensive world map of great earthquakes instrumentally located for a 10-year period (1899–1910).[13] This map (fig. 2) upon a quite different basis confirmed that of De Montessus concerning the twin girdles, but showed that these zones extend outward from the margins of the continents into the sea and include the trough deeps upon the sea floor. The zone of maximum instability, moreover, corresponds to the steep slope which joins the mountain arcs of the coasts and islands to the deeps which lie parallel to them. The identity of these special earthquake girdles with belts of mountain growth—of wrinkled formations upon the earth's surface—seems thus to be confirmed from a new quarter.

Magma pocket below and vent above earth wrinkles.—Geologists no longer generally believe, as formerly they did, that the earth's interior is molten. The source of the molten rock (magma or lava) which issues from active volcanoes is now believed to come from reservoirs which are relatively small. There is reason to believe that these reservoirs are usually located beneath the arches of the mountains. Though the earth's interior is believed to be hot enough to melt the rock were it at the surface of the earth and under air pressure only, the rock is believed to be kept rigid by the load upon it. The formation of the wrinkle at the surface locally lifts this load and thus permits a magma reservoir to form beneath it, and above this reservoir the volcanoes naturally develop.[14]

Omori's law of geographical succession of earthquakes within girdles.—The late Professor Omori, distinguished Japanese seismologist, has given his adhesion to the view that the earthquakes within the great girdles of the earth are connected with mountain growth. It was in 1907 in his report upon the California earthquake that he called attention to the geographical order of succession of earthquakes within the earthquake girdles. An earthquake which occurs within any section of one of the girdles may be regarded as relieving the strain by transforming potential into actual energy, this relief being partial only beyond the area characterized by heavy shocks. The greatest probability of an impending earthquake

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[13] H. H. Turner and others, 20th Rept. Seismol. Comm., Rept. Brit. Assoc., Manchester meeting (1915), 1916, pp. 52–79, pl. 1.

[14] Earth evolution and its facial expression," 1921, chaps. 3–5.

applies, therefore, to those sections of the girdle which are farthest removed from regions of recent relief.

Earthquake prediction.—Upon this assumption after the California earthquake in 1906, Professor Omori predicted on August 4,

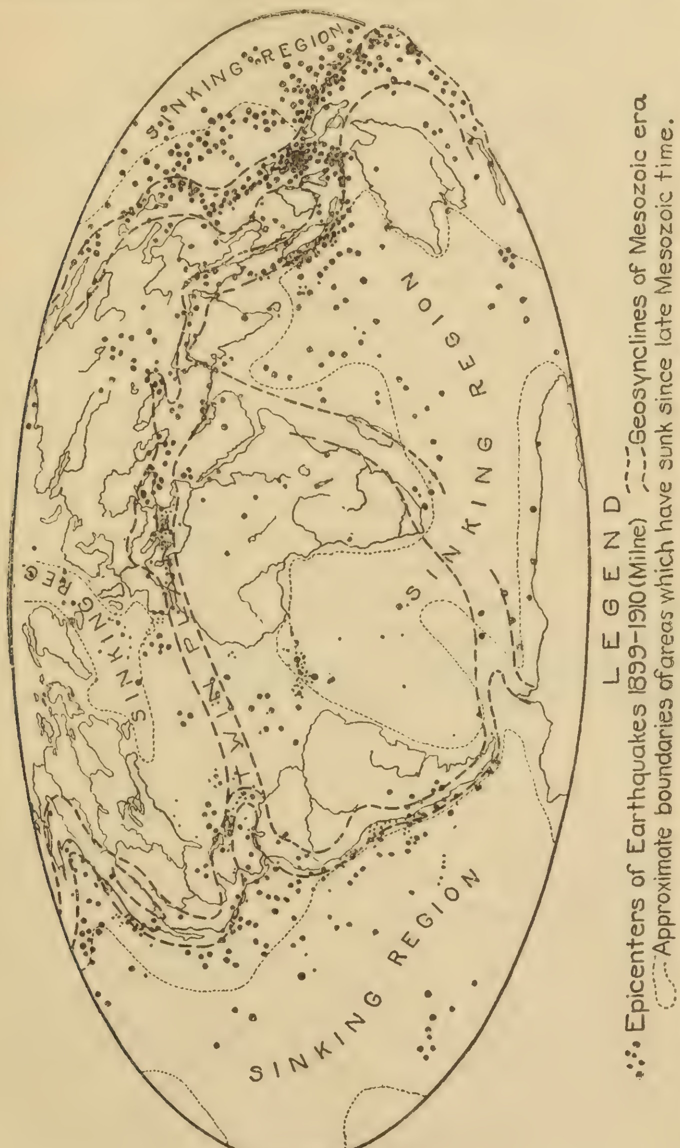

Fig. 2.—World map of earthquake distribution for the period 1899–1910, made from data assembled by the British Association, but transferred to the Mollweide projection

1906, just before he sailed for Japan that the next earthquakes within the circum-Pacific girdle would probably occur south of the equator— in South America. Before his ship had reached Japan occurred the great Valparaiso (Chile) earthquake of August 17, and upon the same day the great Aleutian (Alaska) earthquake.[15]

Utilizing the Omori suggestion, the writer in 1909 predicted that "the zones in which the probability of heavy shocks is now most imminent, are the Japan-Kamchatka segment, the Peru-Bolivia segment, and the archipelago region to the southeast of Asia."[16] (See fig. 3.)

The mountain range does not, so far as our knowledge goes, appear to be forming throughout the circuit of the great circle hemming in the Pacific, but terminates in West Antarctica and in New Zealand. It is in the New Zealand region, particularly, that future shocks may be looked for. Tokyo was largely destroyed by earthquake in 1855 and again in 1923. A heavy earthquake visited the vicinity of Wellington, New Zealand, in 1855, producing a fault scarp which may still be followed at the surface, and it is reasonable to suppose that a recurrence of movement in this neighborhood will take place in the not distant future.

After the meetings of the Second Pan-Pacific Science Congress held in Australia in 1923 and just before his lamented death, Professor Omori traveled in the writer's company from Sydney to Honolulu. Referring to the great Tokyo earthquake which had occurred less than a fortnight before, Professor Omori told the writer that he had fully expected this earthquake to take place within the Tokyo region, though not for another 50 years. This statement of his illustrates well the possibilities of a fair prediction of earthquakes as to their general locality, at the same time that it exposes our limitations with respect to the time of arrival of these devastating visitations.

ELASTIC REBOUND THEORY OF REID, 1910

Theory stated.—When in 1906 America was first awakened to the understanding that an earthquake peril exists upon its Pacific Coast, it had few scientists who possessed a background of earthquake lore, as had, for example, the Mediterranean countries of Europe and Japan. It is unfortunate, therefore, that those who came to be charged with the investigation of this earthquake did not endeavor to study the literature of the subject before writing the report and supplying a theory of cause.[17] Reid's theory of elastic

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[15] F. Omori, "Preliminary note on the cause of the San Francisco earthquake of April 18, 1906," Bull. Imp. Earthq. Invest. Comm., vol. 1, No. 1, Jan., 1907, pp. 21–25. For later expression of this view see "Earthquake zones in and around the Pacific," ibid., vol. 11, No. 1, 1923, pp. 28–32.

[16] "The evolution and the outlook of seismic geology," Proc. Am. Phil. Soc., vol. 48, July 6, 1909, p. 32.

[17] See Bull. Geol. Soc. Am., vol. 32, 1921, p. 45.

rebound is based upon the assumption that there was a single line of dislocation—the visible San Andreas rift or fault—and that the displacement along this plane was entirely in a horizontal direction,

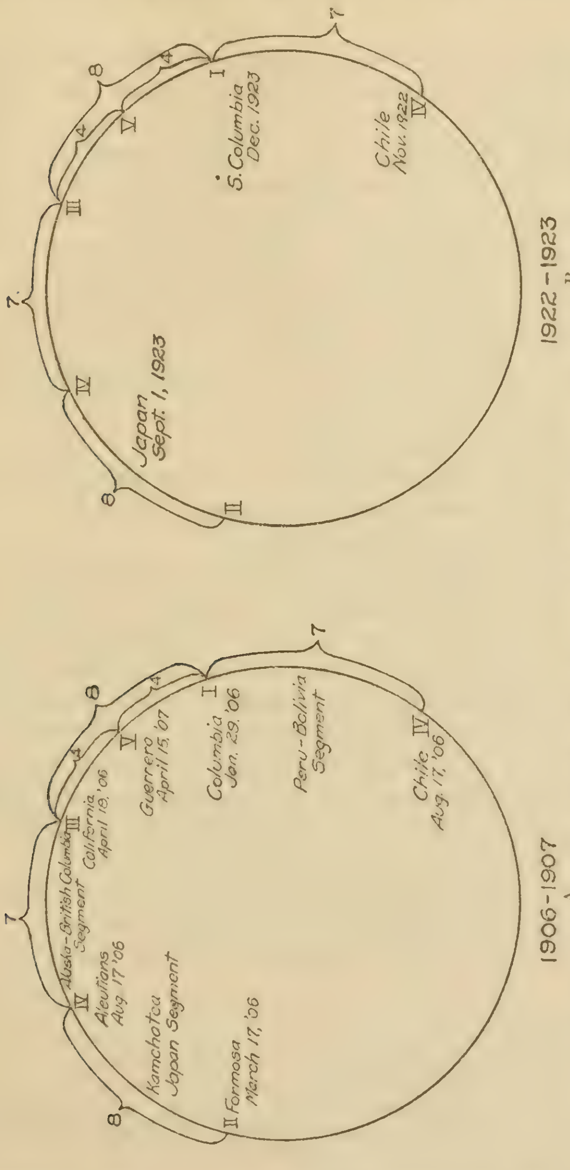

FIG. 3.—A. Reproduction of the writer's map published in 1909 to show the sequence of recent earthquakes at that time. B. Map showing positions of subsequent large earthquakes.

the area to the westward being supposed to shear upon that to the eastward. This shearing strain, generated, according to the assumption, as the result of a current or of currents within the subcrustal region on directions parallel to the San Andreas rift, dragged, it was believed, the overlying crust along with them. The strain so set up was believed to be relieved through rebound on the fault plane at the instant of the earthquake.[18] This theory has been further developed by Lawson under the name "crustal creep and elastic rebound" theory.[19]

Its inadequacy.—As already pointed out, the elastic rebound theory of earthquakes is a reversion to the notion that within any district an earthquake is the result of a slip on a unique plane of faulting, and this new theory was set up without any apparent attempt to fit it to other earthquakes. Evidence of vertical, as well as horizontal, displacement along the San Andreas rift was, however, to be noted, especially at Skinner's ranch, where the writer among many others examined it. It is perhaps true that the revealed displacements upon the San Andreas rift were proportionately more largely horizontal than in the case of many other earthquakes; but lateral displacements of the same order of magnitude combined with large vertical displacements were measured, for example, in connection with the Japanese earthquake of 1891 and the Owens Valley earthquake of 1872. One of the most striking things about earthquakes is the almost monotonous uniformity observed in the nature of the phenomena which accompany them.

Now that geodetic observations have been completed over a sufficient area of the southwestern United States to determine changes of position of triangulation stations since the locations made before the earthquake of 1906, it has been learned that these movements have been quite different from those claimed in the California report to have taken place. The maximum movement recorded is now found to be, moreover, not even within the region of the San Andreas rift. Thus the elastic rebound theory of earthquakes, far from explaining earthquakes generally, can not be made to fit the facts for the one earthquake to which it was originally applied.[20]

Sekiya's wires.—Many years ago Prof. S. Sekiya undertook to represent the sequence of directions of shock received at his earthquake station during a single earthquake with the result of showing that so complex are these motions that to represent their directions

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[18] H. F. Reid, "On mass movements in Tectonic earthquakes and the depth of the focus," Gerlands Beitr. z. Geophysik, Leipzig, vol. 10, 1910, pp. 318–351; also Rept. State Earthq. Invest. Comm. (Carneg. Inst., Wash.), vol. 2, 1910; also "The elastic rebound theory of earthquakes," Bull. Dep. Geol., Univ. Calif., Pub., vol. 6, 1911, pp. 413–444.

[19] A. C. Lawson, "The mobility of the coast ranges of California, an exploitation of the elastic rebound theory," Bull. Dept. Geol., Univ. Calif. Pub., vol. 12, No. 7, 1921, pp. 431–473, 19 text figs.

[20] William Bowie, "Earth movements in California," Spec. Pub. No. 106 (Ser. No. 273), Dept. of Commerce (U. S. Coast and Geodetic Survey), Washington, 1924, pp. 1–22, figs. 1–6. Arthur L. Day, "The study of earth movements in California," address of the president of the Washington Academy of Science, Jan. 13, 1925, Science, vol. 71, No. 1578, Mar. 27, 1925, p. 325.

and successions by a bent wire, it was necessary to employ three complicated snarls of wire in order to cover a minute only of time. Such a result favors strongly the view that not one fault slip but very many on differently placed surfaces are the cause of the earthquake phenomena.[21]

GENERAL STATEMENT OF PROBABLE CAUSE OF EARTHQUAKES

Proximate cause.—The proximate cause, or in common language the occasion, of earthquakes, so far as they occur within the earthquake girdles of the earth, would seem to be the formation of a fold or flexure within near-surface earth strata; such flexure being incident to the erection of a range of growing mountains of scalloped pattern accompanied by a series of parallel deep troughs. Such elevation of a mountain range is accompanied as a natural consequence by pockets of lava beneath the arch, and above these are formed a series of vents for the escape of the volcanic materials, both molten rock and gases.

If we omit the special characteristics, the proximate cause of earthquakes may be stated to be adjustments which take place in position or inclination of portions of the outer shell of the earth, and this broad general statement may be applied outside as well as inside the earth's earthquake girdles. Such adjustment on the basis of many observations implies many individual movements among blocks composing a fault mosaic.

Ultimate cause.—The ultimate cause of earthquakes, the deep-seated reason for the changes brought about in the configuration of the earth's surface, is by geologists generally believed to be the continuous loss into surrounding space of the heat from the earth's interior portions. This loss of heat is accompanied by a reduction of volume, a shrinking of the interior core of the earth; and the outer shell of rock being already cooled to a relatively stable condition must wrinkle as it adjüsts itself. The old illustration of an apple in late winter which wrinkles from the loss of water and consequent reduction of volume of its interior portion, may still serve well at the present time.

PART II.—EARTHQUAKES OF THE EASTERN UNITED STATES

THE REGION A RELATIVELY STABLE ONE

Historical earthquakes of the region.—Northeastern North America lies outside the seismic girdles of the earth (see fig. 2, p. 265) and at least since its settlement by Europeans it has relatively seldom been vexed by destructive earthquakes. That light shocks have not

[21] S. Sekiya, "A model to show the motion of an earth particle during an earthquake," Trans. Seis. Soc. Japan, vol. 11, 1887, pp. 175–177, pls. 1–2.

been infrequent within recent times, or since newspapers and the telegraph have been widely distributed, is, however, evident from compilations made by Rockwood.[22] In the State of Michigan alone within this period some 10 earthquakes have been put on record, the latest of which occured February 28, 1925.[23] Contrary to general opinion earthquakes of devastating violence have also visited the region of the eastern United States. These greater earthquakes have seemed to have relation especially to the drainage basin of the St. Lawrence River and Great Lakes, to the lower Mississippi region of heavy deposition, or to the coastal plain east of the Appalachian Mountains. Accounts made between 1610 and 1791 by the French Jesuit missionaries from within the area reached by canoes about the St. Lawrence River and lakes, show that earthquakes were felt within that region in 1638, 1661, 1663, 1664, 1665, 1668, and 1672; that of February 5, 1663, described in the letters of Jerome Lallemant having been of devastating violence and probably comparable to the greatest earthquakes that are known. The full accounts of the missionaries translated and edited under the direction of the late Reuben G. Thwaites and published in 73 volumes by Burrows Bros., of Cleveland, have been searched for earthquake data and the extracted results published by Rev. Father Odenbach, of Cleveland.[24]

In 1811 within the lower Mississippi Valley a really great earthquake generally referred to as the New Madrid earthquake was felt over a relatively broad area of the Mississippi Valley. For more than a century the region has now been generally quiet, but the scars of the disastrous disturbances of 1811 still arrest the attention, and this earthquake must be reckoned among the most severe of any that have been anywhere recorded.[25]

The Charleston earthquake of 1886, while of greatest intensity in the vicinity of that Southern city, was felt as far north as the City of New York.[26] All three of these great disturbances of the eastern United States were within areas far outside the seismic girdles which mark the earth's zones of special instability.

If we look upon the earthquake of the late seventeenth century within and about the St. Lawrence drainage basin as more or less completely relieving the strains which had quietly been accumulating within that area, and much less completely relieving the outside

[22] C. G. Rockwood, 14 articles in Am. Journ. Sci., from 1872 to 1885.

[23] W. H. Hobbs, "Earthquakes in Michigan," Pub. 5 (Geol. Ser. 3), Mich. Geol. and Biol. Surv., Lansing, 1911, pp. 69–87, 2 pls.

[24] Twelfth Ann. Rept. Meteorol. Observ., Coll. St. Ignatius at Cleveland, Ohio, 1906–7, pp. 7–15. For an abridged summary see the author's "Earthquakes," Appleton, 1907, pp. 315–320. Lawson seems to be quite unaware of this earthquake (Bull. Seis. Soc. Am., p. 139; reprints indicate no volume or date).

[25] Myron L. Fuller, "The New Madrid earthquake," Bull. 494, U. S. Geol. Surv., 1912, pp. 119, pls. 10, figs. 18.

[26] C. E. Dutton, "The Charleston earthquake of Aug. 31, 1886," Ninth Ann. Rept. U. S. Geol. Surv., 1889, pp. 203–528.

areas characterized by lighter shocks; then the New Madrid earthquake of a century and a half later may be considered to have accomplished a similar result for the large area to the south and west, the valley of the lower Mississippi. Three-quarters of a century now elapse and the residue of the broad area, that to the south and east, finds relief during the earthquake of Charleston in 1886, with some relief also within the outlying areas where no destructive shocks, but only jars and tremors, were felt.

Geological evidence is available from within the destructive area of the New Madrid earthquake, to show that an earthquake of devastating intensity and comparable in this respect with that of 1811, visited the region at least 100 years earlier. Altogether, then, we have the evidence that at intervals averaging a century or more, this broad region of eastern North America, usually looked upon as especially favored by its stability, has been visited by racking earthquakes of the first importance. It is therefore necessary to-day to modify in a measure the views which have been generally held concerning earthquake distribution. The fact that the settlement of America by Europeans came so recently, and that of the three great earthquakes known from the region, two belong to the early period of sparse settlement, pioneer scientific method, and imperfect historical record, largely explain the failure to assign proper values to these really great earthquakes.

Epeirogenic earthquakes of De Montessus.—Doctor de Montessus in a magistral posthumous work which came from the press in 1924, has described a new class of earthquakes for such regions as lie outside the earthquake girdles. These earthquakes he ascribes to epeirogenic movements, up-and-down movements of neighboring sections of the earth's surface layers—and hence block movements which are unassociated with the folding process, as are those which occur within the earthquake girdles.[27] In this he clearly recognized that his two earlier volumes, through laying especial stress upon the importance of the two earthquakes girdles, ascribed far too little importance to those earthquakes which occur outside.

It is easy to account for the earthquakes of the lower Mississippi Valley through the gradually accumulating load over the delta region and the lower flood-plain of this great river. It has been estimated upon good authority that 513 million tons of suspended matter are carried out each year to tidewater in Louisiana, and this takes no account of the vast load that is laid down within the broad area of the flood-plain in the States of Arkansas, Missouri, Tennessee, Mississippi, and Louisiana.

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[27] F. de Montessus de Ballore, La Géologie Séismologique, les Tremblements de Terre, Colin, Paris, 1924, Ch. I.

Coastal changes of level, which though extremely slow are yet recorded in the uplifted terraces of wide tread and small rise along the Atlantic coast of the country, may account for the Charleston earthquake of 1886 and the many light earthquakes felt along the Atlantic sea board. A no less apparent cause for adjustment of the outer shell of the earth relates to the area of the Laurentian Great Lakes, and here fortunately we have a much greater body of evidence at our disposal.

Epeirogenic adjustments within Great Lakes area.—During the latest—and present—geological period, the Pleistocene, continental glaciers of an estimated thickness of between one and two miles for a portion of the time lay over northern America so as to cover at their culmination the greater part of the area east of the Rocky Mountains and north of the Missouri and Ohio rivers. Such a burden of ice must be conceived to have brought about a depression of the earth's surface within the region, from which recovery would presumably be either wholly or partially obtained when the ice waned and finally disappeared. The evidence is conclusive that since the retirement northward of the latest continental glacier, the Laurentian drainage region has been undergoing an elevation which began toward the southern margin, has increased in amount toward the north, and is still continuing to-day at a somewhat rapid rate.

There is an extensive literature of the subject[28] as regards the nature of the evidence of uplift, but the explanation of the earthquakes of the region as a consequence of this uplift and uptilt of the land was, so far as he is aware, first made by the writer in two related papers published in 1911.[29]

Summarized for the general reader, the available data which prove the uplift and uptilt of the Laurentian basin relate: (1) to the evidence of already accomplished movement, and (2) to the evidence that this upward movement still continues and so may be invoked to explain the earthquakes within the region.

The evidence of the already accomplished uplift and uptilt is derived from the present positions and inclinations of the now abandoned shore lines of the system of great ice-dammed lakes which lay along the front of the continental glacier during its retreat. These shore lines, which were of course horizontal when first formed, are now tilted upward toward the north at angles which increase rather rapidly as one proceeds north. The uptilt has been likened to that of a trap-door in the floor rotating upon

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[28] The more important series of papers are by Gilbert, Leverett, Taylor, and Goldthwait.

[29] "The Later Glacial and Post Glacial Uplift of the Michigan Basin; Earthquakes in Michigan," Mich. Geol. and Biol. Surv., Pub. 5 (Geol. Ser. 3), Lansing, 1911, pp. 87, pls. 2 and 3, and figs. 48 and 5.

its hinge, the hinge line for the Laurentian region taking an average direction in the neighborhood of the Great Lakes of about 15° to the north of west. The case is, however, not quite so simple as this, for the main hinge line of the region has itself migrated northward since the beginning of the uptilt, and secondary hinge lines within the trap-door itself appear also to have functioned. One may liken the complex movement in its main

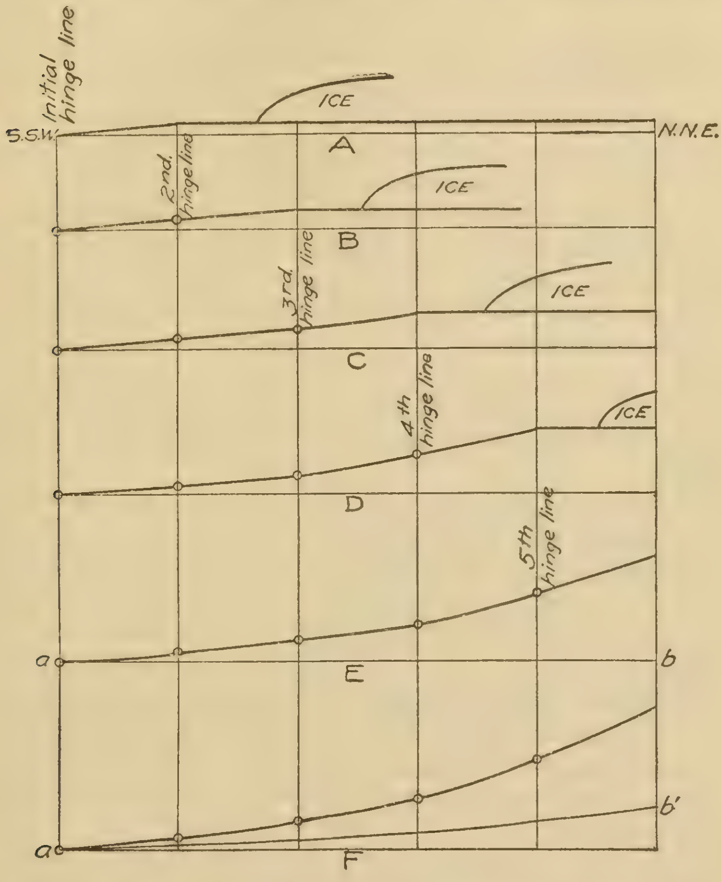

FIG. 4.—Diagram to show the nature of the Laurentian region as the continental glacier retired northward

lines to that of a trap-door made up of several planks all parallel to the main hinge and each hinged to its neighbors, all hinges being or having been in action. (Fig. 4.)

We are now chiefly concerned, however, with the evidence that uptilt of the land is still going on, and may therefore be responsible for the earthquakes of the region. The earliest clear recognition of such present-day uptilt was made by a land surveyor of Wisconsin, Mr. G. K. Stuntz, who in 1870 published a brief paper on observations made by him in the years 1852 and 1853 about Lake Superior.[30] Stuntz had noticed that on the northern shore of Lake Superior there were evidences that the land had recently risen, whereas on the south shore there were as clear signs of recent overflow. It was as though one were to take in the hands a partly filled basin of water and by tilting it cause the water to withdraw from one side, where in consequence the bottom of the basin rises out of the water; and to flood the opposite side. Additional observations from Lake Superior which confirmed these observations by Stuntz were made by Lawson in 1891.[31] The attention of geologists was first strongly directed to this tilting by Gilbert in 1898, when he investigated the series of records of the several gauging stations about the Great Lakes and found additional confirmation of the uptilt.[32]

Upon the south side of Lake Superior in Michigan the evidences are especially easy to read. The rivers of this coast have estuaries especially marked in the stretch from Ontonagon westward. At some points in the Porcupine Mountain district the trees along the shore of the lake stand 6 to 8 feet out from the shore in 6 to 8 inches of water. At other points where the trees are at the shores, the waves are beating against them and removing the bark. Here the lake has already encroached upon roads so that they have had to be abandoned.[33]

Evidences of a somewhat similar nature to those found characteristic of Lake Superior belong also to Lake Erie. They show that here also the tilt of the land is upward toward the north. From the rate of flooding of the shores of Sandusky Bay Moseley has estimated that the rate of submergence on this shore is 2.14 feet per century.[34]

Lake Michigan-Huron, for this is a single body of water, has its outlet at Port Huron far to the south and now to the southward of the hinge-line of uptilt. Were this not the case, flooding of the Chicago shore of Lake Michigan and of Bay City shore of Saginaw Bay would be going on.

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[30] G. K. Stuntz, "On some recent geological changes in northeastern Wisconsin," Proc. Am. Assoc. Adv. Sci., vol. 18, 1870, pp. 206–207.

[31] A. C. Lawson, "Sketch of the coastal topography of the north side of Lake Superior with special reference to the abandoned strands of Lake Warren [Lakes Nipissing and Algonquin, W. H. H.], 20th Ann. Rept. Geol. and Nat. Hist. Surv. Minn., 1893, pp. 181–289.

[32] G. K. Gilbert, "Recent earth movement in the Great Lakes region," 18th Ann. Rept. U. S. Geol. Surv., 1898, pt. 2, pp. 595–647.

[33] F. E. Wright, "Report on the progress made by the Porcupine Mountain party during the summer of 1903," Rept. Geol. Surv. Mich. for 1903 (1905), p. 37.

[34] This is notwithstanding the fact that the present hinge line of tilting now crosses the northeastern half of the lake. Gilbert's earlier estimate of the rate of uptilt (18th Ann. Rept. U. S. Geol. Surv., 1898, pt. 2, p. 637), even as corrected by Lane (Geol. Surv. Mich., vol. 7, 1900, pp. 36–39), is in error and much too large, since he conceived the entire area about the lakes to be tilting like a plane without recognizing the positions and the migrations of the hinge lines (Mich. Geol. and Biol. Surv., Pub. 5, 1911, pp. 40–41).

Postglacial faults.—Evidence is at hand that faults have been an accompaniment of the epeirogenic movements which have been going on within this region. The continental glaciers which in the yesterday of geology covered the region, planed the rock surfaces to a freshly polished condition upon which any subsequent displacement, even though of small measure, must be revealed whenever diligently sought for. No such search has been generally made, but already a considerable number of observations widely scattered through the region have been put on record. (Fig. 5.)

Such postglacial faults appear to have been first noticed by Mather [35] at Copake, N. Y., near the common corner of Massachusetts and Connecticut. Similar faults have since been described by Matthew [36] from St. John, New Brunswick; by Chalmers [37] from many localities in the Province of Quebec; by C. H. Hitchcock [38] from Littleton, N. H.; by Woodworth [39] from many localities in eastern New York and Massachusetts; by Lawson [40] from Banning in western Ontario; by Hobbs from Sawyer, Wis.,[41] and the French River in central Ontario;[42] and by Loomis [43] from Mount Toby, Mass. While these faults are often small individually they are numerous and they grow large in the aggregate, and in some cases they are measured in tens of feet.

The faults of eastern New York have been found chiefly along the lineament which follows the Hudson River and its continuation northward. The lineaments of the northeastern United States in their relation to the recorded earthquakes of the district as the data have been assembled by De Montessus have already been put upon record.[44]

CONCLUSION

The earthquake of February 28, 1925, was felt throughout the glaciated area of North America and at relatively few places outside. It was peculiarly an earthquake of this Laurentian area, and it is best explained as due to epeirogenic block movements as a result of

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[35] W. W. Mather, "Geology of New York, report on first district," 1843, pp. 156–157.

[36] G. F. Matthew, "Movements of the earth's crust at St. John, New Brunswick, in postglacial times," Bull. Nat. Hist. Soc., New Brunswick, No. 12, 1894, pp. 34–42.

[37] R. Chalmers, "Report on the surface geology and the auriferous deposits of southeastern Quebec," Geol. Surv. Can., Ann. Rept., vol. 10, 1897, pt. J, pp. 10–12.

[38] C. H. Hitchcock, "The geology of Littleton," in History of Littleton, 1905, pp. 28–29.

[39] J. B. Woodworth, "Postglacial faults of eastern New York," Bull. 107, N. Y. State Museum, 1907, pp. 4–28.

[40] A. C. Lawson, "On some postglacial faults near Banning, Ontario," Bull. Seismol. Soc. Am., vol. 1, pp. 159–166.

[41] W. H. Hobbs, "The late glacial and postglacial uplift of the Michigan Basin," Mich. Geol. and Biol. Surv., Pub. 5, 1911, p. 45.

[42] W. H. Hobbs, "Postglacial faulting in the French River district of Ontario," Am. Journ. Sci., vol. 1, 1921, pp. 507–509.

[43] F. B. Loomis, "Postglacial faulting about Mount Toby, Mass.," Bul. Geol. Soc. Am., vol. 32, 1921, pp. 75–80.

[44] Beiträge zur Geophysik, vol. 8, 1907, pl. 2.

continued uptilt of the area depressed during the periods of glaciation. The earthquake history of the region affords no warrant for the belief that the region of the northeastern United States is to

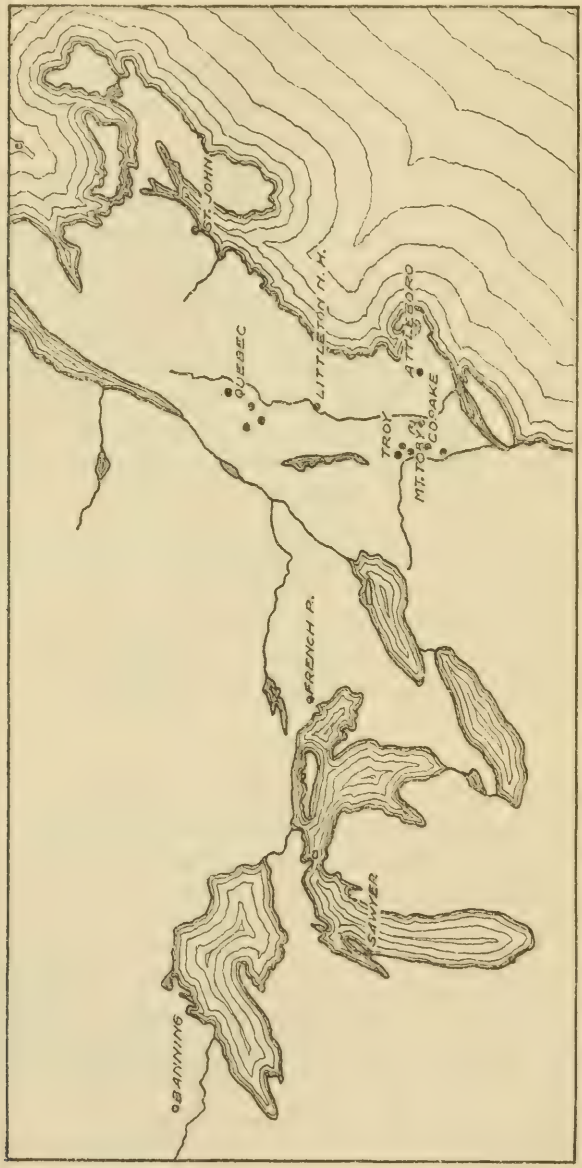

FIG. 5.—Sketch map to show where postglacial faults have been observed within the glaciated region of North America. Of those from the Province of Quebec only a few have entered

remain immune from destructive earthquakes. Such visitations, it may be assumed, will be far less frequent than earthquakes which occur within the great girdles where mountain growth is proceeding justily, but there is every reason to suppose that the future will bring to the Laurentian region earthquakes which are comparable in intensity with those of 1663 and 1811. So long as light shocks continue within the region, there is reason to believe that at least a partial relief from earth strain is being secured, and the date of the next destructive shocks is correspondingly removed farther into the future. Paradoxical as it may appear, the time for alarm will come whenever the region becomes abnormally quiescent.

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THE LOESS OF CHINA[1]

By George B. Barbour

Yenching University, Peking

[With 6 plates]

CONTENTS

INTRODUCTION

Every traveler who returns from a first up-country tour in Chihli or Shansi has some comment to make upon the curious sights of the loess country, if not a photograph to show of picturesque canyons or quaint cave dwellings. But despite frequent literary references to loess in China from before the days of its description by the explorer Baron v. Richthofen (10–56)[2] until to-day, any attempt to get at facts about its true nature and origin reveal how limited our actual knowledge is. For instance, careful inquiry has so far brought to light only three chemical analyses, none of these being in print. Descriptive notes, each usually from a different point of view, may be found scattered through articles or chapters by various authors.

Detailed descriptions of its occurrence are given in the researches of v. Richthofen and Willis. In recent years by far the most critical study has been that contributed by Dr. J. G. Andersson, mining advisor to the Chinese Government, based upon geological field work

[1] Reprinted by permission from The China Journal of Science and Arts, Vol. III, No. 8, August, 1925, pp. 454–463, and Vol. III, No. 9, September, 1925, pp. 509–519.

[2] Note.—References, where not given as footnotes, are indicated by two numbers, the first that of the publication as listed in the bibliography at the end of the paper, the second the page quoted in that volume.

by Doctor Zdansky and himself. Doctor Anderson's conclusions are embodied in the Geological Survey's memoir on the Cenozoic of North China (1–121).

No attempt seems to have been made recently to bring together more than one aspect of our present knowledge. Such an attempt may now serve to unify the results so far gained, and act as a basis for later more complete scientific study. A summary of this kind does not aim at being exhaustive, and avoids more than passing reference to disputed points which are discussed elsewhere. At the same time, in this instance it is possible to add also certain field and laboratory observations recorded here for the first time. Prof. E. O. Wilson of Yenching University, Prof. T. New of Tsinghua College, and Prof. W. C. Lowdermilk of the University of Nanking, have placed at my disposal the results of researches they have carried out, in each case making valuable contributions which fill important gaps in our previous knowledge. I am glad of this opportunity to express my appreciation of their generous cooperation.

DISTRIBUTION OF LOESS IN GENERAL

Loess is an important fine-grained loam formation, widespread in various parts of the Northern Hemisphere. Its uncompacted nature won the name "loess" in the German Rhineland, where it forms a soil of high fertility. It is widely developed in a farm-land belt that stretches across northeast France and Belgium and extends irregularly into Poland, Czechoslovakia, and Rumania. In the United States it covers large parts of Ohio, Indiana, Illinois, Iowa, Kansas, and Nebraska, with a long southern projection through Missouri down the east bank of the Mississippi.

Even in Asia, China has no monopoly of the loess. According to v. Tillo (4–566) loess covers 511,150 square miles, or 3 per cent of the continent. Assuming an average depth of 30 meters, Walther has calculated that this represents a volume of 40,000 cubic kilometers of material, almost all produced by rock decay in arid regions (11–193). Sven Hedin and other travelers report it from places in the interior.

THE LOESS OF CHINA

In China loess is strongly developed throughout the basin of the Yellow River and at other places in Chihli, Shansi, Shensi, Honan, Kansu, and Shantung. Small accumulations are reported from Anhui, Kiangsu, and elsewhere.

It should be said at the outset that in the case of the Chinese loess the term has been used to include other deposits which, though somewhat similar in appearance, differ vastly both in age, composition, character, and mode of origin from genuine loess. This confusion has given rise to the very exaggerated estimates of its thickness recorded by many observers. Von Richthofen gives figures of 500, 600 and even 1,500 feet, and one reads travelers' references to "hundreds of feet of loess." But it is doubtful if there exist outside of Kansu deposits of much more than 200 feet thickness, the deeper deposits proving almost invariably to include the underlying Hipparion clay, or more recent gravels, silt, and "redeposited loess." Andersson (1-123) gives 60 meters as the maximum thickness of true undoubted loess observed in any place.[3]

A second cause for such overestimates is the failure to realize that loess was spread by wind over a valley-dissected land surface. Hence, though often found at considerable altitudes, it may have no greater vertical depth there than it does on the lower valley slopes,

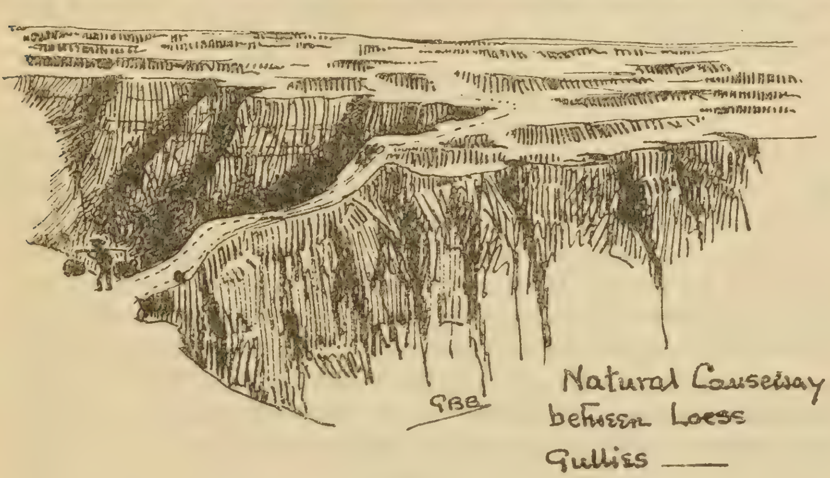

FIG. 1

just as the people in the back rows of an amphitheater are under no obligation to be taller than those in the front seats.

The true Chinese loess is a yellow-gray poorly consolidated loam deposit of the fineness of silt, which shows a characteristic absence of horizontal layer structure, being essentially nonstratified, and a tendency to split along roughly vertical joint planes, so as to form perpendicular cliffs and walls. No attempt is made here to describe the remarkable erosion features, natural arches, crevasses, pinnacles, sinks, etc., common in loess regions. These are well described in such articles as those of Fuller (3-570) and Sowerby (2). (See pls. 1-6.)

For the most part it is nonfossiliferous, the only animal remains found in any quantity being the shells of small nonmarine snails

[3] In conversation Doctor Andersson has mentioned that recent careful observations in Kansu have showed that in one or two places this maximum ought to be increased by some 20 or more meters. Dr. George G. Cressey has measured cliffs over 300 feet high near Sui-te-chow on the west bank of the Yellow River in Shensi. Even greater thicknesses may exist in a few restricted localities.

(*Helix*, *Pupa*, etc.). But mammal bones are found in small numbers scattered over the wide area in which loess occurs. Doctor Andersson's list of those recorded by different observers includes elephant, hyena, hippopotamus, horse, stag, turtle, and a mole-like rodent, commonly known as mole rat (*Myospalax*) (1–127). A fossil of special interest is the ostrich egg (*Struthiolithus*), which seems to be fairly widely distributed.[1] One such was found at Ch'enchow by Mr. Max Engel, of Peking, 25 feet below ground level when digging a well. Its length is 180 millimeters. The photograph which he kindly allowed me to take, shows clearly the calcareous incrustations often found attached to the surface of such fossil eggs. Though complete eggs are rare, broken bits are more frequently found. I have found fragments in eight localities within a radius of a few miles of Kalgan, which tally with observations in other regions.

CHEMICAL ANALYSIS

Failing to find any published quantitative description of the material which composes it, I examined typical specimens of loess from Chihli and Honan; the former was collected from a point 10 miles southwest of Hsuan-hua, in northern Chihli, the latter was kindly furnished by Dr. W. H. Wong, Director of the Geological Survey. The latter material was kindly analyzed for me by Prof. E. O. Wilson of the department of chemistry, Yenching University. For comparison, the analysis given in his report is here set beside analyses of loess soils from the Rhine Valley, from Switzerland, and three from America, showing the wide range of variation in composition of loess.

	1	2	3	4	5	6
SiO_2	64.22	58.97	71.09	81.13	69.66	86.96
Al_2O_3	18.1	9.97	16.78	8.52	12.71	4.69
Fe_2O_3		4.25		2.92	4.89	2.86
CaO	6.31	11.31	1.81	.31	1.09	.71
MgO	2.09	2.04		.39	1.28	.43
Na_2O	.22	.84	.23	.52	1.17	1.67
K_2O	.99	1.11	1.30	1.78	2.42	.91
TiO_2				.78	1.72	.69
P_2O_5			.11	.08	.15	.07
N				.11	.23	.11
CO_2	4.1	11.08	.80			
MnO_2	Tr.					
H_2O at 110°	.73					
Loss on ignition	1.81					

1. Loess from Honan, analyzed by Prof. E. O. Wilson.
2. Loess from Rhine Valley (Bischoff, Chemical Geology).
3. Loess from Neubad, Switzerland (7–318).
4. Memphis silt loam, Mississippi (Robinson, United States Department of Agriculture Bull. 551, 1917).
5. Loess soil, Cherokee, Kans. (Bennett, Soils and Agriculture, 1921).
6. "Silt loam," Weeping Water (Alway, quoted 6–63).

[1] See Andersson "On the occurrence of fossil Struthionidae in China" (1–53).

It is clear from the range of composition shown by these samples from widely separated localities, that the reasons for the peculiar characteristics common to them all must have a physical, rather than a chemical, basis and be a result of the size, shape, and relative position of the grains rather than the minerals that compose them.

The following two additional analyses have been kindly furnished by Dr. W. H. Wong, Director of the Geological Survey, and are particularly interesting as supplementing the data given above; the surprising similarity of composition of samples from widely separated localities is also worth noting.

Analysis of loess made by the Geological Survey of China

	Loess from Wei-ning, Kansu	Loess from Tai-yuan, Shansi		Loess from Wei-ning, Kansu	Loess from Tai-yuan, Shansi
SiO_2	59.30	61.23	$CaCO_3$	14.90	13.40
Al_2O_3	11.45	11.35	$MgCO_3$	4.58	3.95
Fe_2O_3	2.32	3.50	Na_2O	1.80	1.65
FeO	1.55	1.20	K_2O	2.17	2.10
TiO_2	.60	.70	SO_3	.20	.20
P_2O_5	.20	.18	H_2O	.96	.64

MINERALOGICAL AND MECHANICAL ANALYSIS

Viewed microscopically, loess presents the appearance of Figure 2 which is a *camera lucida* drawing of the grains of the Honan loess already referred to, enlarged 104 times.[5]

Working at 400 magnifications, it is not possible to make accurate quantitative observations on the very finest particles without first separating these from the coarser silt grains to which they cling. Hence, in the absence of apparatus for elutriation, the material of diameters below 0.005 millimeter was disregarded; a major part of this is probably clay, with some limonite, but no attempt was made to determine physically what percentage of the total amount was fine enough to be so graded. Excluding these extremely fine particles, the average diameter of 758 grains in this sample was 0.0124 millimeters. Thus, according to the United States Bureau of Soils classification, the bulk of the material falls within the limits of silt (0.005-0.05 millimeters). The outstanding features are the angularity of the grains (which in many cases are practically free from traces of rounding), and the surprisingly fresh condition of the mineral grains, many of which are still almost unattacked by weathering. The determination of the various minerals proved hard at first, as, owing to the extreme fineness of the particles (averaging, as noted above, less than five ten-thousandths of an inch in diameter), the

[5] Cf. also G. P. Merrill (7–317), fig. 33, "Chinese Loess."

ordinary methods of rock microscopy had to be replaced by special tests. By these means it was possible definitely to identify quartz, biotite, orthoclase and plagioclase feldspar, hornblende, carbonate, kaolinite, and apatite in approximately that order of abundance, together with some grains of one or two other minerals which, in the absence of means for making further more delicate tests, could not be determined with certainty. If allowance is made for the fineness of grain of clay, of which a relatively large percentage would fall below the minimum size determinable, the kaolinite might perhaps stand a little higher on the list in an analysis of the total material. To the naked eye this sample has a somewhat unusually high biotite content.

FIG. 2.—Grains of loess from Honan (magnified 104 times). The graduations on the cross wire indicate one-tenth millimeter

In connection with a more extended piece of research from a different point of view, Prof. W. C. Lowdermilk has analyzed loess-soil material from Shensi in the department of forestry, University of Nanking. Professor Lowdermilk has most generously placed his preliminary results in my hands. The mechanical analyses were carried out using two samples from an uncrushed block of loess from Liu-lin on the Red Cross Road near the Yellow River.

Sample 1:

		Per cent
(*a*) Percentage of sand and silt by settling		80.01
Percentage of clay		19.46
Error		.55
		100.00
(*b*) Sieve study:		
Grains over 0.1 millimeter diameter		2.15
Grains under 0.1 millimeter diameter		97.85
		100.00
(*c*) Micrometer study:		
Class	Average diameter of particle	
Fine sand	0.13 millimeter	1.59
Very fine sand	.065 millimeter	27.44
Silt	.033 millimeter	50.97
Clay	.0035 millimeter	20.00
Error		.10
		100.00

Sample 2:

	Per cent
(a) Percentage of sand and silt by settling	81.70
Percentage of clay	18.30
	100.00

(b) Micrometer study:

Class	Average diameter of particle	
Fine sand	0.10 millimeter	1.00
Very fine sand	.063 millimeter	25.00
Silt	.030 millimeter	54.00
Clay	.004 millimeter	20.00
		100.00

SOIL CHARACTERISTICS OF LOESS

Reasoning *a priori* from the mineralogical and chemical analyses above, it might be expected that loess would differ in several respects from normal river silts of corresponding texture. These latter, owing their fineness to prolonged wearing down by stream action, and exposure to the attack of chemical weathering, tend to form products of relatively stable composition (especially silica, ferric hydroxide, and clay), from which the more soluble elements have been removed. Such clayey soils let water permeate only with difficulty, are sticky and heavy to till, and may call for fertilization by the addition of those chemical elements desirable for plant growth, which have been gradually leached out by the solvent action of water. In these points Chinese loess shows a strong contrast. The analysis above is of special interest in showing how fresh and undecomposed much of the material of true loess may be, the minerals being those commonly found predominating in ordinary unweathered granite and allied rocks, and appearing actually almost less affected by alteration than the weathered surface of any average rock. It may be said here in anticipation that this seems to form additional evidence in favor of the now generally accepted belief that such loess is, in the main, a wind-blown deposit formed under arid or steppe conditions.

There is as yet a dearth of quantitative data as to the favorableness of loess as a soil. No information could be obtained as to the extent to which cropping of the soil in China through past years with the soya bean and other legumes has enriched (or impoverished) it, especially in the matter of nitrogenous compounds, though there is no question that farmers have discovered experimentally through centuries of practice the penalties of nonrotation of crops; this knowledge and the universal practice of manure fertilization makes it hard to isolate the results due to any one factor. Certain generalizations, however, are possible, particularly where based upon experience of loess soils in other countries. Lyon and Buckman state,

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for instance, that under heavy cropping, where little organic or mineral matter is returned, loess soils need the addition of phosphoric acid and lime (6-63)—a deduction that might almost be made directly from an inspection of the analyses given above. In general, they say, whenever moisture relations are favorable loess is an exceedingly fertile soil. Since the Chinese loess often already carries a high lime percentage and the practice of manuring is universal, water supply becomes the vital factor.

These theoretical conclusions seem to be borne out by the facts wherever observed in the field. During water-supply investigations

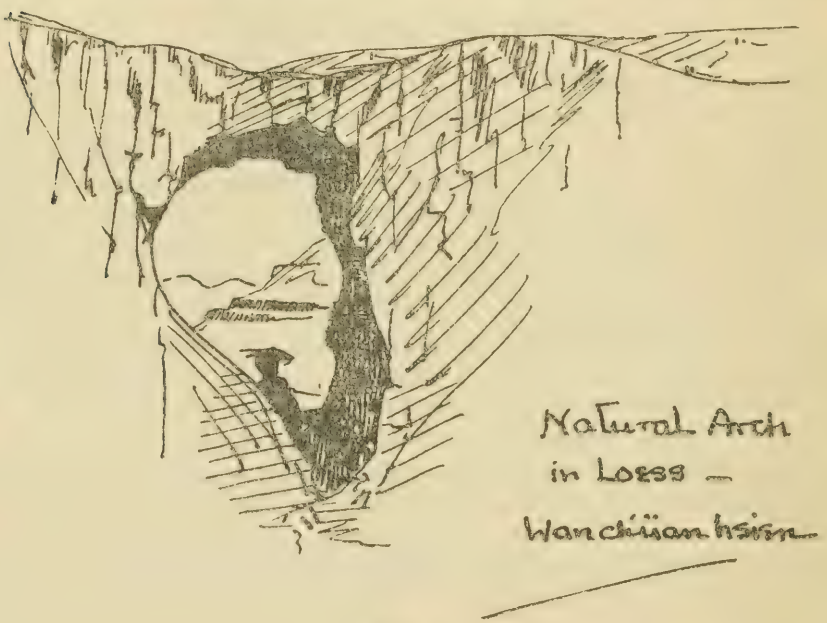

FIG. 3

along the foothill area west of the Peking-Hankow Railway in the Tingchow-Shuntehfu region I noticed that though the loess was porous enough to take up immense quantities of water[a] the fineness of its grain held the moisture by capillarity and prevented a rapid percolation of the ground water out from the walls into partially dug wells. (See Willis 12-250ff.)

The fertility of the loess is due, then, in part to its physical condition (which, combined with a clay content comparatively low for such a fine texture, creates a porous soil both light to till and easily penetrated by water) and in part to its relatively fresh chemical con-

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[a] Slichter notes that the pore space in fine alluvial clays may amount to 40 or even 60 per cent of the total volume. (U. S. G. S. 19th Annual Report, Part II, 1899, quoted by Willis, 12-250).

dition, especially as regards the presence of lime and other soluble mineral material available for plant nourishment.

Both of these characteristics could naturally be explained as resulting directly from an aeolian mode of accumulation, since the mineral decomposition occurring during transport by wind is almost negligible in comparison with that due to prolonged water action. But before discussing the origin and age of the Chinese loess it is advisable to refer again to deposits of loess in other parts of the world and to those other formations in China whose similarity has led to their being mistaken for it.

THE LOESS OF EUROPE AND AMERICA

In most respects the descriptions of Chinese loess could be applied equally to that of Europe and America. The same features call for special explanation—the fine texture and angularity of the particles and the vertical cleavage responsible for the perpendicular cliffs and canyon walls. But in these countries there is in many localities distinct horizontal bedding, suggesting water action. A rough stratification is found also in the loess-carrying deposits which overlie the general loess in China, but these formations belong to a period of time, distinct and definitely later than the loess, which is not the case with the European and American stratified loess.

In these countries it was recognized at an early date that loess had a complex origin different from that of the fine-grained silts made by river erosion. Of the other natural forces capable of producing quantities of "rock flour" of such fineness, explosive eruptions yielding vast amounts of volcanic dust may be ruled out at once; the distribution, age, chemical and physical analyses, and habit of loess are against such an origin. On the other hand glacial boulder clay invariably contains a large amount of powdered rock material that has been crushed into minute sharp-cornered fragments; in Switzerland to-day the water of many Alpine streams is made whitish by the presence of much rock powder so fine as to be wholly inpalpable. But this water-borne "rock flour" is normally deposited in layers on lake bottoms or swept down to the sea. An equally fine powdery dust fills the air in desert sandstorms.[7]

It is significant that the European and American loess belts lie along the line marking the glacier front of the Great Ice Age, or in adjoining areas into which it might have been carried by streams or wind. The vertical cleavage and general absence of stratification in loess has led to the belief that in Europe and America wind played a major part in distributing the rock dust originally powdered by the grinding action of glaciers. However, it is equally certain that

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[7] Walther, *Denudation in der Wuste*, Leipzig (p. 566 and 581).

at times rain and stream action were important factors in spreading the loess over the country. The wind-blown deposits would naturally form during the arid periods that came after the more humid glacial times. Osborn therefore places the date of Western loess accumulation during the interglacial stages following the second and third great advances of the ice-sheet and still more after the final retreat of the ice.

LOESSLIKE FORMATIONS IN CHINA

A. OLDER THAN THE LOESS

1. Hipparion beds.—Previous to the careful work of Andersson and Zdansky, the upper and lower limits of the loess had not been recognized. Hence the distinction between it and the more reddish clay underlying it in many localities passed unnoticed by v. Richthofen and by many others since. In fact, the great explorer notes, as typical of the loess, the presence of large lime concretions which in point of fact are much more characteristic of the red clay. Sowerby (2–116) in the report of the Clark Expedition of 1908–9 recognizes the red clay as a distinct unit (*shao t'u*), but having no fossil evidence on which to separate it, classed it, as did Willis, with the loess. Perhaps this in part accounts for the extreme thickness he attributes to the loess.[8]

On the north margin of the loess basin the name is perhaps misleading, as here the "red clay" is not a true clay and is often only reddish brown in comparison with the yellow gray of loess. In the center of the area it is more true to its name. It has the appearance of a residual soil resulting from the decomposition of rocks *in situ*. Moreover, Andersson has noted that its distribution is practically limited to the old limestone lands. This has led him to suggest that though the bulk of the loess came as dust blown from the desert in the manner suggested by v. Richthofen, much of it may have been material formed locally and only re-sorted or slightly shifted by the wind.

Locally the red clay shows a poorly developed stratification marked by gravel beds, may reach a thickness of 200 feet, and in several localities, which are thought to have been oases, has yielded rich collections of animal remains. According to Drs. Wiman and Zdansky the animal types of this Hipparion fauna[9] indicate the existence of steppe conditions in China at the close of Miocene and the beginning of Pliocene times.

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[8] The loess covers the whole of the sedimentary rock to an average depth of 1,000 feet * * * south of the Ordos Desert the depth increases to 2,000 feet (2–128).

[9] Andersson (1–109) gives a provisional list of the animals found by Zdansky in one locality, which includes, among others, deer, antelope, boar, fox, hyena, saber-toothed tiger, elephant, mastodon, and turtle, together with *Hipparion richthofeni, Aceratherium, Stegodon*, and the ostrichlike bird referred to already.

As Andersson points out, however (1–107), there exists in many places no sharp line of demarcation between the loess and the red clay. Instead, locally a gradual transition occurs through layers showing characteristics intermediate between them. It is, however, a distinct and older formation.

In other places Zdansky describes the loess as making sharp contact with the Hipparion beds below. In the district East of Wan Ch'uan, near the Mongolian border, I have observed shallow deposits of typical yellow loess occupying gullies cut in an underlying reddish clay-loam formation, that has all the appearance of such a resorted residual deposit. In this are large carbonate "loess-püppchen" often over a foot in length.

Père Teilhard de Chardin has mentioned in conversation that a similar concretion-bearing red clay underlies the loess in many parts of the Eastern Gobi Desert recently visited by Père Licent and himself. At the same time he pointed out that, as far as his observations went, gravel beds were frequently found at the base of the loess, and he expressed the opinion that in certain restricted areas fluviatile conditions may have existed after the greater part of the land surface was already ruled by aridity. In any case it is not surprising that on a continental area sharp contrasts of conditions should exist locally even during arid times.

2. *Kansu continental deposits.*—Recent observations made independently by Dr. J. G. Andersson and by Dr. George B. Cressey of Shanghai College, point to the existence in many parts of Kansu of heavy beds of red sands and gravels overlying the Hipparion clay, and, therefore, presumably of Pliocene age. They look like the deposits of a great delta or alluvial system, and from their description may well represent the products of the period of greater moisture that came between the time of the red clay and the days of the loess.

3. *San-Men beds.*—In a number of localities sand and gravel beds may be seen at the base of the loess. The moisture conditions suggested by these seem to have been widespread over North China. Dr. V. K. Ting first described a series of such beds from the San-Men rapids of the Yellow River (1–118). These underlie the loess and carry large fresh-water bivalves (*Quadrula*), which Doctor Dall of the Smithsonian Institution of Washington regards as probably early Pleistocene in age.

When the caissons for the new bridge opposite the Governor's yamen in Tientsin were being lowered, shells of similar large fresh-water mollusks were found at a depth of 81 feet below ground level. Through the courtesy of Mr. P. L. Yang of the Chihli River Conservancy Board, I was given facilities for examining on the spot the material brought up from the various levels while the caisson was going down. Besides the *Quadrula*, there were a great number of very small gastropods, some less than $\frac{1}{16}$ of an inch in diameter. A careful log was kept by the engineer in charge of the work, Mr. Malin, which will be published when the fossil material has been studied by Dr. A. W. Grabau, chief paleontologist to the Geological Survey.

4. Sang-kan Ho Beds.—In 1923 a farmer brought me part of a silicified rhinoceros femur and several other petrified bone fragments, all of which were said to have come from the same locality near Ho Chih Liao in the Sang-kan Ho Valley. Later similar silicified mammal bones were shown me at Kalgan by Père Vincent of the Mission Apostolique. The reverend Father has made a series of scientific contributions in several branches of natural history, and in conversation was able to confirm from personal observation the theory current locally among the villagers that the present course of the Sang-kan Ho west of Ni-ho-wan cuts through a lake deposit of olden days; this perhaps influenced the theory of the American geologist Pumpelly (9) regarding the past changes in the course of the Yellow River. I made a brief reconnaisance of the area during the summer of 1924.[10]

Forty miles southwest of Hsuan-hua in the valley of the Sang-kan River there is a magnificant development of terraces cut in two super-imposed series of nonmarine beds. The lower series are green and brown in color and carry large bivalves, one type like the *Quadrula* of San-Men, the other much more fragile and without the florid bosses which ornament the coarser type. The beds also have gypsum and plant remains and abundant small gastropods like those at Tientsin. The upper beds are of a uniform brown color, and lie on an erosion surface of the lower series. Locally they seem to pass up into a dark brown loesslike deposit without marked stratification. Silicified mammal bones and bits of *Struthiolithus* were found in this upper series. The problems raised by these beds are so vital as to call for careful study.

During the spring of 1925, Père Licent and I were able to visit the area and found many deposits of silicified mammal bones. Père Licent has since returned to the locality and secured a large collection of fossil material. A preliminary study by Père Teilhard de Chardin appears to confirm the fact that the fauna, which indicates a steppe association, is of basal Pleistocene age.

More recently I have found fresh-water beds with abundant mollusks along the railway east of Huai-lai. The species are just enough unlike those found in the Ni-ho-wan beds to suggest a dif-

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[10] See Geol. Soc. China Bull., vol. 3, No. 2, Peking, 1924, p. 167.

ferent, perhaps slightly older horizon. Several fragmentary mammal bones were recovered.

Fresh-water beds with fossils of the San-Men type have been found by members of the Geological Survey near Pao-ting Fu; Doctor Andersson has mentioned finding them south of Ta-tung Fu, and they will certainly be reported from many other spots. They imply fairly widespread conditions of greater moisture before the onset of the aridity.

B. YOUNGER THAN THE LOESS

1. Redeposited loess.—In many places, especially on the lower slopes of the hills, the loess is overlaid by series of sand and gravel beds with layers of loess. For the most part this formation is poor in fossils, but bones of bighorn sheep, oxen, and deer are occasionally found in the gravels. I have found remains of both the latter two animals in gully banks in and near the Hanoorpa Pass from Kalgan to Mongolia. The definitely stratified nature of this formation shows that torrent action was the chief determining factor in its deposition, though wind may have played a minor part in the case of the layers of loess. The individual lenses of loess are never more than a few feet in thickness but the aggregate thickness of the sediments may reach at least 50 feet. The material occurs typically as a valley or torrential deposit, and, where seen in contact with the true loess, is invariably found to overlie it, or to occupy gullies cut through it. Doctor Andersson has applied the name "Redeposited loess" to this formation. The animal remains and the character of the material making the beds point to a date distinctly more recent than that of true loess, and indicate also a great change of climate from that ruling during the earlier steppe epoch.

2. Alluvium.—Still more recently the rivers of the present cycle of erosion have deposited gravel and alluvium on the broad flood plains or in narrow valleys.

AGE OF THE LOESS

The age of the loess may be determined in two ways. Firstly, by comparison of those few types of animals whose remains have been found embedded in it with fauna of other regions that have been studied, taken in conjunction with our knowledge of the climatic conditions ruling in eastern Asia and other parts of the globe at different stages during the last half million years. Secondly, by bracketing its age between the dates of older and younger beds which are found respectively to underlie and overlie the genuine loess.

With regard to the latter line of reasoning, the loess must be more recent than the Hipparion beds which mark the close of Miocene and opening Pliocene times. Dall's determination of the San-Men fossils would narrow the lower limit to later than early Pleistocene. It is possible that the upper series of Sang-kan Ho beds will still further reduce the bracket,[11] especially if they can be correlated with the beds observed at the base of the loess by Fathers Licent and Teilhard de Chardin in the Ordos region, who discovered at this horizon paleolithic stone implements strongly recalling the Moustierian stage of human culture.[12] The upper limit is set by the fossils found in the gravel of the redeposited loess. Of these it can only be said that they are comparatively recent, but are in some cases distinct types from the species living to-day.

Judging from the data offered by the loess itself, it must be admitted that no more exact date can be given. Andersson concludes that the fauna is "decidedly Pleistocene in type, and assuming that Dall is right in dating the mussels of the subloess San-Men beds as early Pleistocene, it will follow that the loess is of Middle Pleistocene age. It would then be the arid equivalent of the Pleistocene ice age" (*loc. cit.*).

From what has been said it will be clear that the loess is certainly as young as the date given by Andersson, and that it probably corresponds in time to the later stages of the Pleistocene ice age, but formed under more arid conditions.

ORIGIN AND MODE OF ACCUMULATION OF LOESS

The present position of many loess deposits, perched high up on the slopes of mountains, the uniformly fine grain, the absence of evidence of water action and the known semiarid conditions of the time, all point strongly to wind as the great agent responsible for the accumulation of the Asiatic loess. This was recognized by v. Richthofen in 1877. The fact that the geological study of erosion has for the most part been carried out in lands of moist climate has tended to give too little weight to the work of the wind in drier regions, whether cold or hot. The very fact that wide areas of such rock deserts as the Gobi have to-day no covering of sand implies that the eroded material of past ages has already been carried off as dust clear out beyond the margins of the desert, to sink and collect wherever moister conditions, the shelter of mountain ridges, or the pro-

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[11] The studies in the Huai-lai Basin already mentioned together with later investigations in the Sang-kan Ho area confirm this hypothesis. Moreover as an epoch of erosion intervened before the beginning of the loess epoch, the date of the latter was probably Middle Pleistocene. (Footnote added October, 1925.)

[12] "If found in Europe, such implements would be taken to indicate that the overlying deposits were as young or younger than the interglacial period between the third and last (Wurmian) great advance of the ice sheet; following Osborn's estimate that would fall well within the last 75,000 years. At present, however, no such exact correlation with China is possible."

tection of vegetation can hold it. How far to such desert-borne material must be added the decay products of rock decomposition in the locality can only be a matter of conjecture.

Schlosser, referring to Doctor Andersson's observations on this very point, quotes the latter's remark that "he had not seen real loess, at least in larger masses, on the Mongolian Plateau." Schlosser agrees that the absence of loess may be due to its removal by northerly winds as fast as it was produced by rock decay. Once across the Chinese border, however, the mountains protect it from the extreme effects of the violent winds. Schlosser[13] believes that the chief material which yields the loess by decomposition is the Hipparion clay, which may thus grade up into the loess locally, as happens with the Miocene "Flinz" near Munich, where the transition is so gradual as to defy demarcation of the two formations.

The scouring out of immense quantities of fine dust from deserts has probably been a much more common occurrence than we are apt to think. It has doubtless affected vast stretches of Central Asia and Africa and other areas which in former days had more arid climates. Much of the adobe soil of southwestern North America has the same origin. Keyes[14] thinks this factor has been seriously underestimated in the case of the deserts of the western United States and the deposits of the middle western plains.

Such vast quantities of the finest products of rock decay clearly call for conditions very unlike those of to-day. During the whole of Pliocene and Early Pleistocene times, Mongolia and southern Siberia stood at a much lower altitude than at present. Relatively moist conditions favored extensive decay due to the attack of meteoric waters, and this proceeded to considerable depths, as the relief of the land was low and the rivers did not carry off the disintegrated material. Pumpelly has discussed the relation of this secular disintegration to the development of loess and allied deposits (8). Widespread uplift of the central plateau in Pleistocene times was accompanied by increased aridity and high winds, which found a ready supply of material awaiting ablation.

When the dry steppe conditions gave place to moister times, dust was lifted more seldom and carried for shorter distances. Its surface was periodically planed off by the wash of heavy rains, which also helped to distribute it further. During this later time of the piling up of "redeposited loess," it is likely that the new supply from the desert was small, the bulk of the loess being shifted only a short distance and then "redeposited."

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[13] Max Schlosser, G. S. C. Palaeontologica Sinica, Ser. C., Vol. I, fasc. 1, "Tertiary vertebrates from Mongolia," p. 104 (seen in proof through the courtesy of the Director, Geological Survey).

[14] Pan-American Geologist, XLII, 3, 1924, p. 225.

VERTICAL CLEAVAGE OF LOESS

One of the puzzling problems is the explanation of the cleavage responsible for the vertical walls of the canyons and cliffs which form such a feature of loess districts. Many are dissatisfied with the theory of v. Richthofen that this is due to the lines of weakness produced by plant roots.

It is true that to-day in almost any loess gully plant roots or their remains, often encased in a tubelike sheath of carbonate or other cement, may be seen piercing to several feet below the surface. A photograph taken near Kuo Ts'un (Huan-hua) shows such a root exposed by a collapsing cliff to a vertical depth of 13 feet without reaching the tip.

Among the objections raised to the "rootlet theory" is the fact that it is curious that plants which could thrive prolifically under such a variety of climatic conditions fairly recently have no real living counterpart to-day. Such root tubes equally might be the result and not the cause of vertical weakness.

As an alternative Willis (12–253) suggests the following explanation. Owing to the lightness of the grains, the dust on first falling was very loosely packed. Under the weight of further deposits on top and alternate drying and soaking by surface water sinking into the ground, the material settled slowly and became compressed vertically, though no corresponding lateral force existed to lessen the distance between grains on the same horizontal plane. Moreover, the closer the grains the stronger the bond between them made by the weak cementing action of salt-charged percolating waters. Hence the direction of least resistance, which moving air and water would tend to follow, would be the up and down direction in which the material now splits to-day.

A much more convincing explanation was recently suggested to the writer by Dr. C. P. Berkey, geologist of the third Asiatic expedition, on his return from Mongolia. As far as can be ascertained, this particular point of view has not been emphasized by other students of the problem, and Doctor Berkey has been so kind as to permit it to be offered here for the first time.[15] He points out, however, that the explanation is based primarily upon observation of conditions at present ruling in parts of the Gobi and upon certain considerations regarding climatic variations in recent times established by researches in Mongolia, rather than upon any extended study of the loess formation itself, which is not extensively developed in the areas explored by the expedition.

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[15] Since this paper was first printed, the writer finds that a closely similar explanation was arrived at independently by Dr. Bailey Willis for the vertical cleavage in adobe deposits in Patagonia in the neighborhood of springs where the moisture was enough to allow vegetation to take hold. (See "Northern Patagonia," Scribners Sons, New York.)

The principles involved are three—(1) continued abundant growth of steppe vegetation, especially course grass and bent; (2) contemporaneous and steady supply of fine dust, which was carried into the region by the winds and settled down to the ground, where it was protected by the vegetation from further disturbance and became part of the permanent soil mantle; and (3) subsequent destruction of all traces of such preexisting vegetation under climatic and ground conditions that led to the almost complete oxidation of the organic matter. The principal factor in such destruction is apparently oft-repeated moistening followed by drying and access of fresh air, just as happens when rain waters percolate through the loose ground above the permanent water level in a region of moderate but frequent rains.

This explanation suggested by Doctor Berkey tallies with observed fact in climatically analogous regions to-day. The dust which partially buries the standing blades of growing grass, consolidates round them and tends to preserve the structure lines of the vegetation; it thus possesses from the outset the vertical lines of weakness that lead to the characteristic cleavage afterwards.

With regard to the question of the removal of the evidence by ground conditions especially destructive to organic remains, it might be pointed out that the fossils habitually found in the loess are those capable of resisting such attack from ground water in the vadose zone, while all more delicate and unstable structures are wiped out; the *Struthiolithus* shell is frequently found in the loess, whereas not a single example of the bones of the bird itself is known to science.

This explanation in the main reestablishes the picture of conditions given by von Richthofen and revives his vegetation theory so criticized by Kingsmill, Ward, and Willis, but with modifications, which, as far as can be ascertained, do not appear to have been put forward in exactly this form by any other student of the problem.

"HUANG T'U" AND "LOESS"

Willis in his researches gives the formation name "huang t'u" to the entire series which is now recognized as including the red clay, the true loess, and the gravels with "redeposited loess." This is also the broader sense in which the word "loess" is constantly used to-day.[16] It is true that such observers may fully recognize the inclusion under this term of deposits of both stratified and unstratified material, and Willis, for example, states that the age "ranges from late Pliocene or early Pleistocene to the present, it (the *huang-t'u*) having been continuously in process of deposition throughout the Quaternary and possibly since a prequaternary date." But it has

[16] E. G., Sowerby (2–116).

been shown that not only do the deposits span a longer interval of time than is here suggested but there were gaps and periods of sharply contrasted climatic changes included within its limits. There is often little to be gained by trying to restrict the use of a scientific term that has been accepted popularly in a wider sense. On the other hand, loess and its origin is of general interest and yet has aroused much discussion that would have been seen to be beside the point had the theorists realized they were talking of a thing that was not one, but many! Moreover, in this case even the broad range of variation covered by the word as used in Europe and America is exceeded if we use it to include deposits definitely distinct from true loess in composition, texture, habit, age, origin, and fossil content.

By recognizing these perfectly observable differences there is reason to hope that we may in the near future solve the remainder of the puzzles presented by the loess in China.

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1. THE COLLAPSE OF PART OF A VERTICAL LOESS WALL UNDERMINED BY RECENT RIVER EROSION

2. A VILLAGE IN THE LOESS, SHANSI. THE SCALE IS INDICATED BY THE ANIMALS IN THE FOREGROUND

Photograph by J. E. Baker

1. A FOSSIL EGG OF THE GIANT OSTRICH (STRUTHIOLITHUS) FROM THE LOESS

2. "REDEPOSITED" LOESS, SHOWING GRAVEL LAYERS

1. A CAVE DWELLING IN A LOESS CLIFF

Photograph by Miss Blanche Hedgson

2. A DISSECTED LOESS PLAIN NEAR KUO TS'UN, HSÜAN-HUA FU, NORTH CHIHLI

1. A DEEP CUT ROAD IN THE LOESS COUNTRY

Photograph by A. W. Hummel

2. A ROAD IN LOESS GULLY, P'U T'AO

A VISIT TO THE GEM DISTRICTS OF CEYLON AND BURMA[1]

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[With 6 plates]

CEYLON

The island of Ceylon, which is one of the most beautiful possessions of the British Empire, has been an abode of man from the very earliest times. The Veddhas, a wild tribe of some 4,500 people still living in the fastnesses of the jungle in the east central portion of the island, are believed to represent a remnant of the oldest inhabitants of which we have any actual knowledge, but in the caves in which they live there are found the stone axes and other implements of Paleolithic people who represent the first race of men who inhabited our globe, and of whom they may be, for all that is known, the direct descendants. About the fifth century before Christ there came the Aryan invaders, apparently from the north of India, who drove the Veddhas into the remote fastnesses of the jungle and developed the remarkable Singhalese civilization, whose high character is demonstrated by the remarkable and very extensive system of irrigation works which they built up and through which they made the island wonderfully productive. Great cities arose, some of which are believed to have had a population of over a million souls and whose temples and public buildings show that the people were accomplished architects and sculptors. About the third century before Christ there began a series of waves of invasion by the Tamil people of the south of India, who defeated and drove the Singhalese down into the southern half of the island, completely destroying the great irrigation system and throwing down the cities. They "let in the jungle," which, slowly advancing as the years went by, resumed its ancient domain and completely covered up the former glorious abodes of men. The "buried cities" of Anaradhapura, Pollonnaruva, and Siguri, whose remains can be seen in the midst of the jungle, constitute one of the most striking examples of an obliterated civilization. Occasional travelers from Greece and

[1] Reprinted by permission from Transactions of the Canadian Institute of Mining and Metallurgy, part of Vol. XXIX, 1926.

Rome penetrated to these far eastern lands and called the island Taprobane, the name employed by Milton for "India's furthest isle"—and later, in A. D. 1507, came the Portuguese and took possession of the country, only to be dispossessed in A. D. 1656 by the Dutch, who in their turn gave place to the British in A. D. 1796. The latter, however, were the only people who ever penetrated to the interior and took possession of the whole island, which they did in A. D. 1815.

Ceylon has an area of 25,332 square miles, and is thus about five-sixths the size of Ireland, and now has a population of 4,500,000, consisting chiefly of Singhalese, Tamils, "Moormen" (the descendants of ancient Arab traders, of whom Sinbad the Sailor was one), Burgers (the descendants of the Dutch people), and the English. The island supplies its own food and exports tea, rubber, and the products of the coconut. The people are prosperous and contented and have representative government under a governor appointed by the Crown.

The periphery of the island consists of a plain only a few feet above sea level, narrow in the south but much wider in the north, and which marks a comparatively recent and very moderate elevation of the island above sea level. From this coastal plain the central and southern portions of the island rise rapidly into higher land, culminating in mountain peaks, of which the most celebrated, though not quite the highest, is Adam's Peak (7,353 feet).

The higher portion of the island is composed exclusively of very ancient Archean rocks, closely resembling those of certain parts of the Laurentian area of North America and probably of the same age.

There is no evidence that this area of ancient rock has ever been under water. It is believed to owe its present form to the long-continued processes of subaerial decay acting through the almost endless ages of geological time. This decay is still continuing everywhere. The rocks over large parts of this interior portion of the island are thus mantled with reddish residual clay, which forms the fertile soil of the rubber and tea plantations, clothing the steep slope of these ancient hills, and which is washed down into the river valleys, forming alluvial flats and discoloring deeply the waters of all the streams and rivers which flow through them. This clay in some places is replaced by a relatively hard, red laterite or lateritelike material, which, while soft enough to be very readily worked, shows a marked resistance to the action of the weather and is very generally employed for building houses.

While this decay is often deep-seated, it is remarkable to observe the very rapid transition from the completely decomposed rock represented by the red clay to the perfectly fresh rock, the two frequently being separated by a transitional layer only a few tenths of an inch thick. Thus the clay when washed away by the tropical rains or cut through in road making lays bare surfaces of clean fresh gneiss, which under the microscope is seen to show no traces of alteration. It is thus possible to see good exposures of the underlying rock, at intervals at least, in almost all parts of this Archean area.

The heavy rainfall on the island runs off these high lands in a system of streams coming together into small rivers. These occupy deep V-shaped valleys whose course is usually determined by the strike of the gneissic rock, but in some cases follows the direction of joint planes or lines of faulting which cross the strike of the rock at right angles. The bottoms of these valleys are occupied by heavy alluvial deposits laid down by their respective streams, and it is in these alluvial deposits that the gems are found.

The gems have, of course, in all cases been derived primarily from the ancient Archean rocks which underlie the whole country, but they are seldom found in these rocks. John Davy, M. D.,[2] who visited the island in 1818, in a letter to his brother, Sir Humphrey Davy, written in that year, says, "I have ascertained that the native rock of the sapphire, ruby, cats-eye, and the different varieties of zircon is gneiss. These minerals and cinnamon stone occur embedded in this rock." A. R. Coomaraswamy, however, who for a number of years was Government mineralogist of Ceylon and is one of the most trustworthy writers on the mineralogy and geology of the island, in a paper written some years ago says that most of the interesting gems of Ceylon have not as yet been found in their original matrix.

J. S. Coates, Esq., B. A., the present Government mineralogist, in whose company the writer had the pleasure of visiting the gem workings in the Ratnapura district, informed him that he believes the various forms of corundum (sapphire, etc.) originate in quartz-free pegmatites cutting the gneissic series. If such proves to be the case, the occurrence is essentially identical with that of the corundum in the Bancroft district of Ontario.[3] The beryls (aquamarines) the writer has himself seen in quartz pegmatites, and Mr. Coates states that the zircons have their origin in the same rock. In Burma the rubies undoubtedly originated in the limestone bands of the gneissic series. Davy's statement may have been based on some information given to him by the natives, or by the term "gneiss" he may and probably did mean the gneissic series as a whole.

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[2] Journal of Science and the Arts, Vol. V, 1818, p. 233.

[3] Adams and Barlow, Geology of the Haliburton and Bancroft Areas, Province of Ontario, Memoir 6, Geological Survey of Canada, 1910, p. 327.

The gems then have their origin in the ancient Archean rocks, but in just which members of the series they took their birth is not as yet known with certainty, except in the case of a few species.

While gems are found in many parts of the area, it is the streams flowing through the Balangoda, Rackwana, and Ratnapura districts that afford the chief supplies of precious stones. These three districts lie near one another in a relatively small area in the central part of southern Ceylon, halfway between the city of Kandy and the southern shore of the island.

The Ratnapura district is of especial interest, and much attention has been directed to it in recent years. Ratnapura signifies in Singhalese "City of Gems," and the little town which gives its name to the district is situated in the midst of the most exquisite scenery in Ceylon. It lies in a wide depression surrounded by hills 800 to 3,000 feet in height, the whole clothed with wonderfully beautiful, intensely green tropical vegetation. The finest views of Adam's Peak are obtained from here, and the outlines of the hills and mountains, resulting from age-long secular decay acting on the folded and jointed system of ancient gneisses, gives the hills and mountains sharper outlines than those presented by the rocks of corresponding age in our glaciated regions of the northern world. The slopes when not washed bare, as they are in places, are mantled with red residual soil or "cabok." Apart from its tropical features, the landscape must present a picture similar to that which was displayed by the Laurentian Plateau of Canada in pre-glacial times. Everywhere along the bottomlands which border the streams and little rivers flowing through the Ratnapura Valley are paddy fields, the fertile mud yielding under native cultivation rich crops of rice.

Much attention has recently been directed to the gem fields at Palmadulla, about 12 miles in a southwesterly direction from the town of Ratnapura, on account of a remarkable "find" made there a couple of years ago, sapphires and other gems to a value of some 9 lakhs of rupees ($297,000) having been taken from an area of between 3 and 4 acres in extent in a certain paddy field. These included some very large fragments of excellent blue sapphire 1 and 2 pounds in weight, as well as fine yellow sapphires and other less valuable stones. (Pl. 2.)

The Palmadulla workings are situated in a large stretch of paddy field in the bottom of the valley here, which has been cultivated for rice over a period of perhaps 1,000 years. The paddy field is underlain by clay, which is from 10 to 20 feet thick. Immediately beneath this there is a bed or layer of gravel called by the Singhalese "illam," which is usually thin and which in its turn rests on the decomposing surface of the country rock. The gems, if present, as is the case in all the Ceylonese gem deposits, are found in the illam, which thus occupies a position identical with that of the gold gravels in many alluvial gold regions.

The searching for gems is a highly speculative operation and is usually carried out by a group of native workmen on shares. The owner of the paddy field gets one-fifth of any profits, the man who finances the operation another fifth, the remainder going to the men who carry out the actual work. After selecting a likely spot to sink a pit, the ground is tested from time to time as the work proceeds by driving down into it a long steel bar sharpened and tempered at the point. By pushing this down and twisting it around an experienced operator can tell on examining the bar after withdrawal at what depth below the surface the illam occurs, its thickness, and probable character. When the point of the rod passes through the illam and strikes the underlying decomposed bedrock, which looks like French chalk, the clay will be found adhering to its point, and if the surface of the rod is scratched this would indicate the presence of quartz or corundum pebbles or fragments in the gravel.

To get the illam out it is necessary to sink a small shaft or pit. In order to prevent the mud from flowing down into the pit, the latter is lined by a series of vertical poles driven down into the mud, behind which are laid branches of trees, sticks, or palm leaves. A man, sometimes with an assistant, works at the bottom of the pit shoveling the clay into a small bamboo basket, which, when filled, he throws deftly upwards and is caught by a man at the surface, who empties out its contents, then throws the basket down into the shaft again. When the pit gets deeper a third man sits on a transverse pole placed across the shaft from side to side and catches the basket thrown up by the man at the bottom of the shaft and in his turn throws it up over his head to the man at the surface. In this way all the clay is taken out and the shaft is sunk to the illam. This in its turn is then brought to the surface and is placed by itself on a clean, flat piece of ground prepared to receive it. The men engaged in these operations wear no clothes except a loin cloth and carry on an animated and evidently humorous conversation with one another, giving the whole operation the appearance of a pleasing pastime. If the weather is hot a rude shed, roughly thatched, is built over the opening of the shaft to give shade to the workers.

As the paddy field is usually wet, it becomes necessary to keep the pit free from water, which is done by bailing it out by means of an old kerosene oil can attached by a rope to a long pole balanced between two upright members, the whole resembling the device used for raising water from wells in many parts of French Canada. (Pl. 1.) It may be mentioned in passing that the kerosene can is employed throughout the Far East for a most amazing variety of purposes and affords a humble but convincing evidence of the widespread peaceful penetration of the most remote eastern lands by western influences.

When all the illam in the pit has been brought to the surface the miners proceed to wash it. This is carried out, if possible, in one of the streams running through the area. The writer was fortunate enough when at Palmadulla to find a party engaged in washing illam and to join them in this, the most exciting part of the game. A few stakes had been driven down into the bed of a small rapidly flowing stream and some branches of trees laid across them so as to partially dam back the water at the place where they desired to wash, thus giving a greater depth of water Four or five Singhalese men, naked except for their waist cloth, were lined up across the stream in the water, which was some 3 feet deep; each was provided with a shallow basket closely woven of strips of split bamboo. The baskets are circular and measure about 2½ feet across at the top, the sides sloping down in a parabolic outline to the bottom point, somewhat similar in shape to the pans used in Brazil for washing alluvial gold. Other men brought down to the workers in small baskets the illam, which is then washed in the same manner as alluvial gold. The washing, however, is not carried as far as in the case of gold, the object being to wash away all the mud and leave the gravel behind in the basket. When this is done the basket is brought to the shore. When half a dozen of these baskets, containing the washed gravel are ready, another man, expert in the recognition of gems, takes the baskets and examines them carefully in succession. The basket is tilted up so that the sun shines upon the gravel which it contains, the man squatting down in front of it places his hands together, raises them in the rapid invocation of the "powers" to give him good luck, and, with rapid circular motion, goes over the gravel with his right hand, sweeping the surface layer down toward him into the side of the basket next to him. This process is continued until all the gravel has been sorted over. Squatting down beside the operator the whole process was clearly seen. The large gems, if any, are met with first in the coarse gravel near the top of the mass. By keeping a sharp lookout, any gem present can be detected by its color and transparency. In the six baskets which we examined there were three fragments of sapphires of good size; one of them was of fairly good color and would yield, when cut, a stone of commercial value, the other two had little or no commercial value. As these were found they were at once handed to the man who acted as the banker of the little group working this claim, and who carefully watched the proceedings to be certain that no gem which was found was secreted. As the sweeping process continued the gravel became finer and finer in grain and at one stage showed a red color due to the presence of a large number of minute red garnets. When the whole contents had been worked over, the basket was passed to another man who reexamined its contents with greatest care in order to pick out any minute particles of gems which might still remain in the gravel and which might bring some small return. When all the illam was washed the gems found would be taken to Colombo and sold and the proceeds divided pro rata among the partners in the claim.

The location of the pits often seems to have been selected in a haphazard manner, although frequently the attempt is made to locate them in what is conjectured to be the course of the old stream which originally meandered through the valley.

Visitors coming to the district from abroad often think the gemming could be carried on much more efficiently and to great advantage by employing large modern dredging plants. The chief reason why this can not be done is that it is very difficult to secure titles to any extended piece of territory. The paddy fields are held in small areas by different owners, who, as a general rule, have many mortgages and liens on their lands—often of the most complicated character—so that it is practically impossible to secure a clear title, free from encumbrances, to an area sufficiently large to operate a dredge.

The following precious and semiprecious stones are found in Ceylon: Amethyst, aquamarine, chrysoberyl (and its varieties, alexandrite, and cat's-eye), garnet, moonstone, peridote, ruby, sapphire, spinel, topaz, tourmaline, and zircon. They are all found in the alluvial deposits just described, but the moonstone (a clear chatoyant variety of orthoclase feldspar) is more generally obtained from pegmatites and other quartz-feldspar rocks which are found in situ.

Ruby and sapphire have the same composition, being clear, transparent varieties of corundum, the former red and the latter blue in color. Some stones show a peculiar blending of the red and blue colors, the latter preponderating, and are known as "oriental amethyst." While the true sapphire is blue, yellow sapphires (called sometimes "oriental topaz") and white sapphires are frequently found as well. Diamonds, emeralds, opals, and turquoise are not found in Ceylon.

Much has yet to be learned concerning the details of the processes by which the gem stones have been transported and concentrated in the gravels in which they are now found. Of the gems washed from the same deposit some are found to have suffered but little rounding of the crystal edges through attrition, while others are so much rounded that no traces of the original crystal form remain. This is true even of exceedingly hard gems, such as sapphires, and would seem to indicate that while some of the stones have been moved but a short distance from the veins (?) in the bedrock whence they are derived, others must have been carried a very considerable distance under conditions of intense mechanical wear. The thick deposits of alluvial and residual clays which mantle the underlying rock in the lowlands, where the gems are found, have made it impossible as yet to read all the details of the history of the processes by which these precious stones have been assembled where we now find them.

While it is impossible to obtain accurate statistics with reference to the value of the annual output of gems in Ceylon—the work being carried on by little bands of men working here and there all over the gem-bearing districts and continually changing their scene of operations—J. S. Coates, Esq., B. A., the government mineralogist of Ceylon, informed the writer that it amounts to between 8 and 10 lakhs of rupees—that is to say, between $264,000 and $330,000 annually.

As is well known, the gem trade has in the last few years been much disturbed by the fact that it has been found possible to make artificial "synthetic" rubies and sapphires of the various colors displayed by the natural stones, as well as certain other gems hitherto to be obtained only from the rocks or gravels of the earth's surface. Furthermore, these artificial stones are not mere imitations of the true gems—they are actual crystals of ruby, sapphire, etc., identical in composition and all physical properties with the latter. They are true gems made in the laboratory of man, instead of in the laboratory of nature, and can be distinguished from the natural stone only by the most expert examination—if at all. This fact shows how dangerous it is to prophesy what science will or will not be able to do as time goes on. One of the best-known books on Ceylon, entitled "Ceylon, by an Officer of the Late Ceylon Rifles, 1876," contains the following passage: "We can take life, but we can not restore it; we can reduce a costly and brilliant gem to a worthless powder, but we can not turn the powder into a gem; nature has hitherto defied the cleverest savant and will continue to do so until the end of time." Artificial stones are built up or grown by heating, by means of a powerful blowpipe, a fine powder having the composition of the gem it is desired to produce, and the powder under these conditions of great heat grows into an actual crystal.

BURMA

Burma is now administered as a Province of India. It is bounded on the west by Bengal, Assam, and the feudatory State of Manipur, on the east by Siam, and on the north by Thibet and China.

The dominant physiographic feature of Burma is the Irrawaddy River, running from north to south through a valley with low banks. The river rises in the mountains of the far north, one tributary branch coming from Thibet. The head of navigation for river boats is at Bhamo, which is situated about 25 miles from the Chinese border, and the river is thence navigable to the sea, a distance of over 900 miles. It is a rapidly flowing stream, running most of the way in long meanders between low banks, but about Prome it commences to divide up into a number of branches, which find their way to the sea in a series of devious courses through the very fertile and highly cultivated delta of the Irrawaddy. A flotilla of no less than 550 shallow-draft steamboats, belonging to the Irrawaddy Flotilla Co., run regularly up and down the river, and pushing into every nook and corner of the delta constitute the main transportation system of the country.

Bordering the river on either side is a wide tract of flat land with ranges of hills running north and south. These physiographic elements constitute the land of Burma.

Burma is rather more than ten times the size of Ceylon, having an area of 262,000 square miles and a population (including that of the Shan States) of 13,212,000 persons.

As in the case of Ceylon, the Portuguese were the first Europeans to settle in Burma, which they did in A. D. 1519, to be followed less than 100 years later by the Dutch, and soon after this by the English. About the middle of the seventeenth century all European merchants were expelled from the country, owing to a dispute between the Burmese governor of Pegu and the Dutch. The Dutch never returned; the English were subsequently invited to return to Burma, which they did. The Government of Burma in the following years passed from one ruler to another and the English settlements were attacked from time to time, which led in succession to the first, second, and third Burmese wars and eventually to the annexation of the whole country to the British Dominions in A. D. 1886.

Burma now has representative government, and the country, being freed from the tyranny of oppression, exercised by its successive rulers in former times, enjoys a higher degree of freedom and prosperity than it has ever known in times past. The Burmese as a race are short in stature and thick-set. The men wear long hair on their heads, but have little or none on their faces, and show in their features a strong infusion of Chinese blood. They are well clad; both men and women wear skirts and both delight in bright colors and silk attire. There is probably no country in the world which presents in its streets and market places such a wonderful display of bright, harmonious color. In many respects Burma presents a striking and pleasing contrast to India. The merry, brightly clothed Burmese have no counterpart in Hindustan, and the richness of the soil and exuberance of the vegetation, together with the sleekness and vigor of the cattle, is at once marked by a visitor coming from India. The life of the Burmese is free from the deadening effects of castes and the seclusion of women, two customs which stereotype the existence of so large a part of the inhabitants of India. The country back from the Irrawaddy, in northern Burma, in the Shan States and westward toward the Arakan hills, is inhabited by various less-civilized peoples, each with its own peculiar dress and appearance, who come down to the river in picturesque groups to buy and sell when the market boats pass up and down on their regular sailing schedule.

The country is rich in minerals. The great silver-zinc-lead deposits at the Bawdwin mines have been worked from the most remote antiquity. Tin and tungsten are of widespread occurrence in southern Burma. Coal occurs in many parts of the country, and the oil fields are large and highly productive. The greater part of the jade carved in China really comes from the Myitkynia district of Burma, where there are also large amber deposits.

As will be seen in the accompanying sketch map (fig. 1) showing the main features of the geology of Burma, a long and generally narrow band of very ancient pre-Cambrian (Archean) rocks, having approximately a north-and-south direction, forms a protaxis running through the entire length of the country, passing across the border into China, and probably finding its farther continuation in one or the other of the narrow bands of Archean rocks shown in western Yunnan on the geological maps of southern China. This belt, coming up from Tenasserin, broadens out to the north of Mandalay and underlies the celebrated gem area of Mogok.

This district is reached by taking one of the Irrawaddy River boats at Mandalay (pl. 2) and ascending the river where picturesque groups of native people await the arrival of the boat at every landing place (pl. 3). At Thabeikkyin, a point about 70 miles above Mandalay, a good motor road runs back from the river in an easterly direction for a distance of 60 miles to the little town of Mogok, near the border of the northern Shan States. This road starting from Thabeikkyin, which is 600 feet above sea level, rises at first slowly and then passes through a group of mountain ranges over a pass 5,000 feet high (pl. 4) and descends to the Mogok Valley, which has an elevation of 4,000 feet. The higher portions of this road afford a view in all directions over a veritable sea of mountains clothed with a luxuriant forest in which are magnificent flowering trees and many birds, the scene being one of extraordinary beauty. Much of this forest has been set aside for Government forest reserves.

The isolated hill at Mandalay (954 feet), which rises abruptly from the plain on which the city is situated, is composed of a white crystalline limestone, rendered impure through the presence of grains of pyroxene, biotite, graphite, etc. It is identical in appear-

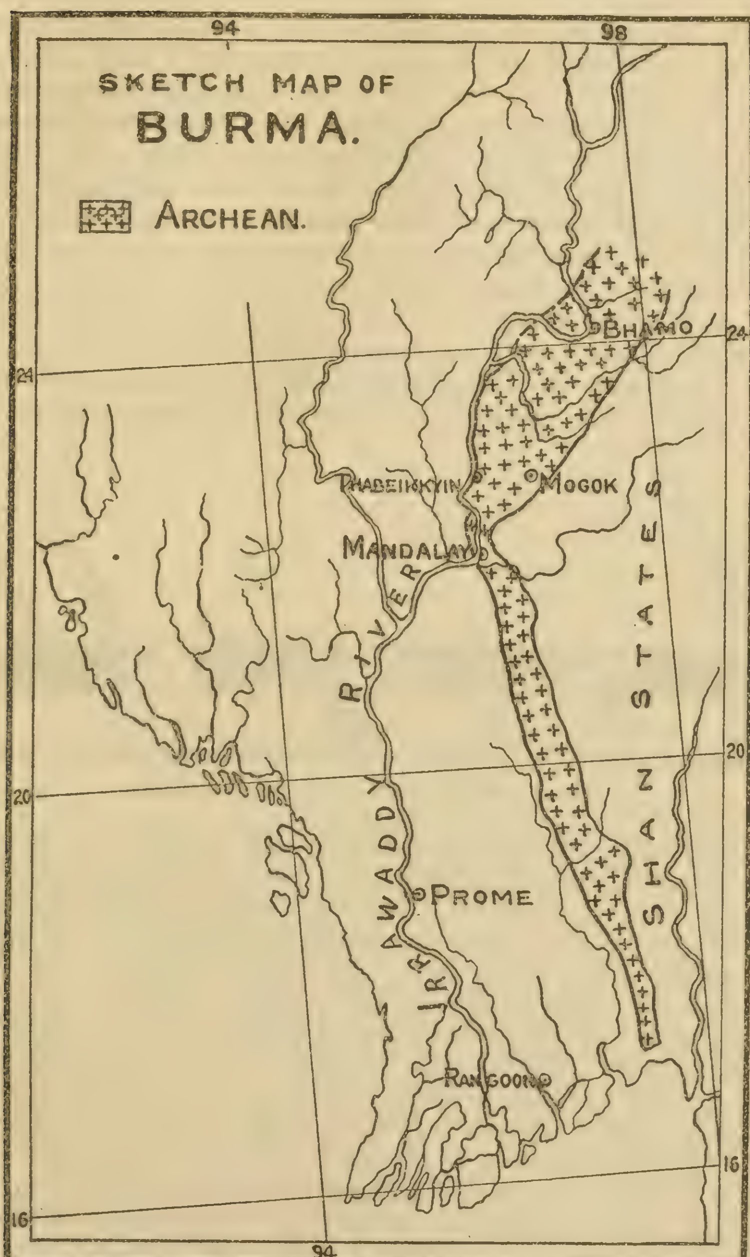
SKETCH MAP OF
BURMA.
ARCHEAN.
94
98
24
20
16
94
BHAMO
MOGOK
THABEIKKYIN
MANDALAY
PROME
RANGOON
IRRAWADDY RIVER
SHAN STATES

FIG. 1

ance with the crystalline limestones of the Laurentian of Canada (Grenville series).

At Thabeikkyin the steep bank of the river is composed of a soft friable rock containing thin beds holding water-worn pebbles of Tertiary age. This is confined to the immediate vicinity of the river. On the road running to Mogok it is immediately succeeded by exposures of the pre-Cambrian rocks. This road between Thabeikkyin and Mogok, running directly at right angles to the strike of these ancient rocks for a distance which, in a straight line, is about 40 miles, although by the road it is about 60 miles, affords an excellent section across the series, which present a most remarkable and striking resemblance to a section through the Grenville series in Canada. The section (fig. 2) consists of alternating bands of gneiss and white highly-crystalline limestone with some subordinate bands of quartzite. The gneisses are in part reddish (sometimes grayish),

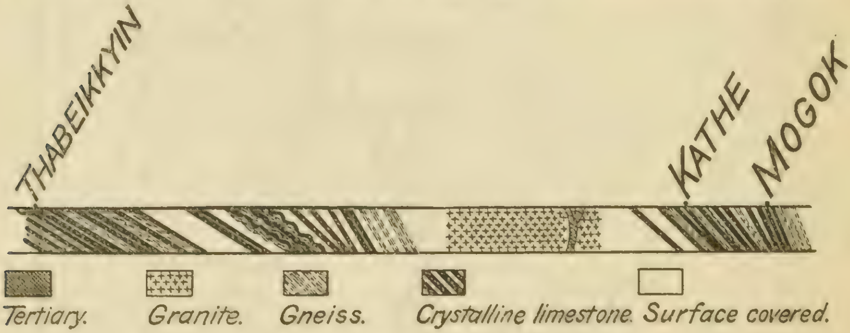

FIG. 2.—Section from Irrawaddy River to Mogok

garnetiferous orthoclase biotite gneisses, with many stringers, streaks, and lenses of reddish pegmatite running parallel to the foliation, closely resembling those so abundant in the Laurentian Plateau of Canada. They are excellently displayed at the eastern end of the section in the bed of the Yaynee River near the power house, about 2 miles south of the village of Mogok, where their appearance suggests a series of highly altered and granitized sedimentary rocks. They are also well seen in many other parts of the section. In addition to these there are light colored pyroxene (augite) scapolite gneisses, which occur intimately interbedded with the crystalline limestones at Mogok, Kathe, and at many other parts of the section. The quartzite, which is white and vitreous in character, is seen at milepost 22 on the road between Thabeikkyin and Mogok. It contains a little biotite and a few grains of orthoclase scattered through it and bears a striking resemblance to certain quartzites in the Grenville areas of Canada. There are large exposures of graphitic quartzite about 18 miles from the former station.

The limestones, which occur in very thick bands over wide areas are white and highly crystalline. Some bands are nearly pure, others contain little grains of biotite-pyroxene, graphite, and other accessory minerals marking the lines of bedding, and they are again identical in appearance with those of the Grenville series in Canada. These limestones are in some cases more or less magnesian. The metamorphism to which the whole district has been subjected was very intense and the limestones are in many places very coarsely crystalline. As mentioned, the rubies for which this district is renowned have these limestones as their original matrix and are more abundant in the coarser grained than in the finer grained varieties.

At one place between Mogok and Sinkwa (on the road to Thabeikkyin) there occurs by the roadside, closely associated with the limestone, a most interesting occurrence of a nepheline rock of the variety known as urtite. It is a rather coarse-grained rock, dark in color, and showing an indistinct banding, and is composed essentially of greenish-yellow elaeolite and a black aegerine-augite. It also contains a considerable amount of primary calcite and resembles very closely certain varieties of nepheline rocks found associated with the Laurentian limestones of the Bancroft district of Ontario. Under the microscope the rock is seen to contain as accessory constituents a grayish-brown sphene in rather large grains inclosed in both the augite and the nepheline, as well as a little microcline, apatite, and black iron ore.

The extent and detailed geological relations of this unusual rock could not be determined, but it is very interesting as affording another instance of the association of nepheline rock with bodies of limestone, so strikingly seen in the case of the nepheline rocks of eastern Ontario, and in a large proportion of the occurrences of similar rocks in other parts of the world.

The only true granite met with in the district is a great intrusive mass which is crossed by the Thabeikkyin-Mogok road and which is exposed at intervals from about milepost 44 to milepost 30. It is a very even, fine-grained, typical gray granite, which at milepost 40.8 towers up above the road in beetling crags. Under the microscope it is seen to be composed of orthoclase with some biotite, and quite subordinate amounts of quartz and plagioclase with a few grains of rutile. Its contact with the sedimentary series, through which it cuts, is not seen on the road as low land conceals it on either side.

Just east of Sakangei, cutting this granite mass near its eastern margin, is an enormous pegmatite dyke which was opened up and worked extensively by the Burma Ruby Mines (Ltd.) some years ago. The dyke is at least 100 feet wide, although only one wall is

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seen, this being the granite, here much decomposed. The dyke at the adjacent wall rock is very much kaolinized. The dyke consists of orthoclase almost entirely converted into kaolin with very large and fine crystals of quartz, many of which are as clear and transparent as glass. Individuals up to 6 inches in diameter were seen, but it is stated that even larger ones were found. Crystals of lepidolite measuring 6 inches or more across the cleavage faces, as well as muscovite and biotite and large, clear individuals of colorless topaz of perfect crystal form, were also found in the dyke. One of the latter had a diametral measurement of 3¼ inches. The dyke also contained small bunches of cassiterite here and there. The cassiterite, and the quartz crystals, sold to the Chinese traders for the manufacture of the various objects which the artists of that nation cut in quartz, were, it is understood, the chief products of economic value, and as these were not found in sufficient quantities to warrant the continuation of operations, work was abandoned and the openings are rapidly filling in under the action of the heavy tropical rains.

Leaving this granite intrusion and continuing on to the east, after an interval where the rocks are covered, the limestone series is again seen in frequent outcrops and the picturesque village of Kathe is reached, lying in a valley surrounded by high hills. Many of the lower hills are crowned by pagodas and the presence of many of the "twinlone" referred to below, which are seen in various parts of the plain, show that the underlying gem-bearing gravels have been tested at a great number of different places. It is at Kathe that the chief operations of the Burma Ruby Mines (Ltd.) are now being carried on. The road then rises and continuing on over the same limestone-gneiss series for a further distance of 9 miles descends into the Mogok Valley in which lies the little town of the same name. This is a most beautiful little valley, 10 miles long by 2 miles wide, and, like the Kathe Valley, is surrounded on all sides by hills, the highest reaching an elevation of 3,500 feet above the town, which has an elevation of 4,000 feet, clad with tropical vegetation, many picturesque pagodas being seen on prominent points and lending a distinctly Burmese appearance to the scene. A small stream winds through lower ground.

The beds of this series of limestones and gneisses, which are exposed almost continually along this section from Thabeikkyin to Mogok, strike north and south, although sometimes bearing a little to the east with a strike of as much as north 20° east. They dip uniformly to the east. The dip near the west end of the section is quite low, but 10 miles from the Irrawaddy the dip increases to 30°. About milepost 12 the strata are much contorted, but to the east of this, after a covered interval, the well-defined north and south strike is again seen with an easterly dip of about 60°. This dip again decreases to about 30° at Kathe and Mogok but in the lit-pas-lit gneiss in the valley of the Yaynee River, just south of Mogok, rises to 70°. In the section as shown in Figure 2 the dip is represented as gradually increasing from Kathe to the Yaynee.

The strike of this limestone series on the road between Thabeikkyin and Mogok is not correctly shown by Barrington Brown,[4] but, as he states, before the construction of the road in question it was impossible to make accurate observations on the course of the limestone bands in this part of the area, owing to the very heavy fresh covering.

A microscopic study of the rock specimens from Mogok, brought to England by Barrington Brown, was made by the late Prof. J. W. Judd. In their joint paper the whole tenor of Professor Judd's description leads the reader to the conclusion that Judd believed that he had evidence from the microscopic studies of these rocks that the Archean limestones of Burma had originated from the alteration of certain pyroxene gneisses. Since the publication of this paper it has been repeatedly stated in print that this was the conclusion reached by Judd from his studies of the Mogok limestones.

When preparing the present article the writer, in looking over some old papers, found a letter written to him by Professor Judd under date of November 4, 1896, evidently in reply to a communication of his to Professor Judd, expressing surprise that he had reached such a conclusion. In this letter Professor Judd writes: "I must disabuse your mind of the idea that I want to put forward a theory to cover all the metamorphic limestones of Archean age. I do not think such a chemical theory as I have suggested at all likely to meet the case of the enormous mass of limestone regularly bedded over vast areas like those mentioned by Barrington Brown in Burma, or referred to by you in Canada. It is the special thin bands that contain rubies, spinels, and other marketable minerals that I am referring to." This letter is perhaps worthy of mention as no one would discover from a perusal of Professor Judd's paper that he intended by his theory to account merely for certain small streaks of limestone in the Mogok series and not for the whole succession of bedded limestones which are so strikingly displayed in this region.

That enormous developments of bedded limestones, such as those found in the great series under discussion, really represent highly altered and very ancient sediments is borne out in all respects by a study of their field relations, a conclusion which is also reached by LaTouche[5] in his study of the geology of the northern Shan States.

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[4] Barrington Brown and Prof. John W. Judd: "The rubies of Burma and associated minerals." Phil. Trans., Royal Society, vol. 187, 1896.

[5] Records of the Geological Survey of India, Vol. XXXVI, pt. 3.

The little town of Mogok is situated on the valley floor, the population consisting of Burmese, Chinese, Shans, and some Indian Tamils. All look well and happy, requiring a very small income for their support and being apparently tolerably contented with what they have. Lines of sturdy, well-cared-for pack ponies with their quaintly clad drivers come over the hill trails from the Shan northern States and from China with loads of rice or other merchandise, and on market days the bazaars present a scene which, for color, movement, and picturesqueness of costume, can hardly be surpassed anywhere. These bazaars contain, even in this remote corner of the Far East, a large variety of western goods, as well as all manner of native products. The Burmese women, who carry on most of the retail trade of the country, usually wear skirts and jackets of very bright but well-matched colors, often of silk, with a large piece of some bright-colored fabric folded about the head, giving them a very graceful and picturesque appearance. Bath towels of western manufacture are now often used as a head covering in Burma or are worn thrown about the shoulders. Gems and native silverware are very generally offered for sale.

The rocks in the Mogok region are everywhere covered by a mantle of residual soil produced by the secular weathering. This seems to be heavier than in Ceylon. It is almost impossible to obtain specimens of the fresh rock except by blasting. Where good cuts have been made the rock is seen to have been bleached and kaolinized, while this kaolinized product is in its turn overlaid by a thick covering of red clay, which in some places approaches laterite in appearance, although it is less compact. This red clay, which also overlies the limestones, is remarkable for the manner in which it retains its form and even the tool marks upon it when cut into vertical walls or into steps running down steep declivities. Notwithstanding this fact, large quantities of the residual clay are washed down to the lower level by the heavy tropical rains, where it mingles with that formed by the weathering and solution of the rocks in the valleys, and in some places is subjected to further transportation by the action of streams running down the valleys, especially during the rains. Thus the residual soils pass into alluvial deposits.

There are three distinct ruby bearing areas in Upper Burma—those of Mandalay, Mytkynia, and the district about Mogok (including Kathe). The latter is by far the most important and constitutes the principal ruby producing tract in the world. Other areas will undoubtedly be discovered in the valleys of Upper Burma as time goes on; in fact, when the writer was going up the Irrawaddy, in the month of February, 1925, a party of gayly clad prospectors left the boat at Dundan, about 25 miles north of Thabeikkyin, a boom being then in progress at a point 5 miles inland, where sapphires had been discovered in the low-lying paddy fields.

Practically no Europeans visited this district until the annexation of Upper Burma by the British in 1885. In 1889 the Secretary of State for India granted to Messrs. Streeter & Co., of Bond Street, a mining concession in the Mogok district, a seven-year lease being given, at a rent of 4 lakhs of rupees ($126,666) per annum, plus 16.66 per cent of the net profits. The Burma Ruby Mines (Ltd.) was thereupon formed to carry on mining. In 1896 the original lease was renewed for a period of 14 years, and in 1910 it assumed its present form, and runs till May 1, 1932, there being a fixed rental of 200,000 rupees per annum, plus 30 per cent of any excess of license income above 200,000 rupees per annum, the Government also claiming 30 per cent of the net profits. The Government gave the native miners every protection, in so much as they were not allowed to be in any way disturbed in their work or dispossessed except by purchase; otherwise, the company holds a monopoly of the right to mine or wash gems over the whole area designated as the Mogok Stone Tract.

The rubies, which form by far the most important of the gems yielded by this district, have their origin in the white crystalline limestones of the country rock, which have been described above. In the Mogok district (including Kathe) these limestones are intensely metamorphosed and are often very coarsely crystalline. It is stated that the more coarsely crystalline limestones are those which are richest in rubies. These gems are evidently developed in the limestones as one of the results of the intense metamorphism to which the district has been subjected. A. D. Morgan, the general manager of the Burma Ruby Mines (Ltd.), informed the writer that the sapphire, which while much less common than the ruby at Mogok, is nevertheless frequently found, occurs not in the limestone but in a rock, a specimen of which containing a large sapphire was submitted for examination, and which proved to be a granular white acid plagioclase intimately intergrown with orthoclase constituting a microperthite. The rubies and the other associated gems, however, do not occur in the limestones or their associated rocks in sufficient abundance to enable these to be worked for these minerals. Occasionally a native prospector will find a spot in the limestones where there is an unusual accumulation of rubies and will extract them, but this is rarely the case. The rubies and other gems are obtained in practically all cases from the residual or alluvial clays of the hill slopes or more usually of the valleys.

In the valley workings, as at Mogok and Kathe, there is a definite succession in these clays, the recognition of which is very important. In sinking a pit or shaft this first passes through reddish or yellowish clay which contains no gems; beneath this is found, resting on the bedrock, a clay containing pebbles, and in this all the gems which the deposit contains are concentrated. This is known locally as "byon," and corresponds to the stoney clay which, in the gem region of Ceylon, occupies a similar position and is there known as "illam." When working such a deposit the overlying barren clays are first removed and the underlying byon is then carefully collected and taken directly to the mill.

Upon the removal of this byon, the surface of the underlying limestone is seen to present a curious appearance. It is a surface of solution and an immense number of "hoodoos"—10, 20, or 50 feet high and of sharp jagged outline—rise from the general surface, if indeed there can be said to be one, while deep, irregular crevices run down into the limestone, often to great depths. When the residual clay has been entirely removed from the valley floor, as is the case in the exhausted workings in the valley running through the town of Mogok, it is almost impossible to cross the valley except on specially constructed roads or paths owing to the extreme irregularity of the limestone surface, the spectacle presented when looking across the valley being weird in the extreme. The byon lying in the pockets and depressions in the very irregular limestone floor and filling up the crevices penetrating it, is often very rich in gems and, although contrary to law, the natives frequently, when unobserved, busy themselves in digging out the byon from such holes and corners and washing it for the gems that it may yield.

The native methods of mining are three in number, namely, by loodwins, hmyaudwins, and twinlone.

The loodwins are workings by which the byon in caves and fissures in the limestone is extracted and then washed.

The hmyaudwins are cuttings driven into the rain-wash on the hill slopes, the extracted byon being washed by sluicing, water being brought from some adjacent stream.

Twinlone—in this, which is the commonest method, pits are sunk into the alluvium of the valleys from 2 to 9 feet square, and by means of these the gem-bearing gravel is raised to the surface, often from a considerable depth. After a few feet have been excavated, strong posts, 12 feet in length, are driven in vertically around the sides of the pit and short timbers are fitted between adjacent posts, and a lagging of twigs and dry grass is provided to support the walls. As the sinking progresses, new posts are sunk. The excavated earth and any water which accumulates is raised to the surface by a bucket—or an old oil can—attached to one end of a bamboo balance pole swinging on a high bamboo frame as shown in Plate 1. As already mentioned, this device is also in use in Ceylon. A great number of these pits, each with its bamboo frame and swinging pole, are seen distributed far and wide over the plain of Kathe, showing the extended prospect-ing operations which have been carried out in this area, which is at present the largest producer in the Mogok concession.

The Burma Ruby Mines (Ltd.), however, desiring to work these deposits on a large scale, adopted western methods of excavating and transporting the materials to be handled, and built mills provided with modern concentrating machinery for the purpose of separating the gems.

The workings at the town of Mogok, as they appeared some years ago when mining here was at its maximum development, are shown in Plate 7, which is taken from a photograph reproduced in Escard's "Les Pierres Precieuses" (Paris, 1914). This stretch of alluvium has now been worked out. The company is now working at Enjouk, on the margin of the Mogok Valley, as well as on a small scale at Bigom, Nanyasen, and other points, but its chief operations are now centered at Kathe, 8 miles to the west of Mogok. Unfortunately the rubies here are very often coarse and rough and not of the best color.

At Kathe the geological conditions are the same as those at Enjouk and as in the old exhausted workings at the town of Mogok. The country rock is white crystalline limestone, often holding numerous flakes of graphite, phlogopite, and other minerals, with many interstratified bands of harder silicate rocks, chiefly plagioclase-scapolite gneiss resembling the limestones in color and a few other allied gneisses. One darker band was found to be composed essentially of a plagioclase and a brown hornblende, with a little pyroxene, biotite, scapolite, and iron ore as accessory constituents. Nothing that could be recognized as an igneous intrusion was seen in the workings.

These rocks under conditions of secular decay and solution present the remarkably irregular "hoodooed" surface already described, covered with a mantle of residual clay. This, with the underlying limestone series, is seen in Plate 5, which is one of the working faces at Kathe. The byon lies directly on the irregular limestone surface and is overlain by the barren clays.

The byon is brought to the mill in trucks, hauled from the working face by an endless wire cable, and thrown first on a grate of spaced iron bars, which separates the large pieces of rock. The material which falls between them goes to two successive sets of revolving trommels into which water is fed. The coarser material from these goes directly to a table and is hand sorted by one of the company's officers. Here, when the writer was visiting the mill, a ruby rather over 1 inch in diameter was found.

The finer material from the last set of trommels goes into diamond washing pans, the gravel which is retained by these representing 1 per cent of the original byon fed to the mill. This is then carried to a series of jigs which reject three-quarters and keep one-quarter of the product received from the diamond washing pans. This quarter of 1 per cent of the original material is then placed on sorting tables having a surface consisting of an iron plate and is sorted over by one of the company's officers (a European). He takes out any large gems which may be present. The gravel then passes on to a series of tables around each of which a number of men (natives) are seated, about six to a table, who re-sort it very carefully, removing every stone which has any value. Each man wears on his head a large box with a front of iron gauze which prevents him from secreting any stones in his mouth or from swallowing them. A foreman (native), who is supposed to be strictly honest, watches the operations at each table. These men are very expert at stealing stones and are carefully searched before they leave the building at the close of the day. The exhausted tailings are then taken from the mill and sold to a Burmese woman, who buys the whole output and who then divides it up into a series of little conical heaps and sells them at a rupee a piece to other women, who go over the pile grain by grain and collect from it every minute ruby which it may contain and sell these to be used in making watch bearings and for other purposes to which they may be of use. A group of women sorting over these little piles is seen in Plate 6. The gems which are obtained in the mill are sent to the headquarters of the company in the town of Mogok and are subjected to a final sorting and classification into the various grades which are then marketed. For this purpose small quantities at a time are taken by certain expert gem sorters, whose honesty is undoubted, and placed on shallow highly polished brass plates about a foot and a half in diameter and sorted over in the bright sunlight. These sorters are seen at work on the veranda of the company's office at Mogok, in Plate 6. The man at the margin of the photograph on the right is cutting a ruby on a wheel turned by a second man.

In addition to rubies, other gems are found in the byon, although less abundantly. On looking over the concentration product as it comes to the office from the mill there can be distinguished: 1. Rubies of various intensities of color. 2. Sapphires, blue, yellow, or white, showing similar variations in color. 3. Spinels usually pink in color, the intensity of the color differing in different individuals. These often show the characteristic octahedral form. These spinels are, next to the ruby, the most common gem in this district. 4. Common opaque corundum. 5. Tourmalines. 6. Zircons. 7. Quartz. 8. Other minerals, such as beryl, scapolite, apatite, and fibrolite (very rare).

While Mogok has produced the finest rubies which have ever been found, the value of the output seems small when compared with outputs of districts where metallic ores are mined. From 1899 to 1905 the mines yielded annually gems to the value of about $450,000. In later times the yield has fallen off and is naturally subject to fluctuation from year to year according to the value of the stones recovered. This is indicated by the following figures, which show the value of the rubies produced in Burma in some recent years:

1913	$228, 304
1914	198, 603
1915	165, 000
1917	212, 210
1919	425, 800
1921	224, 414
1922	224, 409

The great increase in the value of the output for 1919 was due in part to the finding in that year of an exceptionally valuable ruby, which was sold for three lakhs of rupees ($100,000).

In addition to these gems, most of the jade, which is cut and polished in China, comes from northern Burma, and not very far from the jade mines are deposits of beautiful amber. As this country is opened up in future years other valuable deposits will probably also be found.

A number of minerals of exceptional interest were obtained by the author in Burma, more especially from the district of the ruby mines about Mogok. Among these brief reference may be made to the following, a full description of which will be found elsewhere.[6]

Chrysoberyl.—This species has not hitherto been described from Burma, but was found near Mogok in the very unusual form of simple crystals, transparent and of a sea-green color, as well as in trillings of a pale yellow color. These show a number of forms which have never been observed in this species from other localities.

Sillimanite.—This species occurs, although rarely, as rolled pebbles accompanying the ruby in alluvial deposits. One specimen showed a cleavage apparently parallel to a macro-dome, which renders it possible to measure the relative length of the vertical axis, which has been unknown in the case of this species hitherto. These measurements show that there is a close correspondence between the axial relations of sillimanite and those of the related minerals, andalusite and cyanite.

Nepheline.—This species, hitherto unknown from Burma, was found in a coarsely crystalline urtite associated with the crystalline limestones near Sinkwa.

Sodalite.—This mineral, having a deep lilac color, was found associated with nepheline at a second locality, namely, the Tajoungnadine mine at Mogok.

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[6] Frank D. Adams and R. P. D. Graham, "On some minerals from the ruby mining district of Mogok, Upper Burma." Trans. Royal Society of Canada, Vol. XX, sec. 4, 1926.

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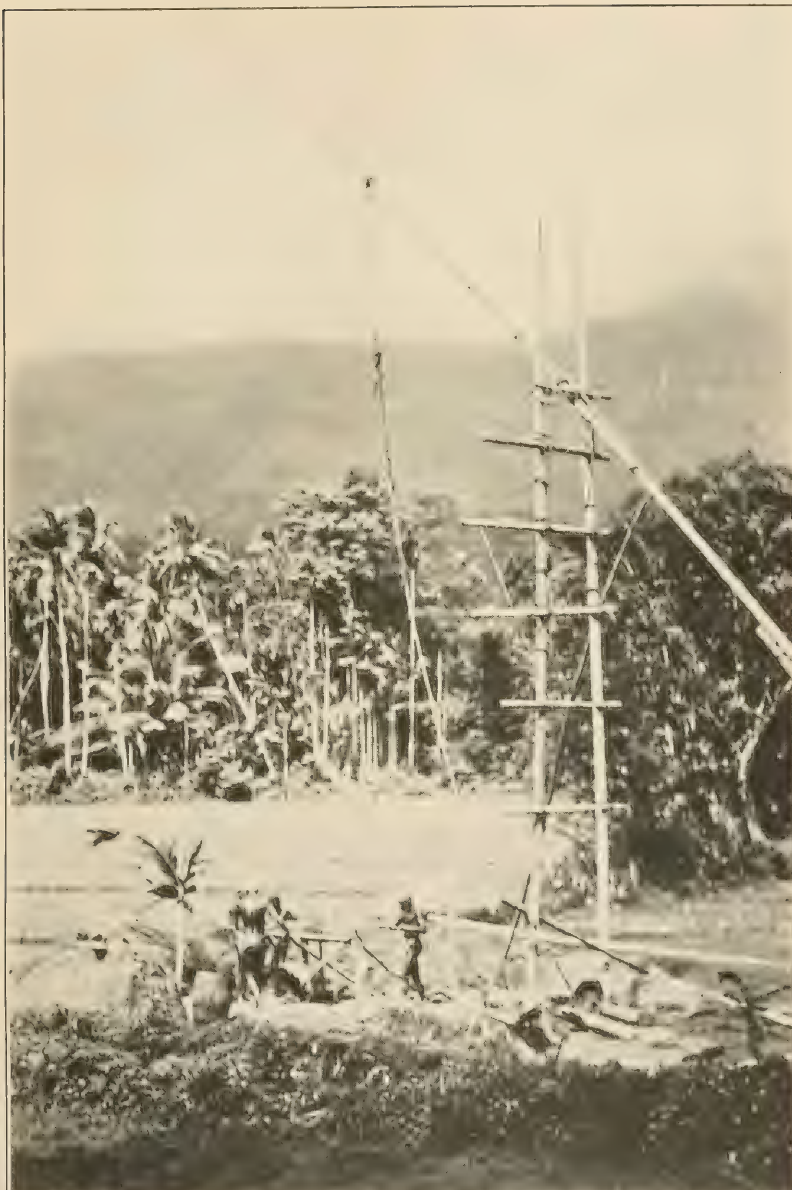
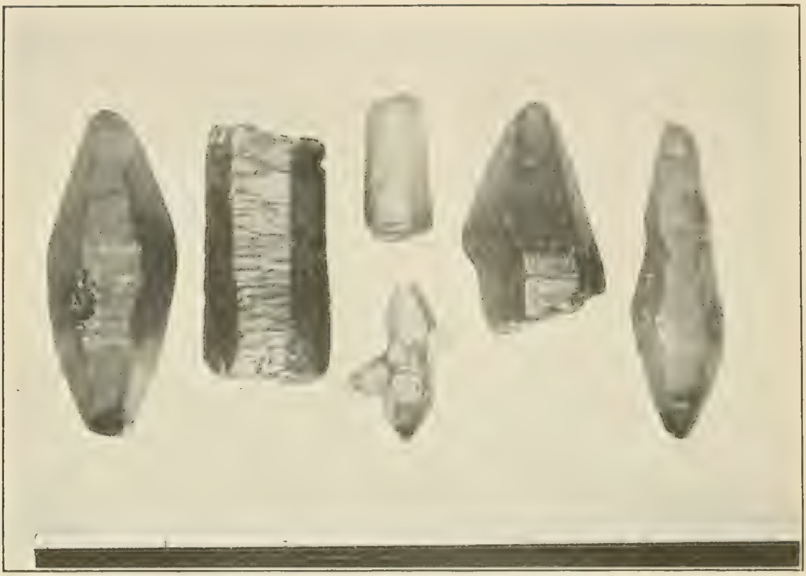
Fosterite.—Occurs as an abundant accessory mineral in certain of the crystalline limestones at Mogok. It has not been formerly reported from Burma.

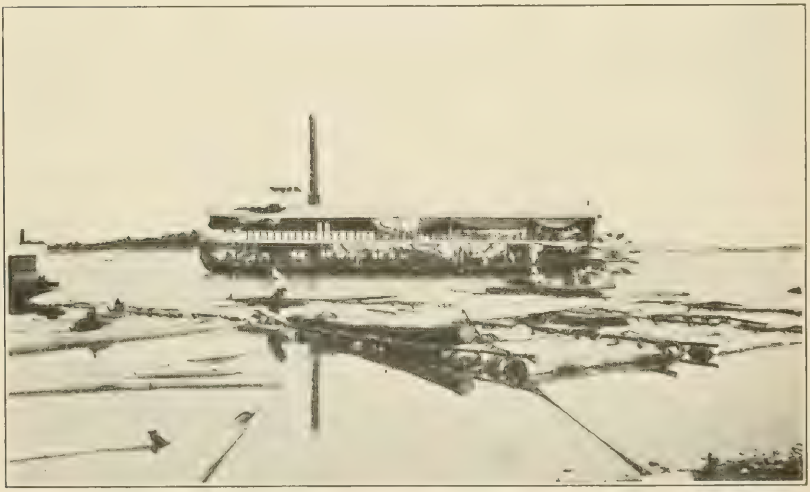
In the great pegmatite dyke at Sakangei, lepidolite in very large crystals, as well as muscovite, topaz, cassiterite, and very large crystals of quartz were seen. The topaz occurs in clear, transparent, nearly colorless crystals several inches in length. A large crystal examined is unique in that it is terminated at one end by the basal plane above and at the other end by pyramidal forms.



SINGHALESE SINKING A SHAFT FOR GEMS, PALMADULLA, CEYLON



1. YELLOW SAPPHIRES FROM WORKINGS AT PALMADULLA, CEYLON

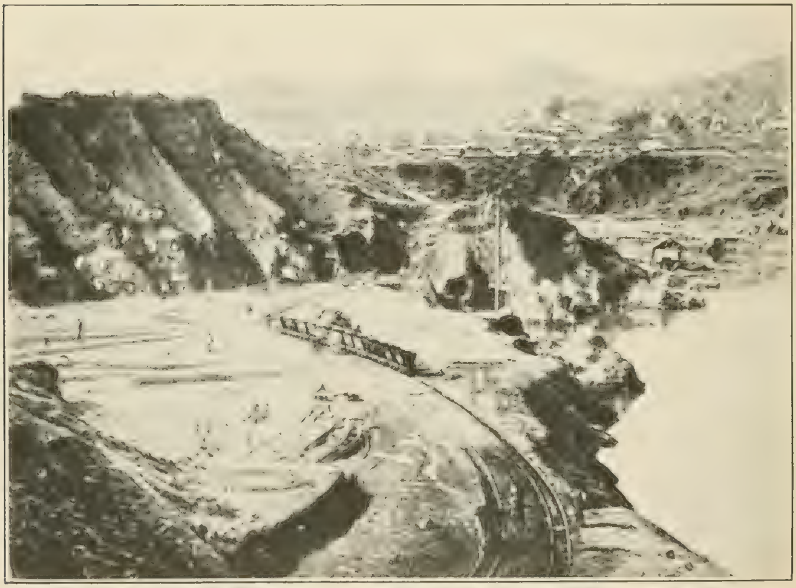


2. STEAMBOAT ON THE IRRAWADY RIVER. RAFT OF TEAK LOGS IN FOREGROUND

1. GROUP OF NATIVES ON THE BANK OF THE IRRAWADY RIVER AWAITING THE ARRIVAL OF THE STEAMBOAT

2. RAFT OF TEAK LOGS ON THE IRRAWADY RIVER

1. ROAD BETWEEN THABEIKKYIN AND MOGOK RUNNING THROUGH BURMESE FOREST RESERVE



2. RUBY MINES AT MOGOK IN PERIOD OF MAXIMUM DEVELOPMENT

WORKING FACE IN THE RUBY MINES AT KATHE, BURMA

1. WOMEN SORTING TAILINGS FROM THE MILL AT KATHE FOR MINUTE RUBIES

2. SORTING AND CUTTING GEMS AT THE OFFICE OF THE BURMA RUBY MINES (LTD.), MOGOK

THE HISTORY OF ORGANIC EVOLUTION[1]

By John M. Coulter

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The meaning of evolution is probably more misunderstood than any doctrine of science. The reason is that it has been discussed very freely by those who are not informed, and in this way much misinformation has been propagated.

The general meaning of organic evolution is that the plant and animal kingdoms have developed in a continuous, orderly way, under the guidance of natural laws, just as the solar system has evolved in obedience to natural laws.

There are at least three important reasons why evolution should be regarded as a necessary part of college training.

(1) It has revolutionized modern thought. Every subject to-day is being attacked on the basis of its evolution. Not only are inorganic and organic evolution being considered, but also the evolution of language, of literature, of society, of government, of religion. In other words, it is a point of view which represents the atmosphere of modern investigation in every field.

(2) It is persistently misunderstood. From the press, the lecture platform, and even the pulpit, one frequently hears or reads amazing statements in reference to organic evolution. If it were made an essential feature of student training, there would be developed a propaganda of information instead of misinformation.

(3) It has revolutionized agriculture. The practical handling of plants and animals, in the way of improving old forms and securing new ones, was made possible and definite when the laws of inheritance began to be uncovered through experimental work in evolution.

PERIODS IN THE HISTORY OF EVOLUTION

There have been three distinct periods in the history of evolution, based upon the method of attack. These three methods may be

[1] Lecture delivered at a joint meeting of the New York Association of Biology Teachers, the Chemistry Teachers Club of New York, the Physics Club of New York, and the Torrey Botanical Club, at the Hotel Majestic, New York City, on March 27, 1926, and arranged under the direction of the science committee of the Board of Education. Reprinted by permission from Science, vol. LXIII, No. 1637, May 14, 1926.

spoken of in general as speculation (ancient), observation and inference (medieval), and experimentation (modern).

(1) *Speculation.*—The idea of organic evolution is as old as our record of men's thoughts, for all the old mythologies are full of it. No modern man, therefore, is responsible for the idea, although it is a common misconception to load this responsibility upon certain distinguished modern students of evolution. For example, the name of Darwin is so conspicuous in connection with evolution that many seem to think that Darwinism and evolution are synonymous. Until 1790, however, organic evolution was a pure speculation, with no basis of scientific work. It should be emphasized that the idea of evolution has always been present in the mind of man.

During the latter part of this ancient period of speculation, certain facts began to be observed that made some thinking men conclude that evolution might be a fact, and not merely a speculation. It will be helpful to note briefly, in historical succession, the kind of facts that set these men to thinking, and that resulted in the second period in the history of evolution, when it became a science.

In classifying plants and animals, which was the initial phase of biology, men rigidly defined the different species, the thought being that the different kinds had descended in unbroken succession "from the beginning," whenever that may have been. When more extensive observations were made in the field, numerous intergrades began to be found. The species as defined seemed to intergrade freely. In other words, the pigeon-hole arrangement, with rigid partitions, did not express the facts. It became evident that species had been defined by man rather than by nature. Some were distinct enough, but many intergraded. This intergrading suggested that one species might come from another, the intergrades marking the trail.

The next observations suggesting that evolution might be a fact had to do with what was called the "power of adaptation," which we now call "responses." It was observed that plants and animals respond to changes in environment, often in a striking way. I have seen what were regarded as two good species changed into one another by changing from a moist habitat to a dry one, or the reverse. This ability to respond to changing conditions seemed to indicate that species are not so rigid and invariable as had been supposed.

As technique developed, and the internal structures of plants and animals became known, it often happened that rudimentary structures were found, which never developed to a functioning stage, but which occurred fully developed in related forms. For example, it was found that in the developing parrot a set of embryo teeth begins, but never matures. The inference was natural that these structures had been functional in the ancestors, but had been abandoned by some of their descendants. In these days, it has become the habit to call these rudimentary structures "vestiges." Many such illustrations could be given. One in the human body is the vermiform appendix. It seems safe to say that we are walking museums of antiquity.

As technique developed still further, the embryology of plants and animals began to be studied in detail, the whole progress from egg to adult being observed. In very many cases, during the progress, glimpses of fleeting structures and resemblances were obtained, which had disappeared when the adult stage was reached, but which related the form to other species.

After this succession of facts, there came a revelation which convinced more men that evolution is a fact than any evidence which had preceded. The geologists had begun to uncover that wonderful succession of plants and animals from the earliest geological periods to the present time. They saw in the oldest periods forms unlike any now existing; they saw gradual changes with each succeeding horizon; they saw a steady approach to forms like those of to-day. until by insensible gradations the present flora and fauna were ushered in. This geological record, becoming continuously more detailed in its interpretation, set men to thinking seriously.

Finally, after all this evidence was in, men began to look around them and to realize what they had been doing for centuries in domesticating animals and plants. They had been bringing them from the wild state and changing them so much by the methods of culture that in many cases the wild originals could not be recognized. Most of our cultivated plants, if found in nature associating with their wild originals, would be regarded as extremely distinct species.

In the presence of such an array of facts, is it to be wondered at that certain men began the serious, scientific study of evolution? As a result, the second period in the history of evolution was ushered in, and evolution became a science.

(2) *Observation and inference.*—In time, this period extends from 1790 to 1900. It is characterized by the appearance of a succession of explanations of evolution. It is important to remember that the men who offered these explanations are not responsible for the idea of evolution, but merely attempted to explain the fact of evolution. They were explainers rather than authors. It is also important to realize the method used. It may be called the method of comparison and inference. Plant and animal forms were observed, and resemblances were assumed to indicate relationship through descent. It was not demonstration, but inference based on observation. Darwin carried the method to the limit of its possibilities, observing not a small range of forms, but observing through several years a world-wide range of forms, in connection with the famous voyage of the

Beagle. His caution is also indicated by the fact that his observations were under consideration for some 20 years before his conclusions were published.

This second period in the history of evolution, which we may call the medieval period, is marked by the appearance of several explanations. I shall mention only the three most conspicuous ones, and there is no need to define these in detail.

The explanation which ushered in the period was proposed simultaneously and independently in 1790 by Goethe, of Germany, St. Hilaire, of France, and Erasmus Darwin, of England. Observations of responses to changed environment led them to the conclusion that environment is the direct cause of change, actually molding forms. This evolutionary factor, therefore, is entirely external to animal or plant. It was a natural first explanation, but of course it was too superficial, and environment as a direct cause of evolution soon passed into the historical background. It deserves mention only because it was the first attempt at an explanation. In 1801 Lamarck, in a series of lectures, announced his explanation, calling it the theory of "appetency." This was really the first explanation with a body of doctrine, and hence, Lamarck has often been called the "founder of organic evolution." The term "appetency," however, has been abandoned, and its real meaning expressed by the phrase "the effect of use and disuse." With Lamarck, environment is not the direct cause of the change, according to the earlier explanations, but the occasion for the change. The cause is the striving, the effort to do something that had become necessary. Thus organs would become developed as a consequence of some change in environment calling them into use; and, conversely, organs would gradually become aborted as a consequence of some change in environment that eliminated their use. This explanation rests absolutely upon the inheritance of acquired characters, meaning characters not inherited by the possessor, but acquired during the life of the individual.

In 1858 the epoch-making explanation of Darwin was announced, an explanation which was dominant for about 50 years. It is too familiar to need explanation. In brief, it claims that nature selects among variations, that the method of selection is competition, that the result is the destruction of the relatively unfit, or as Spencer puts it, "the survival of the fittest." In brief, the theory is really an explanation of what is called adaptation.

As facts multiplied, the current explanations of evolution were found to be inadequate to explain some of them. This led to a general misunderstanding of the situation by the uninformed public. For example, more intensive study developed the fact that Darwin's explanation does not always explain. His name is so identified with evolution in public thought that this criticism of the universal application of his conclusions by certain scientific men was taken to mean that the theory of evolution was being abandoned. The real situation is that every proposed explanation may prove inadequate, and yet the fact of evolution remains to be explained.

All the explanations offered are partial explanations, which simply means that no one of them applies to all the facts. We need them all and more besides. So far from being abandoned, evolution is the basis of all biological work to-day.

The method of comparison and inference continued until the beginning of the present century. Then came a new epoch in the history of evolution.

(3) *Experimentation.*—This may be called the modern period, in contrast with the medieval and ancient periods. It was ushered in by the work of DeVries, who introduced the experimental study of evolution, and announced his explanation of evolution by means of mutation. The problem was to discover whether one species actually produces another one. It had been inferred that it does, but inference is not demonstration. By means of carefully controlled pedigree cultures, DeVries discovered a plant in the actual performance of producing occasionally a new form among its numerous progeny. This form bred true and preserved its distinctive characters; in other words, it was a new species or at least a different species from its parent. Many such species have now been observed originating in this way, both in plants and animals. That one species can produce another one is no longer inferred, but demonstrated, and demonstrated repeatedly. There is no longer any doubt, therefore, that evolution is a fact. It is quite a different question whether the proposed explanations are adequate.

When inferences were the only results, in the medieval period of evolution, it was natural to extend inference to the evolution of the plant and animal kingdoms, and this involved the origin of man. In these days there is no such attempt, for experimental demonstration of the evolution of the whole series of organic forms, culminating in man, is clearly impossible. Biologists, therefore, are no longer concerned with the whole story of evolution, but only in discovering experimentally how one species may produce another one. The fact of evolution is established, but the whole story of evolution must remain an inference.

PRESENT STATUS OF EVOLUTION

Only a very general statement can be made of the present status of evolution, since a full statement would involve an extensive discussion. The experimental study of evolution has led to the development of the field of genetics (heredity), a subject which has grown with remarkable rapidity. It is genetics which must uncover the machinery of evolution, which of course is fundamentally a matter of inheritance. The facts thus far uncovered indicate complexities which were not realized before, but which should have been anticipated, for inheritance, with its resulting evolution, represents the most complex biological situation imaginable.

The present status of evolution as a body of doctrine may be said to be in a state of flux, out of which the truth will emerge eventually. Any meeting of biologists at which evolution is discussed discloses considerable diversity of opinion, not as to the fact of evolution, but as to some attempt to explain the process.

It is evident, of course, that whatever produces variation furnishes a basis for evolution. But what produces variation? Environment is one factor; sex is another factor, especially when strains are crossed; and other factors might be cited. Any factor claimed to induce variation must stand the test of genetics. Variations, however, produced, are of two general kinds, as indicated by behavior, namely, the so-called continuous variation of Darwin's explanation, and the so-called discontinuous variation of DeVries's explanation. The differences of opinion have to do with the method of variation production; that is, variation that may result in a new species.

After such variation is secured, there is no question as to the function of selection. It is merely a statement of fact to say that some variations persist and some are eliminated. It is a very different matter to claim that only the "fit" persist. In some way the selection is made, and the selection factors may be quite variable. In general, it may be said that there is no serious difference of opinion that evolution is based on variation and subsequent selection. It is only a matter of detail to determine the exact factors.

There is a much more serious problem of evolution, however, which is still baffling. The variations observed, which result in new species, as tested by genetics, and for which the cytological machinery has been observed, produce species either laterally or retrogressively; that is, species of the same rank or of declining rank. There is as yet no adequate explanation of progressive evolution, the advance from one great group to another of higher rank. Progressive evolution is a very evident fact, as shown by many an impressive series disclosed by the geological records. The theory of "orthogenesis" is often cited as an attempt to explain progressive evolution. Orthogenesis is not an explanation, however, but a name for progressive evolution. The fact remains to be explained. The multiplication of species is within the reach of experimental study as to causes and methods, and the results are leading to conclusions that may vary with the investigator, but which will be checked up by further investigation. The progressive advance of species, however, is still within the region of inference. It is something like the difference between the tracks in a switch yard and the main line. We have succeeded in investigating the switching, but the through trains are baffling.

PRACTICAL RESULTS

I wish now to call attention to the practical results that the study of evolution has made possible. The experimental study of evolution, leading to the development of the science of genetics, resulting in increasing knowledge of the laws of inheritance, has led to practical results which the public in general do not appreciate. I shall select only one illustration from very many, but it will serve to indicate the sort of service the study of evolution has rendered in a practical way, in addition to its service in the advancement of knowledge. I have selected the revolution in agriculture. It seems a far cry from speculations concerning evolution to a revolution in agriculture, but the continuity is unbroken. Speculation led to observation; observation led to experimentation; experimentation resulted in discovering laws of inheritance; and the application of these laws has enabled us to handle plants and animals in a way that was never dreamed of before. It is a good illustration of the fact that there is no sharp dividing line between what are called pure science and applied science, for pure science may prove immensely practical.

A very brief statement will illustrate the agricultural results in the application of our knowledge of inheritance. It had become evident, for example, that for various reasons the ratio of increase in population was much greater than the ratio of increase in food production. The statement was made that during the 10 years preceding the great war our population had increased 20 per cent, and our food production about 1 per cent. It was certainly an alarming outlook. Under these circumstances, plant crops began to be studied from the standpoint of genetics, and plant breeding became a science.

The lack of crop production arose chiefly from three causes; namely, lack of adaptation of crops to environment, destruction by drought, and destruction by disease. The same races were being cultivated everywhere, and only in certain places was the maximum result obtained. A study of races of crop plants throughout the world, and of the environment necessary for maximum yield, resulted in such an adjustment of crops to conditions that total food production was enormously increased.

The problem of drought is being rapidly solved by the discovery or development of drought resistant races, not only insuring against loss from this cause, but also enormously increasing the possible area of cultivation.

The problem of disease has been attacked in the same way, and disease resistant races of most of the important crops have been developed, much reducing loss from this source. As a result, food production is now beginning to overtake population, and we may thank the persistent study of evolution for the result.

To summarize the present situation in reference to evolution, the following statements may be made. Biologists are testing the earlier conclusions by means of the multiplying facts. They are continually discovering factors which complicate the situation. They must learn the influence of factors by experimentation. As a result the problem of evolution has been discovered to be very complex, not to be explained so simply as had been supposed, and therefore is still "in the melting pot," as a distinguished scientist has remarked. All this means, however, that although this difficult problem has not been solved in all its details, it is still recognized by every biological investigator as a problem to be solved. It is not the fact of evolution that is being tested, but the explanation of evolution.

BARRO COLORADO ISLAND BIOLOGICAL STATION

By Alfred O. Gross, Ph. D.

Bowdoin College, Brunswick, Me.

[With 9 plates]

The great value of a biological laboratory offering facilities for the study of living creatures in their natural environment has long been recognized, and as a consequence we find excellent institutions of this nature located in favorable situations throughout the temperate regions of North America. Until recently, however, the student of animal and plant life has not been given the opportunities of a laboratory in the Tropics where the jungle offers a virgin field in a new world of life.

Our knowledge of life in the jungle has been more or less limited to collections made by various expeditions sent out by museums and individuals interested in the Tropics. Too often the primary object of these expeditions has been to secure large numbers of specimens, whereas a detailed study of these creatures has been secondary and limited to random notes taken at the time the specimens were collected. The success of these expeditions has been measured, and necessarily so, by the number of specimens collected, rather than by the hours and days of study devoted to the behavior of a single individual. The pioneer work of collecting is basic and must be done first, but as far as the birds and mammals of the American Tropics are concerned we now have a fairly complete knowledge of the species to be found, and the time is ripe for more intensive life history work. Such work, however, can not be carried on in the jungle to the best advantage without the facilities of a laboratory located in the midst of the field of operations.

I am indebted to Dr. Thomas Barbour of the Museum of Comparative Zoology, Cambridge, Mass. and to Prof. Alexander G. Ruthven of the University of Michigan for making it possible for me to spend the summer, June to September, 1925, in studying the birds in a jungle laboratory, the Laboratory of the Institute for Research in Tropical America located on Barro Colorado Island, Canal Zone.

Barro Colorado Island is the largest island in Gatun Lake, formed at the time the Chagres River was dammed in constructing the canal.

The birds and other animals which formerly existed in the lowlands were forced by the gradually rising water to seek higher levels, and as a result there is to-day an unusual concentration of animal life in the jungles covering the top of this partially submerged mountain. The island is 3.4 miles long and 3.1 miles wide, comprising 3,609 acres, with a very irregular coast line of about 25 miles. Practically the entire area is covered with a vegetation representing primeval conditions. The surface of the island is hilly, some of the hills reaching an elevation of 537 feet above sea level, or about 450 feet above the average level of Gatun Lake. Running down between the hills, hidden from view by the luxuriant vegetation, are rocky brooks which during the rainy season pour turbulent streams into the numerous coves forming the jagged coast line of the island. These coves are a joy to the naturalist who wishes to explore the interesting recesses of the jungle in a cayuca, the native dugout canoe. Many of these coves are dotted with the stumps and trunks of trees which have been flooded for more than 15 years. Practically all of the trees standing in the lake are now dead, but many of the stumps are laden with masses of ferns, mosses, and other epiphytic plants, including several species of beautifully colored orchids. Birds have found here admirable nesting sites which are free from the hosts of enemies which are ever present on the mainland. In certain places most of the tree trunks immersed in the tropical water so long have rotted at the water level, fallen, and then, driven by the winds, have collected in protected coves, where they are anchored by projecting snags or hemmed in between tree trunks. These log masses form floating islands, many of which have already grown up with grasses and various plants, producing inviting places for the crocodiles and lizards to bask in the sun, and excellent feeding places and nesting sites for a host of birds. As time goes on, the environment as far as these creatures are concerned will improve, and, with the protection given them by the Institute for Research, is destined to provide a richness of life the equal of which will be found in but few places of the world. On the island, it is stated, there are over 2,000 species of flowering plants, innumerable species of insects, comprising many yet undescribed, and numerous reptiles, amphibians, birds, and mammals whose strange habits and life histories are yet unstudied. Since the island has been set aside as a reservation, trails, many of them named after benefactors and distinguished naturalists, have been surveyed and cleared so that all the more interesting sections of the island are readily accessible to those who desire to study the wealth of living forms in this wonderland jungle.

We are indebted to Mr. James Zetek, entomologist of the United States Department of Agriculture, stationed at Ancon, Canal Zone, who first pointed out the great possibilities of this island as a reservation to be preserved for all time for students of the Tropics. Dr. Thomas Barbour, who is greatly interested in all research which pertains to the Tropics, encouraged the idea. It was through their untiring efforts, with the aid of fellow scientists, that the island was set aside as a reservation on April 17, 1923, by the Governor of the Canal Zone and that a laboratory has been built and maintained. The island has been assigned for scientific purposes to the Institute for Research in Tropical America, which was organized in 1922 under the auspices of the National Research Council, to promote research in the Tropics. The laboratory is supported in part by various scientific and educational institutions under the research table plan, which means that the institution, by maintaining a table, can nominate research men to hold it. At present the laboratory is under the direct charge of Mr. James Zetek, who serves as custodian and with his assistant, Mr. Ignacio Molino, is devoting much time and energy toward the development of this important station.

The following excerpt illustrates how the station is appreciated by visiting scientists. It is taken from a letter written August 4, 1926, to Mr. Zetek by Dr. David Fairchild, agricultural explorer in charge, United States Department of Agriculture, after his return from an extensive exploration:

> I have not seen any place in my travels which compares with Barro Colorado Island in point of excitement of the field naturalist kind. In Java and Sumatra the Dutch have built palatial laboratories, but these are far removed from the fresh, new jungle. In Ceylon the British have an agglomeration of buildings like the Department of Agriculture, but it is surrounded on all sides with tea plantations. Everywhere it is the destructive activity of man that is clearing off the jungle and replacing the gorgeous forest with weedy growth or plantations of rubber trees. Hold the virgin character of Barro Colorado at all costs.

Dr. Frank Chapman, curator of the Department of Birds of the American Museum, New York City, writes as follows:

> Some 400 species of birds have been recorded from the Canal Zone, and the greater part of these occur on or near Barro Colorado. The island's chief distinction as a station for bird study, however, is the facilities it affords the bird student and the assurance it gives him of making long-continued observations under the undisturbed conditions of insular isolation. In no other place have I seen these conditions approached.

Doctor Chapman has selected Barro Colorado as the scene and source of materials for his new museum group to represent the bird life of the American Tropics.

There are many features of the Canal Zone which are destined to make Barro Colorado one of the most important and popular biological stations in the Tropics. First of all is its accessibility, for it may be readily reached by steamers from all parts of the world. Steamer service with the United States is frequent and rapid. One can go from New York to Cristobal on the Panama Railroad Steamship Line via Haiti or on the United Fruit Co.'s Line via Cuba in about eight days; steamers going direct make the trip in less time. The United Fruit Co. offers each year a limited number of passes to properly accredited persons who wish to conduct research work at the biological station and the Canal Zone Government has made most liberal concessions, which are greatly appreciated by all of the scientists who have thus far worked at the laboratory. The Government offers a $50 rate on the Panama Railroad steamers and gives passes on the Panama Railroad to each investigator sanctioned by the National Research Council and to members of his family. This latter concession is of the greatest importance, since the railroad is the only means of going to and from the laboratory to the terminal cities and it also puts the investigator in convenient reach of all parts of the Canal Zone territory. There are at present no facilities on Barro Colorado Island for the families of the research workers, but the Government offers the privilege of renting a house or an apartment in Ancon or Balboa, where very comfortable furnished quarters can be had at a reasonable price. No persons except those in some way connected with the service of the Government may reside in the Canal Zone, hence this concession is also a great inducement to visiting scientists who expect to take their families.

Barro Colorado Island being in the Canal Zone is comparatively free from many of the diseases usually associated with the Tropics. No one needs to take special precautions against malaria or typhoid fever, and yellow fever and bubonic plague are unknown. During the rainy season, the time I was there, flies and mosquitoes were negligible. I have never been in the woods anywhere during the summer season where I suffered so little from the bites and stings of insects. I went equipped with mosquito tents to be used inside my blinds while studying birds in the jungle, but these remained in my trunk untouched all summer. During the dry season, however, I am told mosquitoes and ticks are pests to be reckoned with, and unless one exercises care he will become infested with the so-called "red bugs" which are an irritating menace.

In addition to the equipment already mentioned there are popular and technical libraries, clubs, various educational organizations, as well as numerous other inducements, which serve to make the environment of the research worker in Panama most attractive.

The Canal Zone is subject to the influence of two annual seasons, the duration of which is correlated with the prevailing winds. During the dry season the northeast trade winds blowing daily from December to May are accompanied by more or less precipitation on the Atlantic side, while on the Pacific slope there is a true dry season. During the wet season, beginning usually about the latter part of

May and ending the first of December, southerly winds become dominant, and rains are general throughout the Isthmus. During the time I spent in the Zone (June to September) the climate was very pleasing and comfortable. I do not recall that the heat was ever as oppressive as on some of the summer days I have experienced in our northern cities, and the nights were never as hot as they frequently are on the plains of the Middle West States. The evenings were usually cool, and though we seldom used blankets there was never a night when we were obliged to lie awake because of great heat. The temperature during August ranges from 71° F. at night to 90° F. in the daytime. The December extremes are 69° F. to 89° F., only slightly lower than the summer temperature. It is this uniformity of temperature which tires and which seems to sap the energy and vitality of those who remain in the Tropics for more than a few years. To a person who goes to the Zone for a few months or at most a year the climate does not give the impression of being oppressive. Of course, it is necessary to adapt your clothing to the climate, and it is only the most ambitious who exert themselves physically during the hottest hours of the more humid days.

In the Republic of Panama there are three life or faunal zones represented, the lower and upper Tropical Zones which include most of the country and a Temperate Zone limited to comparatively small areas on the tops of some of the highest mountains. In the canal region there is only the lower Tropical Zone, a zone which includes an area of high temperature in which many species of plants and animals range in suitable places throughout its extent while others are restricted to the so-called arid and humid divisions or else reach their greatest development there. The rainfall is much greater, some years twice as great, in the humid than in the arid division. The average rainfall for 13 years at Balboa on the Pacific side of the Isthmus, which is in the arid division of the lower Tropical Zone, is 71.67 inches whereas an average for 40 years at Cristobal on the northern or Atlantic side is 130.03 inches. Although the amount of rainfall is important the most significant difference between the two sides of the Isthmus representing the two divisions of the life zone is the comparative continuity of the supply. In the humid division which extends from the Atlantic Ocean nearly to the Continental Divide, moisture in the form of rain and fog is received at short intervals throughout the year, whereas in the arid division there are long periods of drought. As a result of these contrasting conditions the leaves are persistent and a luxuriant evergreen forest, the so-called "rain forest," is found on the Atlantic slopes, while in the arid division on the Pacific side the leaves are largely deciduous, the forests turn brown, and the savannas become parched in appearance during the dry season. This striking difference in the vegetation of the two divisions of the lower Tropical Zone is closely correlated with a corresponding difference in the animal life. On Barro Colorado Island we find the rain forest supporting a flora and fauna characteristic of the humid division of the lower Tropical Zone, and the immediately contiguous area supplies haunts for aquatic species and others which are characteristic of clearings and cultivated lands.

In this paper it is impracticable to go into the details of the life zone or even the chief biological features of the island, but I will restrict myself to an account of my work, some experiences with the birds studied, and some of the mammals met during the course of my summer in the Canal Zone. The reader is referred to the titles listed at the end of this paper for other aspects of the biology of Barro Colorado Island.

In much of my work Mr. Josselyn Van Tyne, a recent graduate of Harvard University and now a graduate student at the University of Michigan, was associated with me. Mr. Van Tyne is a thorough and enthusiastic student of ornithology and his genial companionship is one of my pleasant memories of the summer. Many phases of our work, especially those which demanded constant uninterrupted observation, would have been impossible without the cooperation of a fellow worker. Mr. Van Tyne and I did not go to the station with any intention of studying the bird life as a whole and we made no great effort to identify a large list of representative species. Our main objective was to study a few species more or less intensively. This kind of work is yet a new field in the Tropics, and it added no little zest to our work to know that we were photographing and learning the habits of certain species for the first time. Only such specimens as were needed for identification were taken and it is gratifying to know that the collecting of large series of skins is strictly prohibited. In addition to our needs in identification we tried to make the most of the specimens secured. Each bird collected was carefully weighed, a series of about 20 measurements were taken, and the color determinations of the iris and parts of the bird which are subject to quick change after death were made before the bird was skinned. Weights and determinations of the food, external and internal parasites, and diseases were all given special attention. We found the equipment of the laboratory, which includes a drying room, scales, microscopes, a complete supply of chemicals and glassware, and a well lighted and screened workroom, ideal for this kind of detailed work. Furthermore there is an excellent dark room, ice for cooling developers, running water for washing negatives, all that could be desired for our work in photography.

Our field studies were confined chiefly to birds which were nesting, for it is then that their life is centered around a restricted area where much of their behavior can be successfully studied from blinds. It is also easier to secure photographic records of the birds under such conditions. I must admit that we went to the island with considerable apprehension as to our probable success in finding many birds nesting after the end of June, but in this connection it is interesting to note that we found so much material that practically all the life history work of the summer was conducted within a few hundred yards of the laboratory. I am greatly indebted to Mr. Frank Drayton, caretaker of the station, who assisted me in locating nests for the field studies.

To anyone who attempts to gain a general impression of the bird life of the Canal Zone by a trip across the Isthmus via train the results are unsatisfactory and perhaps disappointing so far as numbers are concerned, but to me those first impressions of Panama from the train were strong ones, and I still have vivid memories of that initial experience in the Canal Zone. Soon after leaving Cristobal the train passes through a marsh which at that time of the year (June) was alive with herons, of which I noted three different species. Here I saw those beautiful immaculate white egrets (*Herodias egretta*) which stood out in striking contrast with the dark colors of the surroundings. As we passed a dense mass of vegetation growing in the water near to the tracks, about a dozen little blue herons (*Florida caerulea*) in white and gray phases of plumage were startled by the train and a little farther along I saw several black-crowned herons (*Butorides striata*) perched in the top of a palm tree. After leaving the marsh there were fewer birds, but the vegetation was very interesting and we had excellent views of Gatun Lake as we skirted around its eastern border. In the topmost branches of a dead tree partially submerged by the lake was a small group of Brazilian cormorants (*Phalacrocorax v. vigua*). I looked eagerly for the water turkey or snake bird (*Anhinga anhinga*) but it was not until weeks later that I saw this bird when making a trip up the Chagres River on the police boat. Soon after leaving the station of Monte Lirio I saw for the first time several black jacanas (*Jacana nigra*) striding in a most adept manner over the lily pads of a small lagoon. When we stopped at Frijoles several anis (*Crotophaga ani*) were there to greet us and then as the train continued toward the Continental Divide I had fleeting glimpses of many birds, but with the exception of a Panama crimson-backed tanager (*Ramphocelus dimidiatus isthmicus*) I was unable to identify any of them. At Balboa the first birds to attract my attention after leaving the train were flocks of noisy paraquets (*Brotogeris jugularis*), which flew about in solid masses, some of them so near the ground that I saw a boy wing one of them with a club. These birds literally infest the trees along certain streets and always seem in evidence much as are the English sparrows in our northern cities.

After locating my family in comfortable quarters in Balboa and securing collecting permits from the Governor, Mr. Zetek arranged to take me to the island. We took the train to Frijoles, a small plantation village located at the tip of an arm of Gatun Lake, a convenient place for transferring our baggage to the laboratory launch. As we followed the channel leading out to Gatun Lake we passed several thatched native huts surrounded by banana plantations and here and there were groups of palm trees further to remind us that we were in the Tropics. I saw but few birds in going across the lake, merely a number of Brazilian cormorants that were perched on the dead tree stumps and a flock of brown pelicans (*Pelecanus occidentalis*) which were flying over in their characteristic alignment. As we crossed the channel of the Canal a great steamer bore down upon us. We succeeded in crossing its bow in plenty of time but the waves which followed were enough to make some of us think of the life preservers. As we were getting adjusted to the waves I noticed a giant kingfisher (*Streptoceryle t. torquata*) perched on the top of a channel buoy where he seemed to enjoy his ride much more than some of the persons in the launch. We came to a view of the station suddenly and unexpectedly as we rounded a point of the island. There before us, nestled on a hill high above the lake and surrounded by giant trees of the tropical forest, were the buildings of the station. Leading from the boat landing to the laboratory is a long series of steps, over 200 I was told, a number I soon learned to appreciate. The climb to the top is worth the effort of any visitor to the island, for from the laboratory door you have a remarkable panoramic view of Gatun Lake and the surrounding jungle. There is always something interesting to be seen no matter what time of the day you chance to be there. The place seems much like a zoological garden and among your expectations will be the toucans with their enormous and highly colored bills, gorgeous trogons, the long-tailed motmots, dozens of screaming parrots and paraquets and countless smaller birds including brilliantly irridescent hummingbirds and highly colored manakins. The presence and notes of these birds mingled with the howls of monkeys and the cries of unseen creatures in the forest make the place weirdly fascinating. The first time that I walked down the trails alone and heard the queer sounds, the source of which I could not guess, I felt uncomfortable and ill at ease at times, but after living there a few weeks, you soon learn that the animals of the jungle, even the larger ones like the peccaries, monkeys, the ocelot, and the jaguar, are much more afraid of you than you are of them.

The first bird which received special attention after landing at the station was the oropendola (*Zarhynchus w. wagerli*), a large, beautiful bird marked with rich brown, black, and yellow, commonly known as the hangbird or hangnest. This bird, which nests in large communities, attaches its long, pendent nest to the topmost branches of the tallest trees, that often tower high above the other trees of the jungle. A tree of this kind which contained about 50 nests formerly stood in the back yard of the laboratory, but, unfortunately, it was blown down by a storm. An examination of the nests revealed that only two of them were occupied. These contained half-grown young that were killed when the tree crashed to the ground. We preserved the young and all of the nests, which gave us a fine series for measurements and study. The birds remained in the vicinity several days after this catastrophe, apparently very much attached to the old nesting tree. The large number of birds that were there before and after the tree fell lead us to infer that the nests may be used for roosting places long after the young birds are able to fly. The presence of oropendolas about the laboratory was always made known by their characteristic calls, which are so different from those of other birds. The notes have a peculiar gurgling liquid quality, which has been described as "*wo-kee*', *oak-la-hom*' *e*," reminding one somewhat of the notes of their relatives, the bobolinks and the redwings, all members of the family Icteridae. At other times there were notes which sounded much like those produced when large pebbles are thrown into the water. Later in the summer we found another oropendola tree, which stood near the head of an adjoining cove, but the height of the tree and the inaccessibility of the nests made it very impracticable for life-history study.

On June 28 one of the Indian boys at the laboratory found a pendent nest of a small flycatcher attached to a long, flexible stem overhanging the water of the lake in a place not far from the boat landing. When it was pointed out to us it did not seem like a nest but appeared more like a bit of grass and débris which had accidentally become lodged in that position. The entrance to the nest was unusual in that it was completely hidden from view by a covered pasageway, which further aided in its concealment. The entire structure and location of the nest seemed to us ideal, as far as protection from enemies was concerned. It was out of the reach of peccaries, coatis, and members of the cat family, and even the prowling, mischievous monkeys would not dare to descend such a slender branch so near the water. Before the summer had progressed very far we found many of these nests, some in similar locations along the margin of the lake but more of them overhanging the water of the brooks in the deep recesses of the forest. Not a single nest, however, was found remote from the water. The large number of undisturbed nests of this species was convincing proof that it was a most successful type for conditions in the Tropics.

The nest at the boat landing when found contained two fresh eggs of a flesh-ocher ground color with a broad band of ferruginous near the larger end. We built an observation blind on the shore where we could clearly see the bird as it approached and left the nest. After a few visits we were able to ascertain that the upper parts of our bird were a greenish olive, the underparts buffy yellow, the long tail black, and that there was brilliant sulphur-yellow patch on the rump. These characters were sufficient to identify our new flycatcher acquaintance as a species of Myiobius, but it was not until much later when we collected a specimen that we were able to identify it as the black-tailed myiobius (*Myiobius atricaudus*). This bird vibrated its wings so rapidly during flight that it produced a buzzing sound not unlike that made by a humming bird when hovering about the flowers. It was a very nervous creature and left the nest on the slightest provocation. Though the bird is completely hidden from view when on the nest it was evident that it could see us through the weave of nesting materials, and no matter how cautiously we approached she was quick to leave long before we reached the blind. At night she was not disturbed by my presence even when I threw on a flashlight to illuminate the nest. All that I could see of the bird at such times was her tail. There was not room in the small bowl of the nest for such a long appendage, hence she was obliged to hang it in the covered passageway while incubating the eggs or brooding the young. As is the case with many birds in the Tropics, this fly catcher frequently left the eggs for long periods of time during the warmer hours of the day, but she always faithfully brooded them at night. As far as I could determine only one bird, probably the female, did the work concerned in rearing the brood. Only at one time did I see a second bird about one of the nests and that was the occasion of a very spirited fight which resulted in the visitor leaving at once. To be sure the visitor may have been some other than her mate. The quick movements of the bird, combined with the poorly lighted situation and the dark colors of the surroundings, presented a difficult problem in photography. An exposure of sufficient length to insure an image always resulted in a worthless blur. This difficulty was overcome, however, by using light reflected from a large mirror manipulated by Mr. Van Tyne from a point across the cove. Satisfactory pictures were then secured by working the graflex with the stop wide open and with an exposure of one three hundred and fiftieth of a second. For the pictures of the various stages of the young it was necessary to remove the birds from the nest. We were unable to photograph the bird in the act of feeding the young; neither was it possible for us to study this part of their behavior.

In the course of our life-history work with any bird the eggs are measured and are weighed at different periods of incubation and after the eggs hatch, the young are weighed, measured, and photographed each day until the time of leaving the nest. Since such frequent visits might interfere with the normal growth of certain birds, other nests of the same species are used as controls where visits are made not oftener than once or twice during a week. The data thus obtained give us a complete record of growth and behavior which is of value in making comparative studies. As an example it was found that the incubation period of the eggs of myiobius was 21 days, whereas the flycatchers in the temperate regions hatch in much less time. Even the large eggs of such representatives as the kingbird do not require more than 15 days' incubation and the smaller flycatchers which are about the size of myiobius hatch in about 12 days. Furthermore the time spent by the young of this species in the nest was three weeks, whereas flycatchers of this size in the North are equipped with a plumage and ready to fly in about one-half of that time. Whether these conditions are general in the Tropics remains to be determined by further work and it is yet too early to advance a theory to account for this striking difference in the flycatchers. Another fact, which has been noted by others but emphasized by our observations, is that in general birds in the Tropics lay fewer eggs than the birds in the temperate regions. With very few exceptions there were not more than two eggs in the nests we found in Panama, whereas representative species of the same families in the North lay four or more eggs. The purple gallinule (*Ionornis martinicus*) which usually lays as many as eight eggs in the North, did not have more than three or four eggs in the nests which we studied in the Canal Zone.

On August 4, Donato, the Indian boy, showed us a nest of the piliated tinamou (*Crypturus soui panamensis*), a fine game bird of the Tropics, located at the base of a palm tree on the Snyder-Molino trail. We approached cautiously and took several pictures of the bird on the nest at close range without the use of a blind. We then went nearer until I was able to touch the feathers of the bird. She did not move and when I persisted she picked at my fingers. Finally I reached under her breast to feel for the eggs, but this proved too much of an intrusion and she left the nest, walking leisurely into the dense undergrowth a few yards away. The two eggs were of a vinaceous brown, very different from the colors we generally associate with the eggs of birds. The eggs were laid on a mat of leaf fragments already in place when the nesting site was chosen. It was more or less concealed from above by giant leaves of a palm which had fallen to the forest floor. This tinamou seemed like a very promising subject and we arose with enthusiasm early the next morning to begin our life-history study. When we arrived at the place with our cameras and equipment our hopes were blasted for we saw a messed-up nesting site and the bird and eggs gone. But these misfortunes are a part of our life-history work and are to be expected. The birds inside the jungle, especially those which nest on the ground, are subject to frequent molestation. The struggle for existence is hard and it is a wonder that so many birds having similar nesting sites are able to maintain their numbers.

The Formicariidae, the antbirds, are well represented on the island and it was our good fortune to find material for the study of several species of this interesting family. These birds spent much of their time on the ground, and as the name suggests probably feed largely on the ants which are very abundant in all parts of the jungle. A nest and two eggs of Slater's antbird (*Myrmeciza exsul*) was found among the leaves of a low herbaceous plant by Mr. Drayton on July 25. The nest was made of coarse stems and roots and lined with fine rootlets and vegetable fibers. This bird, like the tinamou mentioned above, allowed me to come very near but when she finally flushed from the nest she ran along the ground actively, fluttering her wings and feigning a wounded creature. I followed to encourage her and to see what she would do. After performing in this manner for a distance of 20 yards she flew up to one of the lower branches of a tree and at once began uttering a loud piercing trill. As soon as this note echoed through the woods I heard a similar call answering in the distance. It was her mate and as soon as he appeared on the scene they produced such a commotion that it attracted all the other birds in the neighborhood. They added their notes one by one until the monkeys were aroused and soon the whole jungle was in a pandemonium, all started by one little antbird. During the middle of the day this bird generally sat on the edge of the nest guarding her eggs but toward evening as the temperature dropped she would nestle down on them for the remainder of the night.

On July 6, when returning to the laboratory on the Barbour Lathrop trail, I discovered a fine little nest of the spotted-crowned antvireo (*Dysithamnus puncticeps*) located about 6 feet high in a small tree. The nest was partially suspended from a forked limb and had much the appearance of a poorly constructed red-eyed vireo's nest. In order to study this bird to the best advantage I built a blind with the floor slightly above the level of the nest, where I could look down into it, a good position for observation and photography. The sides of the blind were covered with branches and large banana leaves, and for the top I used a piece of metal roofing secured at the laboratory. A roof is very essential during the rainy season because a torrential downpour is a part of your daily expectation and though a wetting of yourself is of little consequence it is important to keep your camera equipment dry. The study of these antvireos was one of my most pleasant ornithological experiences at the station and I became very much attached to these birds before it was ended.

There was always complete cooperation in this family in all of the arduous tasks concerned with incubation and care of the young. The male and female relieved each other at regular intervals of two or three hours throughout the day. The birds approached the nesting tree walking on the ground rather than flying from the branches above. Just before the shift took place I could hear the approaching bird singing a sweet warbling song. When it reached the base of the tree it hopped to the lowest branch and then came up limb by limb, singing as it came. As it peered over the margin of the nest it seemed to utter notes of greeting, and then without further ceremony the birds exchanged places. Both birds sang and approached the nest in a similar manner, but it was interesting to note a slight difference in their behavior regarding the position assumed on the nest. The male usually faced the blind, as shown in the accompanying photograph, while the female with greater modesty nestled with her head in the opposite direction. While this study was in progress a spotted antbird (*Hylophylax naevioides*) built a beautiful nest, which I could clearly see and observe from the back porch of my blind. My attention and my interests from that time on were divided, a condition which might be compared to a two-ring circus. The spotted antbird, like the ant vireo, sang when it approached the nest. Long before I saw the bird I could hear the loud, clear, robin-like calls coming nearer and nearer from out of the depths of the jungle. When the male was about 10 feet away the female would fly off. He seemed to pay no attention to his mate, but continued toward the nest in a leisurely fashion, singing as he came. Much to my surprise, he would continue to sing after he was on the nest for several minutes. As I sat watching this beautiful enactment of life I could not help thinking that the spirit with which these birds approached their tasks is an example for all of us to follow.

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(Many of the titles in the above list were taken from a list of papers published concerning Barro Colorado Island Biological Laboratory compiled by Mr. James Zetek.)

MR. JAMES ZETEK, CUSTODIAN OF THE BARRO COLORADO ISLAND BIOLOGICAL LABORATORY, CANAL ZONE

Photograph by John Howard Paine

VIEW OF THE LABORATORY FROM THE REAR

Showing the main building (32′ x 55′) near center, the kitchen (12′ x 12′) at the left, and the laboratory annex (12′ x 24′) at the right. The tank in the center has a capacity of 7,000 gallons of pure rain water, which is supplied to the various buildings. In the foreground is a standard rain gauge. In addition to the buildings shown in this view, there is an annex (16′ x 16′) for laborers and cook, fuel house, trail house (16′ x 16′), and the Chapman house (18′ x 24′), a special laboratory building with a (6′ x 24′) porch, a gift of Dr. Frank Chapman. At Frijoles is a boat house in which the new 30-foot launch is housed. The station also has a patrol speed boat, a row boat, and several cayucas for the convenience of the visiting naturalists to the island. Photograph by Mr. James Zetek

GENERAL VIEW OF THE BIOLOGICAL STATION ON BARRO COLORADO ISLAND, SHOWING THE LABORATORY SURROUNDED BY THE GIANT TREES OF A VIRGIN TROPICAL FOREST. AUGUST 13, 1925

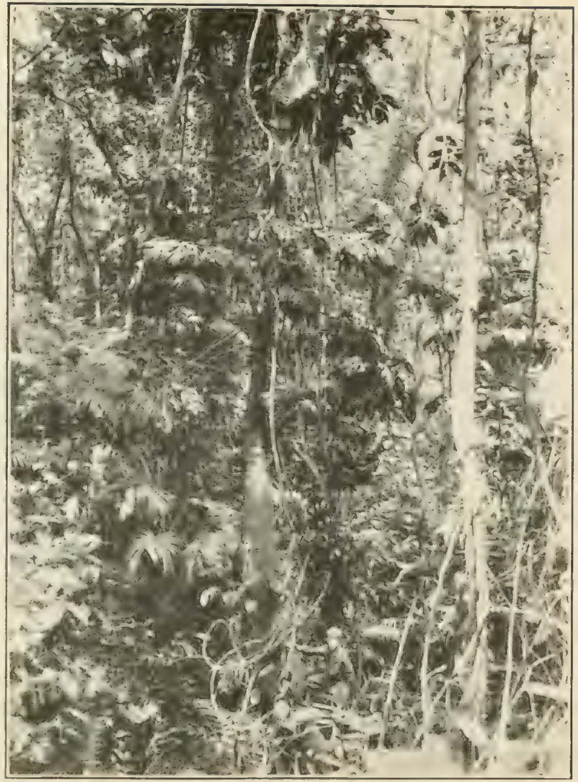
Photograph by A. O. Gross

THE DROWNED FOREST NEAR BARRO COLORADO ISLAND, 15 YEARS AFTER THIS AREA WAS FIRST FLOODED BY THE WATERS OF GATUN LAKE

Photograph by James Zetek

1. THE OROPENDOLA TREE WHICH FORMERLY STOOD NEAR THE LABORATORY. THIS TREE CONTAINED MORE THAN 50 NESTS OF WAGLER'S OROPENDOLA, ZARHYNCHUS WAGLERI GRAY, BEFORE IT WAS BLOWN DOWN BY A STORM ON JUNE 26, 1925

Photograph by James Zetek



2. VIEW OF THE INTERIOR OF THE JUNGLE TAKEN JULY 18, 1925, WITHIN 50 YARDS OF THE LABORATORY. THE NESTS OF THE SPOTTED-CROWNED ANTVIREO AND THE SPOTTED ANTBIRD WERE NEAR TO THIS PLACE. NOTE THE SIZE OF THE BOY IN THE FOREGROUND

Photograph by A. O. Gross

NEST AND TWO EGGS OF THE PILEATED TINAMOU, CRYPTURUS SOUI PANAMENSIS, AUGUST 4, 1925

PILEATED TINAMOU, CRYPTURUS SOUI PANAMENSIS, INCUBATING HER TWO EGGS. THIS PICTURE WAS TAKEN WITHOUT THE USE OF A BLIND. SEE TEXT, PAGE 337

Photographs by A. O. Gross

1. THE ANTEATER, ONE OF THE INTERESTING MAMMALS OF BARRO COLORADO ISLAND. THE TERMITES' NEST AT THE RIGHT IS ONE OF ITS CHIEF SOURCES OF FOOD

2. A MOTHER TWO-TOED SLOTH AND HER BABY. A VERY CURIOUS AND COMMON ANIMAL ON BARRO COLORADO ISLAND. IT EATS, SLEEPS, AND LIVES IN AN UPSIDE DOWN POSITION

Photographs by A. O. Gross

1. NEST AND TWO EGGS OF THE BLACK-TAILED MYIOBIUS, MYIOBIUS BARBATUS ATRICAUDUS. ONE SIDE OF THE NEST HAS BEEN CUT AWAY IN ORDER TO SHOW THE COVERED PASSAGEWAY AND THE INTERIOR STRUCTURE OF THE NEST

2. YOUNG BLACK-TAILED MYIOBIUS IN JUVENILE PLUMAGE, AGE 18 DAYS. THIS BIRD LEFT THE NEST THREE DAYS LATER. AUGUST 18, 1925

Photographs by A. O. Gross

1. SLATER'S ANTBIRD. MYRMECIZA EXSUL EXSUL. AUGUST 5, 1925. THE LIGHT PATCH SHOWING IN FRONT AND BACK OF THE EYE IS NAKED SKIN OF A BRIGHT SKY-BLUE COLOR. SEE TEXT, PAGE 338

2. THE MALE SPOTTED-CROWNED ANTVIREO, DYSITHAMNUS PUNCTICEPS. SEE TEXT, PAGE 338

Photographs by A. O. Gross

1. THE MALE SPOTTED ANTBIRD, HYLOPHYLAX NAEVIOIDES, SINGING WHILE SETTING ON THE NEST, JULY 18, 1925. SEE TEXT, PAGE 339

2. PURPLE GALLINULE, IONORNIS MARTINICUS, APPROACHING HER NEST CONTAINING TWO FRESHLY HATCHED YOUNG AND TWO PIPPED EGGS

This nest was built among the grasses of a floating island not far from the boat landing. It was observed daily from July 11 to August 4, the day the young left the nest

GEOGRAPHY AND EVOLUTION IN THE POCKET GOPHERS OF CALIFORNIA[1]

By Joseph Grinnell

[With 1 plate]

The most universally distributed type of rodent in California is the pocket gopher. It is found thriving at and below sea level, around the southern end of Salton Sea in Imperial County, and above timber line, at 11,500 feet altitude in the vicinity of Mount Whitney; it is found from the arid desert mountain ranges of the Inyo region, such as the Panamint Mountains, to the rainy and foggy coast strip at Humboldt Bay and Crescent City; it is found in the yielding sands of the Colorado River delta at the Mexican line and on the Modoc lava beds at the Oregon line.

This fact of occurrence far and wide might seem to indicate a broad tolerance, tolerance of a number of conditions each varying between wide extremes. How is such an interpretation to be harmonized with the obvious fact that the pocket gopher is an exceedingly specialized type of rodent? Does not specialization ordinarily bring great restriction in habitat? A truism is this statement: The pocket gopher stock has solved successfully the problem of meeting the essential conditions of existence, else its racial line would not have persisted to the present day. Among races of animals the law is evident that only those budding forms persist and continue to evolve that are able to find suitable places, niches for themselves, in the economy of animal existence that are not already preempted and successfully occupied by other forms.

The pocket gophers are rodents restricted to the Western Hemisphere; not only that, they comprise a family (Geomyidae) restricted to the continent of North America; furthermore, that family centers in the southern half of the continent. The family Geomyidae contains several subdivisions—genera, in the parlance of the systematist. The genus *Thomomys*, to which all the gophers of California belong, is still further restricted to that portion of North America lying altogether west of the Mississippi River, and between the twentieth and fifty-fifth degrees of latitude. As to origin,

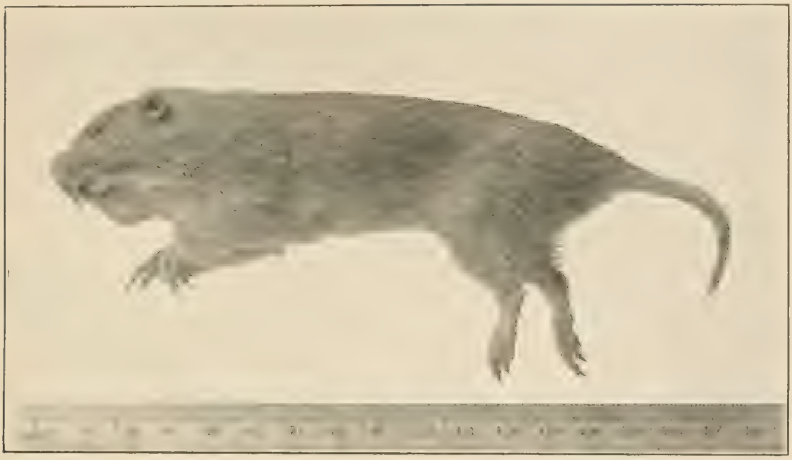
[1] Reprinted by permission from the University of California Chronicle, July, 1926.

pocket gophers are of squirrel-like ancestry. But that was in very remote times, geologically speaking: for the particular genus *Thomomys* has been in existence since the Miocene period. Despite this long lapse of time, then, the group of rodents here under consideration has not found its way beyond certain geographic limits, and yet within those limits it is exceedingly abundant and widespread, in other words, successful. What was the place for itself that the nascent ancestral race, just becoming gopher-like, discovered, and which its descendants, continually specializing, have found so favorable?

Superficial examination of a garden gopher shows the animal to be remarkably formed throughout for existence underground. Observation of its habits shows that in all probability each individual spends fully 99 per cent of its time underground. Its world is limited by the earthen walls of a burrow which the animal is equipped to dig for itself through the soil. In one direction this burrow leads to safety for itself and young from enemies; at the other end it leads to food supply. Thus the conditions of existence for any vertebrate animal, safe refuges and breeding places, and food of right kind and sufficient amount, are met.

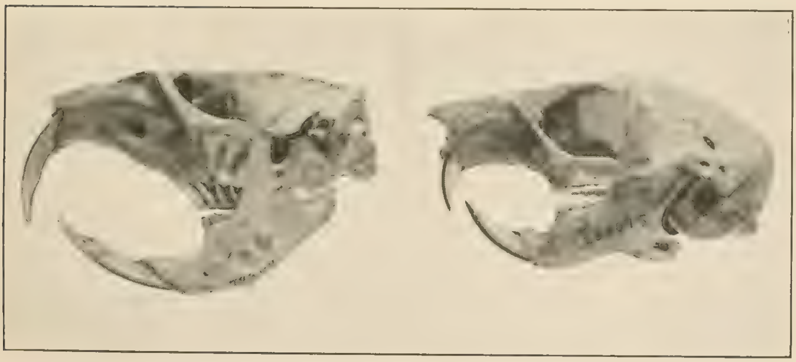
But this discovery of a previously unappropriated means of subsistence, by adoption of the subterranean mode of life, has brought with it deficiencies in certain faculties not bound up with proficiency in digging. To dig, the animal must have short legs and a muscular body, especially anteriorly. The head of a pocket gopher is larger in proportion to its body than is that of any other land mammal in California; there is no obvious neck constriction, and the shoulders are broad. The musculature having to do with the operation of the front feet is massive; and so also are the bones of the skull to which are attached the big muscles which operate the relatively heavy incisor teeth, these being the chief tools with which the gopher loosens the soil as it advances along its underground routes of exploration for food, or digs to greater depths for more secure refuge. Obviously, the acquisition of all these modifications for burrowing has necessitated the loss of that litheness of body and length of limb which would enable it to move freely over the surface of the ground in search of food or in escape from enemies. The pocket gopher is, indeed, well-nigh lacking in powers of locomotion overland.

Furthermore, the pocket gopher is deficient relatively to other rodents with respect to eyesight and probably also with respect to hearing. It is almost as helpless outside of its burrow as a fish out of water. There may be some compensation in a heightened sense of touch, especially as localized in the nose and surrounding vibrissae and in the tip of the tail. While the animal has little need of being



1. A POCKET GOPHER, THOMOMYS BOTTAE, PHOTOGRAPHED FROM FRESHLY CAUGHT SPECIMEN, SHOWING EXTERNAL STRUCTURAL FEATURES CORRELATED IN THIS SCIUROID RODENT WITH SUBTERRANEAN MODE OF LIFE

About one-half natural size. (See text, p. 344)



2. SKULL OF A POCKET GOPHER, THOMOMYS BOTTAE (AT LEFT), CONTRASTED WITH SKULL OF A TREE-INHABITING SQUIRREL, SCIURUS DOUGLASII (AT RIGHT); BOTH NATURAL SIZE

The body weights of the two animals were approximately the same, namely, 225 grams. Note the great development of the facial parts of the gopher's skull, as also the reduction of the orbit and the heavy ridging of the brain case. (See text, p. 345)

apprised of goings-on outside the walls of its tunnel, it does need to be aware of conditions in front and behind. We find that it moves in its cylinder nearly as well in backward direction as forward.

Since, as seems apparent, the general question of the pocket gopher's occurrence over wide territory must take into account its very special mode of gaining a livelihood, it will be useful in our discussion to inquire further as to its digging proclivities and the structures correlated with these. Comparison of the pocket gopher as an extreme type of digger with, say, the California ground squirrel shows significant differences. While the brain case has in the two animals relatively about the same capacity, the skull of a gopher is four times as heavy as that of a ground squirrel, total weights of the two animals being considered. As indicated above, the skull and teeth of the pocket gopher, together with the muscles which operate them, comprise the chief engine of digging. This engine operates in powerful fashion in cutting away the earth, so as to make possible the rapid extension of the gopher's underground system of passageways. The adequate housing of the heavy incisor teeth and the need of meeting the severe stresses during the action of the muscles which operate the jaws have resulted in the great thickening and ridging of the bones of the skull. We find that the fore feet are larger than the hind feet, a reversal of the ratio in animals which can run with agility, and the fore feet are provided with long, laterally compressed, curved claws. The forearm and shoulder are heavily muscled, and thus the actions of the jaws and teeth are supplemented in loosening and particularly in transporting the soil.

So far as is known, no pocket gopher goes into dormancy at any season; none either aestivates or hibernates. The source of food upon which the pocket gopher can depend year in and year out and which it can seek in safety is comprised in the underground stems and root stalks of various grasses and herbs. These it gets almost altogether by digging its way to them; it gathers food only as it can advance under cover. While it is true that gophers do pull into the temporarily open mouths of burrows, stems and leaves of above-ground plants, these latter, I am led to believe, constitute only a minor fraction of the total annual food supply of the animal. The only dependable food source, continuing throughout the year, is comprised in underground stems and roots. And this is an exceedingly important consideration in our present study, for the general geographic limitation of *Thomomys*, to North America west of the one-hundredth meridian coincides with the territory where sharp alternation of dry and wet seasons is characteristic of the climate. Linked up with this climatic peculiarity there is undoubtedly in the Southwest relatively greater abundance of plants with nutritious roots and thickened underground stems, which tide over the dry season, than in the remainder of North America, where there is no long dry season. In other words, the ancestral pocket gophers of the remote past made the fortunate discovery of an oncoming type of food source correlated with the increasing aridity of what came to be a marked climatic and vegetational province.

Restricting our attention now to *Thomomys* as the genus occurs in California, I will revert to the fact of its well-nigh universal distribution within the State. How can the fact of this wide distribution be harmonized with the restriction in the animal's mode of existence which we have just pointed out in some detail? Examination of the territory wherever pocket gophers thrive, from one end of the State to the other, does show most emphatically close concordance of occurrence with those very, and special, conditions—of suitable food, and of consistency of soil which permits of digging. In other words, these two critical factors are widespread, and wherever they extend pocket gophers have gone.

The hindrances, locally, to the spread of pocket gophers are comprised in, not altitude, not cold, not heat, but in discontinuity of ground wherein the pocket gopher can extend its burrows; in discontinuity of ground in which sufficient food of the kind the pocket gopher can use is available throughout the year; and of course, in impassable bodies or streams of water. In other words, we find operating as outright barriers to their distribution only ground such as lava flows which can not be penetrated by gophers, or ground which is too dry or too alkaline to support adequate plant growth for the gophers' food throughout the year, or permanent streams or bodies of water which gophers can not cross.

In this latter connection, the pocket gopher can thrive, we know, without ever drinking; in many parts of the State the only water it can get for long periods is contained in the plant tissues which it uses for food. On the other hand, the animal can live healthily in soil that is saturated with water. Yet it is forced out of the ground when the land is flooded, as during very heavy rains or when under irrigation. Not only a river itself, but the adjacent bottomland subject to overflow at high water, may thus be effective in limiting the spread of gophers locally. A gopher can swim short distances when forced to; but it does not take to water voluntarily. These facts bear on the problem of geographic differentiation of races now to be discussed.

I have pointed out that, despite the pocket gopher's extreme specializations in structure and habits, despite its restriction to a very narrow range of living conditions, yet the fact that these special living conditions are widespread has permitted of the very wide distribution in California, of this type of rodent. Now we come to deal with the observation that while our pocket gopher as a genus exists in every county of California, from below sea level to almost the highest altitudes, from the hottest to the coldest portions of the State, and from the driest to the wettest belts, yet the species represented under all these varying conditions is not the same; the genus

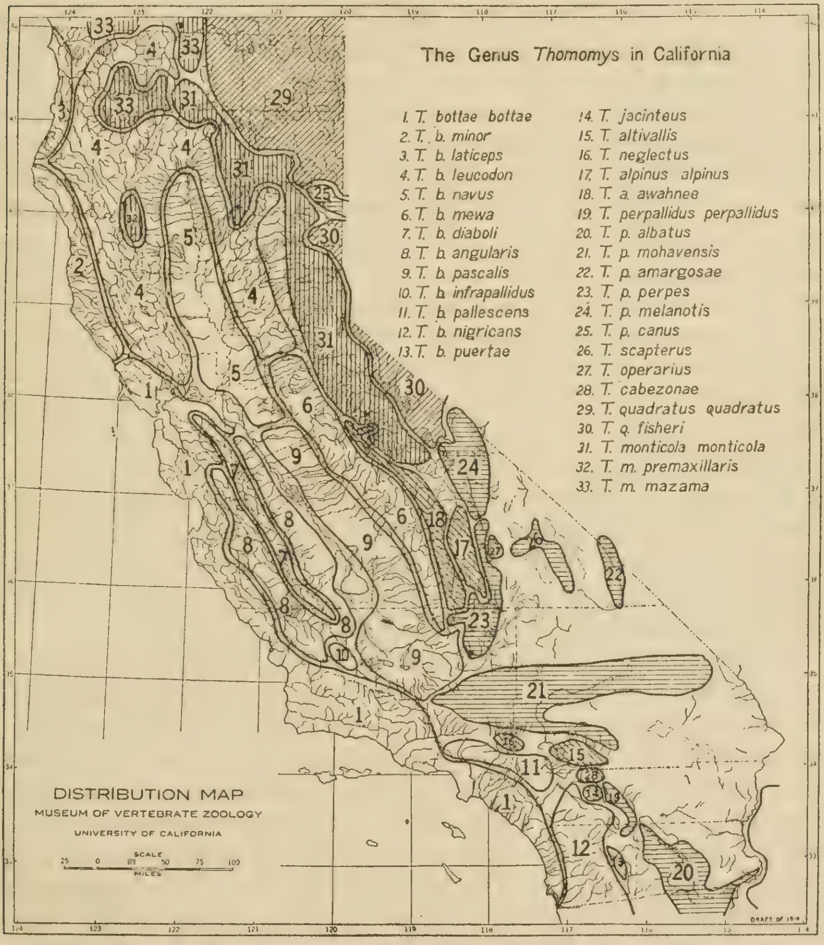


FIG. 1.—Map showing the distribution of the species and subspecies of pocket gopher in California

is broken up, as indicated on the accompanying map, into not less than 33 different races (species or subspecies), no two of them occupying precisely the same territory. And this fact signifies that the varying combinations of conditions resulting from the topographic and climatic diversity in California have made their impress upon the gopher substocks, which are more or less isolated from one another in what may be called differentiation provinces. It is our problem to inquire as to what factors among the present or recently past conditions have resulted in this isolation and consequent differentiation of all these various stocks.

As will be observed from the map, the most conspicuous gopherless areas in California lie in the southeastern desert territory, chiefly on the Mohave Desert. Extended explorations of that arid territory have been made, with the special object of determining the kinds and numbers of rodents and other mammals present. Almost every square mile of those deserts, save on such evaporation floors as those of "Searles Lake" and Panamint and Death Valleys (where there is a heavy deposit of saline substances, and no chance of plant growth), supports a large population of seed-gathering rodents—kangaroo rats, pocket mice, and ground squirrels of certain species. Throughout all the deserts there are, at times, heavy rains, though they may be at intervals of as long as three years; and such rains are followed by luxuriant growths of various herbs. These go to seed and thus give origin to a nutritious type of food, scattered by the winds throughout the drifting sands, to be sought out throughout the long dry intervals by the spermophilous mammals just named. But for the pocket gopher, specialized for gathering, masticating, and digesting roots and stems, and not for seed-gathering, the food resources of the desert are, over most of its extent, inadequate. Only here and there, on mountain tops, where rainfall is more copious and of more regular occurrence than in the surrounding territory, and about permanent springs, is there produced the proper type of vegetation for gopher consumption, in permanent supply.

As a result of these special conditions of food supply, the general distribution of gophers on the deserts is conspicuously discontinuous; the animals exist only in colonies here and there, because surrounded by unoccupiable desert; and such colonies are often far isolated from one another. The feeble powers of locomotion of the pocket gophers mean that they are unable to cross the barren intervals, and they are subjected to the same sort of factor, in evolutionary process, as land animals sequestered on islands in the sea. As happens under this circumstance the world over, we find that greater or less degree of inherent, subspecific or, indeed, specific, sets of differences characterize the more or less isolated stocks.

As an example of races of pocket gophers which evidently owe their origin to the isolation afforded by discontinuity of food supply, we may cite the form *scapterus* on the Panamint Mountains, which range rises high enough above the general base level of the surrounding desert to enjoy a fairly regular rainfall with a consequent copious growth of biennial or perennial herbs.

Another example, is the race *amargosae*, restricted to the immediate vicinity of the permanent springs in the otherwise dry and alkaline valley of the "Amargosa River," at Shoshone, Inyo County. This quite distinct form, in the *perpallidus* group of gophers, may appropriately be looked upon as a relict form from earlier times when conditions of moisture much more generally prevailed in the Great Basin territory, and when the dependent fauna and flora were correspondingly widespread. *Amargosae* is not the only mammal at Shoshone dependent, directly or indirectly, on the presence of permanent water; for there is (or was a few years ago) a distinct race of meadow mouse (*Microtus*) occurring around the same springs. Then the springs themselves contain a unique species of fish, residuary of a stock which evidence shows occurred widely in the general region in former times.

No pocket gopher whatsoever has been found in the depression of Death Valley, into which the "Amargosa River" empties. The lowest parts of the valley are too intensely alkaline to support any vegetation at all; and such water as there is around the margins is either too alkaline, too impermanent, or else too small in amount to have permitted the persistence of gophers there up until the present time.

Even such general areas as that indicated on the small scale map for the race *mohavensis* are not at all continuously occupied by pocket gophers; and examination of representations from different parts of such a general area shows minor differences characterizing the separated colonies. For example, those animals living in the bottom lands of the Mohave River differ slightly from those inhabiting the somewhat higher table-lands surrounding the Providence Mountains, in extreme eastern San Bernardino County.

The Colorado River is significant in our study, in that it has evidently long served as an impassable obstruction to the transfer of pocket gopher populations in either direction. The race *albatus*, occupying the delta and "second bottom" on the western side of the lower course of the Colorado River, is distinctly different in numerous respects, chiefly relating to the skull, from the form *chrysonotus* of the mesa lands on the eastern or Arizona side of the river. The actual distance apart of the nearest populations of these two species is not more than 2 miles in places, yet the intervening river and its "first bottom," of ancient existence and large and permenent volume, has acted effectively in preventing the interbreeding of adjacent stocks. Complete isolation accompanied by even slight difference of environment accomplishes much, granted plenty of time.

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A puzzle, at first glance, is offered by the occurrence of the two forms, *albatus* in the delta silts below Salton Sea, and *perpallidus* on the floor of the northwestern end of the same (Colorado) desert. Both races are restricted to fine-textured soil in the vicinity of water or where at least some underground seepage permits the proper growth of salt grass and other plants whose stems or roots are sought by gophers. *Albatus* follows the western distributaries of the Colorado River over the delta, and of late has found wonderfully favorable conditions for itself, with resulting enormous spread and multiplication of its numbers, on the irrigated lands of the Imperial Valley. *Perpallidus* occurs chiefly at the mouths of permanent streams coming down the cañons out of the San Jacinto and Santa Rosa Mountains onto the floor of the northwestern end of the Colorado Desert, known locally as the Cahuilla Valley. Why should these two races be as distinct as they are from one another when the floor of the general desert area they occupy is continuous, and only about 150 miles in greatest length?

Not long ago, even measuring in years, the northwestern arm of the Colorado Desert was occupied by "Blake Sea," of which the present Salton Sea is the residuum. More remotely yet, the Gulf of California extended continuously up from its present terminus clear through the Cahuilla Valley; and to-day the floor of that desert is in many places covered with shells of ocean-inhabiting mollusks, and shore lines at sea level are to be seen along the bases of the mountains which rise abruptly on either hand. The rapidly accumulating silts from the Colorado River filled in the depression opposite its mouth and cut off the basin of Blake Sea; and the arid climate resulted in the disappearance of the waters of that sea by evaporation. But completion of this cutting off of Blake Sea and the evaporation of its waters was of quite recent occurrence. We can, I think, look to the former long and complete separation of the gopher stocks as resulting in *perpallidus* and *albatus*, respectively, during the period that the waters of Blake Sea, at sea level, lapped the steeply rising rocks on either side, impassable to gophers. Complete isolation was thus afforded for the initial bottom land stocks of gophers at the northwest and to the southeast. With the retraction of the shores of Blake Sea, there is now no barrier between *perpallidus* and *albatus*, save as is comprised in unwatered tracts; and these are getting smaller with the spread of irrigation. It will be interesting to see what happens when and where the two gopher populations meet.

An additional case of isolation by desert conditions is that of *operarius* at Owens Lake, also a member of the *perpallidus* group. *Operarius* is a quite distinct form, so distinct with respect to shape of skull and teeth that individual variation does not bridge over the structural interval between it and its near relative, *perpes*. Hence systematists call it a species, rather than a subspecies, the only criterion for the latter systematic rank being intergradation or blending of its characters with those of another race. *Operarius* is restricted to the vicinity of the permanent springs which occur around the eastern side of Owens Lake in the vicinity of Keeler. There, under conditions of moisture obtaining very locally, there is a luxurious and permanent growth of salt grass, upon which almost exclusively this species of gopher depends for food.

An entirely different motif, as one may say, of differentiation is provided on the tops of isolated mountain peaks or ranges. In general, the 33 forms of the genus *Thomomys* in California fall into five "groups" of major systematic significance. These groups probably represent much older periods of differentiation, and the subsidiary forms have budded from each of these major stems. The composition by races and the distribution of each of the five groups is illustrated by the differential shading of the areas of four of them on the accompanying map. The area for the *bottae* group is left unshaded.

It will be observed that three of the groups, which may be called the *bottae*, *perpallidus*, and *quadratus* groups, respectively, are essentially lowland groups in that they occupy territory of relatively low altitude; while two, the *monticola* and *alpinus* groups, are high-mountain dwelling. In other words, it would appear that some condition associated with altitude has had critical effect in checking the unlimited spread of certain types upward and of certain other types downward.

Relatively thoroughgoing trapping of gophers along a typical section, transversely of the Sierra Nevada, in the Yosemite region shows a sequence of forms by groups from west to east as follows: *Pascalis*, of the San Joaquin Valley floor, and *mewa*, of the somewhat higher foothill, digger pine belt, belong to the *bottae* group; *awahnee*, of the *alpinus* group, occupies middle altitudes on the western slope; *monticola*, of the *monticola* group, occupies the whole upper country from about the 6,000-foot level to timber line and through the passes and down onto the upper eastern slopes; and at the eastern base of the Sierra Nevada is *fisheri*, of the *quadratus* group. (See accompanying profile, showing correlation with "life zones.") It would appear from this sequence of forms that temperature does, after all, in some measure constitute a factor bearing critically upon the successful existence of, and hence determining the geographical limitation of, these several species and subspecies of pocket gophers. It might be supposed that relatively uniform temperatures would everywhere surround an animal staying below-ground; but a fact bearing on this suggestion is that the high-mountain gophers all winter do extensive burrowing through the snow, thereby reaching in safety stems of plants above the ground surface!

Returning now to the subject of isolation of high-mountain types on disconnected mountain masses, interesting examples are afforded on the highest mountains of southern California by members of the *alpinus* group. These are *alpinus*, in the vicinity of Mount Whitney; *neglectus*, on Mount San Antonio, of the San Gabriel Range; *altivallis*, on the San Bernardino Mountains; and *jacinteus*, on San Jacinto Peak. As a rule, low-level types of gophers intervene in the low passes between these boreal colonies, sequestered as they are by some factor involved in altitude. As a further example of montane sequestration we find at the north, in the *monticola* group, *premaxillaris* set apart on the Yolla Bolly Mountains. But, curiously, we find *mazama*, of the same group, on the Trinity Mountains and on the

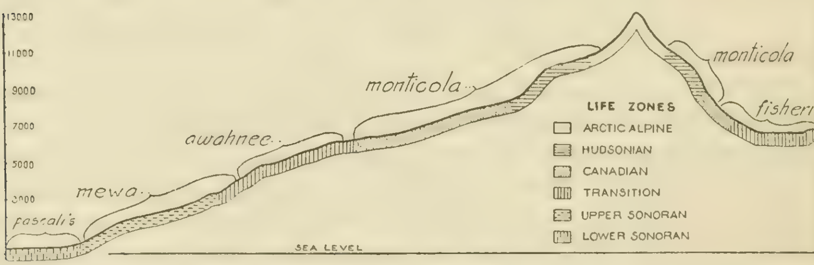


Fig. 2.—Sectional profile of the Sierra Nevada through the region of Yosemite, showing the location of the species and subspecies of pocket gopher according to altitude and life zone.

Siskiyou Mountains, both these representations without any detectable differences between them, separated by the valley of the Klamath River. This intervening valley is occupied by *leucodon*, a member of the *bottae* group.

With respect to differentiation within the lowland groups, we find an obvious association of the areas of differentiation with difference in climatic humidity—rainfall, or perhaps cloudiness. In this connection, the general northwest-southeast trend of the areas of occupancy of the different members of the *bottae* group is significant. Comparison of this map of gopher distribution with a rainfall map of California shows the parallel. Take an east-west section, gopherwise, from the coast at Santa Cruz, and we find *bottae* inhabiting the narrow, most humid, coastal belt; in the interior San Benito or other valleys, of lesser rainfall, we find *angularis;* on the hard-soiled, juniper-clothed ridges of the Diablo range, is *diaboli;* beyond this on the floor of the San Joaquin

Valley, but west of the river, is *angularis* again; to the eastward of the San Joaquin river flood-bottom is *pascalis*, chiefly in the bottom lands of the smaller rivers making down from the Sierras; and higher, on the hard-soiled foothills, is *mewa*. *Bottae* is darkest colored of all, *pascalis* is palest colored in this series; *bottae* is largest, but *angularis* and *pascalis* are also large; *diaboli* and *mewa* are small, the latter smallest. It would appear that the effects of varying rainfall, or of cloudiness, or of relative humidity of the air, are registered in varying tone of color. And soil texture affects size. The trend of the long, narrow area of occurrence of each of these races happens to be with the trends both of the rainfall belts and the mountain axes. The comparative study of the outlines of the ranges of animals brings clues as to the essential conditions for the special existence of each animal.

This matter of coloration of gophers presents a rather baffling problem. The paler colored forms are generally associated with arid habitats; the darker colored with humid habitats. *Bottae* of the coast belt as compared with the almost white *albatus* of the Colorado delta presents an extreme amount of difference. Is the factor which has to do with these diverse conditions of coloration, light, or temperature, or is it humidity of the air?

Let us remember that whatever the locality, the pocket gopher stays fully 99 per cent of its time within the underground burrow; and this burrow in desert territory, as well as elsewhere, may run through soil that is nearly or quite saturated with water, though, more often, it must be said, in deserts it extends through soil of relative dryness. In defense of the theory of concealing coloration, it can be urged that the moment of greatest hazard to the animal is the moment when the gopher exposes itself to view at the mouth of its burrow in pushing out earth, even though the total time involved may comprise only a minute a day. It may be that the pallor of the desert-inhabiting gopher, like *canus* or *fisheri*, in a statistical majority of cases, brings success in eluding enemies. Not so consistent with this theory is the fact that there are dark-colored gophers which inhabit the white sands of river valleys in relatively humid and cloudy belts; also there are pale gophers in arid territories, which live in very dark-colored soil, as in the case of *fisheri* in parts of the Mono Lake district. While in this particular matter of coloration no immediate explanation of the differences between the races is forthcoming, yet I have confidence that not only this, but each and every other character which we find to distinguish races, has its full adaptive justification in the scheme of existence.

Some reader may ask what grounds I have for assuming that long lapse of time is involved in this process of racial differentiation. Why may not the observed differences be induced rather quickly, in one or a very few generations of gophers, as conditions change locally or as the animals move about, say from one kind of soil into another? In reply: For one thing, we find the animals "true to type," in other words, relatively uniform in characters, each within its own distribution area—and this despite the great local differences in conditions. For example, *bottae* from the grassy tops of the Berkeley Hills is quite like *bottae* from the campus at Stanford University, and quite like *bottae* from the wooded slopes of the Santa Cruz Mountains, and also quite like *bottae* from the sand dunes at Seaside near Del Monte.

For another thing, we have in the Museum of Vertebrate Zoology specimens, skins and skulls, preserved by members of the State Geological Survey 60 years and more ago, representative of several of our Californian races. Compared with specimens of the same races collected to-day I see no appreciable differences.

And one other line of evidence pointing to the relative permanence of the species and subspecies with which we are dealing: From the Rancho La Brea asphalt deposits near Los Angeles there have been exhumed an abundance of excellently preserved skulls of *Thomomys* intimately associated with remains of certain mammals, now extinct, of known Pleistocene age. And those gophers show cranial characters identical with not only the species *bottae*, but with the subspecies *pallescens* as it exists in the vicinity of Los Angeles to-day. In other words, in upwards of 200,000 years which it is thought have passed since those Rancho La Brea gophers lived and died, there have been no changes in cranial features such as the systematist would recognize in separating geographic races existing to-day in different parts of southern California. This adaptive, evolutionary process is one which involves very long periods of time, therefore, when measured in years.

To summarize: In this essay I have set forth some of the facts in the natural history of the pocket gopher. I have picked out for especial comment those features of the animal, as regards both habits and structure, which seem significant in a consideration of its general distribution. I have also emphasized the fact of the differentiation of the pocket gopher type (genus *Thomomys*) in California, into numerous races—species and subspecies. Furthermore, I have referred to the seeming correlation of area of occupancy in each race with relative uniformity of the conditions of existence for that race. The inferior powers of locomotion of this type of rodent, as compared, say, with the jack rabbit, has brought upon it a condition of extreme provincialism, as it were. That is to say, especially with the contributing agency of more or less impassable barriers here and there, each of the many and diverse "gopher differentiation areas" thus formed in California has impressed its occupant with its stamp, namely, a peculiar combination of adaptive characters best fitting that gopher to carry on successfully existence in that restricted area. One more inference, of far-reaching implications, fairly forces itself upon us—that evolution of habitats (differentiation areas) must have preceded and guided differentiation of the gopher stocks which came eventually under their impress.

HOW BEAVERS BUILD THEIR HOUSES[1]

By Vernon Bailey, *U. S. Biological Survey*

[With 6 plates]

Beaver intelligence is neither human nor superhuman, as some would have us believe, but for the beavers' needs it meets, far better than human intelligence could do, every emergency of beaver life except one. The one exception is the man-made trap which swept these wise and useful animals to the verge of extinction before man began to realize the foolish waste of his greedy methods. Ages ago the beavers learned to cope with their natural enemies, to outswim, outdive, outbuild most of them, and so to live safe and comfortable lives. As builders of houses, dams, reservoirs, and canals, they have become famous and have won admiration and respect.

Their houses are not only homes, but fortifications, affording convenient, comfortable, and sanitary living quarters, and safe retreats from most of their enemies. A well made and long-established beaver house, with thick walls of tangled logs, sticks, roots, sod, and mud would baffle any animal less powerful than a bear, armed with strong claws and teeth, or man, armed with cutting tools. Even the bear and the man would be so long delayed in forcing an entrance that the occupants of the house would be far out of danger's way, and safely hidden in some other house or secure bank burrow.

Before a beaver house is begun a satisfactory location must be selected. Sometimes it is far from shore, out in water 5 or 6 feet deep, sometimes on the bank of a lake or stream, and often on a floating marsh just back from the edge of deep water, but always where a doorway from the bottom of the house leads down into water deep enough to remain open all winter under the ice. Out in the lake this is simple enough, and the doorway may open out in any direction; on the bank a long tunnel or subway must be dug from deep water up under the house to serve as an entrance and exit; on a floating marsh the beavers must swim under the sod and cut a hole up through to the surface, later building their house around and over it, perhaps the simplest and safest method of all.

[1] Reprinted by permission from Journal of Mammalogy, vol. 7, No. 1, February, 1926, pp. 41–44.

Most new beaver houses are begun where a feeding spot has been in use for a year or more, and such places are always numerous in a populous beaver colony. The water hole, or entrance, is the first step, then at its edges the peeled sticks left from many meals of bark are pushed back from the water's edge, or left to sink in the open lake to form an island. A long and peaceful possession of a feeding ground and a convenient food supply are important factors in the location of a new house, but sometimes the necessity of a mother beaver to provide a place for a new family, or of a father beaver to move elsewhere to make room for his newly arrived children, or some accident to the previously occupied residence, act as building incentives at any season of open water. Old peeled sticks are brought and laid around the water door, new bushes are cut and added to the circle, even trees are felled and the limbs and sections of small trunks brought and laid on the walls until they are two or three feet high, then more sticks are laid over the narrowing top, and last of all, often not until cold weather begins, mud and sods are brought up in great armfuls from under water and piled over the sides and on top of the house. Each year more sticks and more mud are piled on, and the older and larger the house, the more settled and tangled and thicker its walls become, and the safer is the household within. Sometimes a new house will be so thin-walled that the nest within may be seen through the chinks at the top, for the top is the last closed and always the least solid part.

But to return to the inside of the beaver house; instead of numerous rooms and elaborate apartments as once supposed, the inside consists of one room, generally two or three feet high, and three, four, or five feet wide, circular, oblong, or any shape or size, according as one beaver, a pair of beavers, a family, or sometimes two or more families, occupy it. If more room is needed the walls are hollowed out, the sticks cut off, and the earth dug back to make room in any desired direction, the massive walls, often two or three feet thick, allowing for any inside changes found necessary. Nine beavers, five young and four old, is the largest number I have ever found inhabiting one house, but others have reported larger families in very large houses. As the beavers all live in one room, it must be large enough to give sufficient air without becoming too warm, as it would if too small and crowded. More room, more ventilation, and lower temperature can always be obtained by making the walls thinner from within, and the beavers, with heavy fur coats to keep them warm in ice water, need cool houses. Even in solid old houses there is always some ventilation, and steam may sometimes be seen curling up from the peak on frosty mornings or frost crystals filling the cracks in the snow that covers the house in winter.

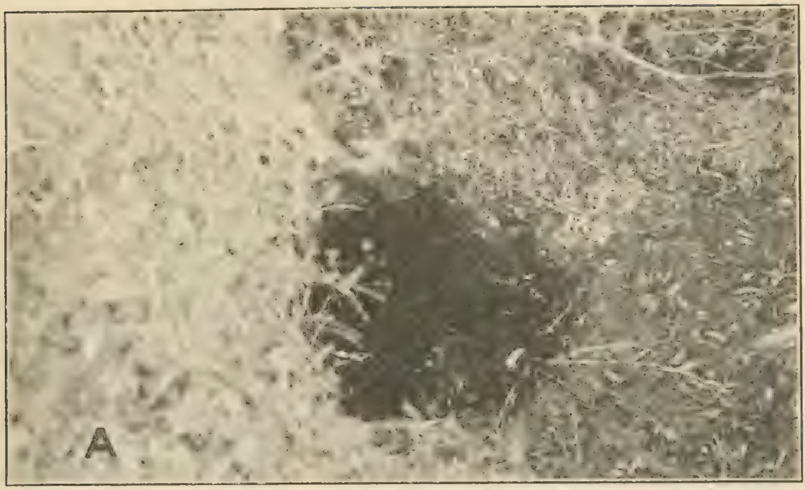
The beds are simply the floor of the house, a few inches above the water-level, usually strewn with bits of bark, grass, or roots left from the food, and are always damp but clean and well drained, generally somewhat musky with the not unpleasant odor of the musk glands. Fresh food is constantly being brought in and eaten, and the peeled sticks and refuse carried out. If the water rises the floor is built up, and if it falls the floor may be lowered to keep the beds near the water door. With newly born young in the house there is a softer bed of grass, leaves, twigs, and rootlets that serve also as food when the young are old enough to begin eating, probably long before they take the deep dive and long swim out to the world of light.

The large water door, usually but one, opens at one end or side of the floor, straight down into the water below the walls of the house, then leads out to the open lake, pond, or stream, often a distance of 10 or 20, and sometimes 40 feet before the beavers can come to the surface. Upon leaving the house the beavers rarely come to the surface near by, and often swim out 10 or 20 rods under water before coming to the surface to look around, or, if frightened, they may go half a mile or more under water and them come up under cover of the bank or shore vegetation, or enter another house or bank burrow. In returning to the house, if unafraid, they often swim up to within 4 or 5 rods and then go under water the rest of the way. Often by lying quietly near the house one can hear them go gurgling out through the water hole, then hear them come bubbling up into the nest chamber again and, if they have brought in food, hear the big chisel teeth scrape, scrape, scrape, as the bark is peeled off and eaten. When young are in the house their whimpering cries can often be heard from outside.

Most of the building and other work of the beavers is done at night so that only by long and patient waiting can one see even a small part of it being done, and the camera, even by flashlight, records but little of their nocturnal industry. Sometimes late in the evening or in the early morning twilight they may be seen cutting and dragging or towing trunks and branches for building material, and with their strong teeth dragging them up on the sides of the house and placing them as desired, or coming up from deep water with fore legs full of dripping mud, sticks, and leaves from the bottom, then rising to an almost erect position on the strong hind feet as they march up the steep slopes, steadied by the broad tails, to deposit their loads on the sides or tops of the houses.

Still more rarely does one get a glimpse of the interior structure of the beaver house, except in its early stages when, from a mere bed in the sphagnum moss, under the grass and low shrubs beside the water door, can it be watched until securely roofed over. On one occasion I happened to be close by when an old beaver on the inside stuffed and plastered up with mud and sticks a hole that had been dug by a mink through the walls of the house. The sticks were pushed into the hole and then mud pushed in around them until light, air, and troublesome neighbors were excluded.

All of the building must be done before the water freezes over and the houses are buried in snow, and the beavers shut in for the winter. With frozen walls there is little danger from outside enemies. The bears are asleep in their own winter dens and trappers are prohibited by laws from cutting into or disturbing beaver houses, even where beaver trapping is allowed. Where trapping is not allowed winter is the season of safety and comfort for the beaver folk, for the water under the ice can not get colder than the freezing point, the room in the beaver house is kept warm by the heat of the animals' bodies, and the food supply is convenient and generally ample. Just how this life is carried on will not be fully known until some of the beavers are tamed so that it will be possible to enter their houses through a "back door" without disturbing them, or get them to live in houses which we may build with modern improvements to suit their taste and our convenience. This will be necessary before beavers can be successfully raised in captivity, as the success of this branch of the fur industry will depend on a full knowledge of the habits, dispositions, and requirements of the animals.



THE BEGINNING OF A BEAVER HOUSE

The first step toward a beaver house is the water door, a big hole through which a beaver can plunge to safety, even from a mere summer bed in the sphagnum moss, sheltered by low bushes or tall grass

THE SECOND STEP

The next step is an accumulation of peeled sticks from which the bark has been eaten. As these are pushed back from the nest the walls of the house are slowly formed and can be quickly completed when a new house is needed. A small beaver house will seem to spring up in a single night, but always on an old foundation and around a satisfactory water hole

A YOUNG BEAVER HOUSE

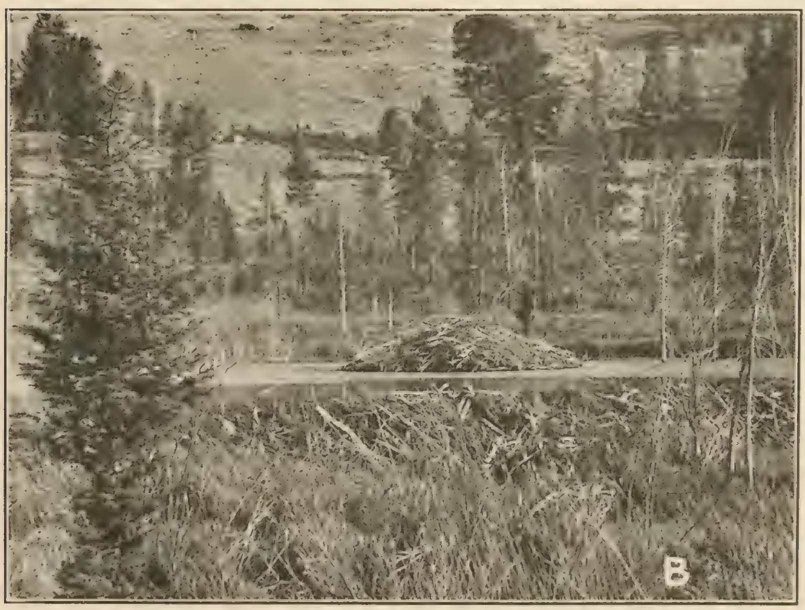
A new or recently built beaver house always has steep sides and is generally as high as it is wide. If located out in a pond or lake there is often as much or more of the house material under water as there is above

A WELL-BUILT BEAVER HOUSE

This house in the middle of a pond was being built up and thickened for winter use. Mud and sticks were piled on the sides and top every night, and green wood cached in the water near the house for winter food. Early mornings and late evenings the beavers were often seen at work on it

A LITTLE-USED BEAVER HOUSE

An old beaver house, not used since the previous year, is always low and wide, with mud washed out of the surface layer of sticks by many rains, and the walls well settled into the water. When used again it will soon be built up with a high and rounded top



A TYPICAL BEAVER COLONY IN THE MOUNTAINS

A well-kept beaver dam, pond, and house on one of the small streams in Yellowstone Park. Photograph by M. P. Skinner

AN ADIRONDACK BEAVER HOUSE

A large and rather new house in summer, before receiving its coat of mud. Estimated about 8 feet high and 35 feet wide at base

A WISCONSIN BEAVER HOUSE

A recently occupied house where the dam had been blown out and the water drained off, showing the foundation and an opening made into the nest chamber, which was large enough for a person to move about inside

A MINNESOTA BEAVER HOUSE

A large and well-built beaver house on the edge of one of Minnesota's numerous lakes

A VERY LARGE WISCONSIN BEAVER HOUSE

This beaver house was said to be 14 feet high and 40 feet wide.

Photographs by W. T. Gray

BEAVER HOUSE IN PROCESS OF CONSTRUCTION

The beavers bring up great armfuls of mud and trash from the bottom of the pond and spread over the top and sides of the house, alternating with sticks until the walls are solid and impenetrable

THE MOSQUITO FISH (GAMBUSIA) AND ITS RELATION TO MALARIA

By David Starr Jordan

[With 4 plates]

One of the most important discoveries of the nineteenth century was that of the nature of malaria, with its kindred diseases, yellow fever, dengue, and the like. It has been found that malaria is not a product of miasma or foul air, as the accepted name of "bad air" would signify. Neither is it "catching" in the ordinary sense of propagation by contact. It is borne from one person to another by the bite of mosquitoes. The big mosquitoes of the North (*Culicita* and the like) may offend by their abundance, their vociferous song, and their vicious bite, but they do not carry disease. The dangerous ones are smaller, less insistent, and with a softer voice, but some of them transmit active and dangerous poisons.

The cause of malaria of all sorts, ague, chills, and fever, "remittent" and "intermittent fever," as well as of the more vicious "Roman fever" and dengue or "break-bone fever," and the most virulent of all, the yellow fever, is the presence in the blood of multitudes of minute, parasitic animals, wormlike in form, which at intervals breed in prodigious numbers, with varied degrees of danger or discomfort. The biting of a man having malarial trouble by a mosquito of certain kinds (*Anopheles*, *Ædes*, and *Stegomiya*) transfers one or dozens of these creatures to its own body, causing it, no doubt, lamentable discomfort. Later the mosquito may bite another person "to take the taste out of his mouth," and in this next victim fever follows, thus passing the malady along from person to person through the agency of the mosquito's body. It is said that in most species only the female bites and that she does so chiefly after drawing blood.

The problem of the cure of malaria rests primarily on our skill in poisoning the malarial parasite with the least damage to their human host. Thus far the most successful method has been the use of salts of quinine. This is extracted from Peruvian bark derived from the tree, *Cinchona calisaya*, and numerous other species of *Cinchona* and *Reinija* and is fatal to all malarial microbes with which it comes in contact. Quinine is not a very wholesome drug as far as man is concerned though used under numerous conditions. The main point is that it kills microbes without killing the patient.

But prevention is always better than cure. The surest way to put an end to malaria ravages is to extirpate the mosquitoes. In rainy regions this is hard to do, but the worst kinds of mosquitoes belong to the Tropics or to regions just north of the Tropic of Cancer. They are often virulent in swamps, but apparently equally so in dry regions in ponds and puddles not connected with jungles. Thus certain districts in the Ukraine, in Anatolia, in Macedonia, in Greece, and in southern Italy have been historically notorious for malarial diseases. The Campagna of Rome, "Five Fingered Sparta," and probably Mycenæ, the original source of Hellenic culture, are classical examples of the undoing of populations by mosquitoes. The fading of "the glory that was Greece," due primarily to her suicidal wars, must have been in large part also the work of mosquitoes. I know personally something of their havoc in Macedonia and I am told that in regions about the Black Sea, Ukrainia, and Anatolia, the plague is still more virulent.

Near Salonika in Macedonia the Turkish authorities built an agricultural school and experimental station near the sea, at the foot of a marshy valley. This was found to be uninhabitable on account of the poisonous mosquitoes.

The work of our Army surgeons, Dr. Walter Reed, Dr. Jesse Lazear, Dr. James Carroll and their associates, in cleaning up fever-stricken Havana, is a classic in medicine. This has been followed up by the drastic purification of Panama, Vera Cruz, Guayaquil, and other poisoned ports, the work of Gen. W. C. Gorgas and others. To get rid of mosquitoes is now one of the most important elements in "preventive medicine" or sanitation.

But how shall this be done? There are three general lines of attack—to get rid of their breeding places, to cover these with oil, or to bring in an enemy which will devour their eggs and young. In this connection I may refer to a plan in Texas to build and protect bat houses, as bats in the night devour mosquitoes as well as other insects. But a colony of bats can operate on a very small scale only, and I need not refer to them further.

Pools and other breeding places can often be drained or filled up with sand or rock. As all mosquitoes lay their masses of eggs in quiet or stagnant water, in which they hatch, a layer of petroleum over the water will smother their larvæ or "wigglers" and will also prevent the winged insect from escaping. But there are many bodies of water in which neither of these methods can be used. In such cases, the mosquito-eating fishes are the best resort. A good many kinds of little fishes will eat mosquito eggs or larvæ when they find them convenient. Sticklebacks, young trout, some minnows, even gold fish do this to some extent. But what is needed is a kind of fish that makes mosquito killing its chief business, which enters on it with alacrity and which will not and can not harm other more choice kinds of fish. In southeastern Asia is a group known as *Betta*, little perchlike fishes, skillful as mosquito devourers, but quarrelsome and destructive to other small or young fishes.

The desired traits are found in perfection in the "top minnows" or "Gambusinos" of the genus *Gambusia* Poey. Of this genus there are numerous species in warmer parts of America. Most of them belong to coast streams of eastern Mexico. Two of them, very much alike, range through our South Atlantic and Gulf States. One of these, *Gambusia patruelis*, is found from Florida to Texas in sluggish streams of the Gulf States and northward to southern Illinois. Another, *Gambusia holbrooki*, extends from Georgia northward, in lowland streams, swamps, and rice ditches of the South Atlantic States, and ranging to the lake of the Dismal Swamp in Virginia. A third, *Gambusia affinis*, belongs to the Rio Grande region, and is now regarded as distinct from *Gambusia patruelis*, though the structural differences are small, and in their habits and food all three are doubtless alike. In Cuba, such littles fishes are called "Gambusinos," hence their scientific name *Gambusia*. When an angler returns without fish, the Cubans say, he has been "fishing for Gambusinos."

The United States Public Health Service has lately published a valuable series of experiments undertaken about Augusta, Ga., by Samuel F. Hildebrand, of the United States Bureau of Fisheries. This is entitled, "A Study of the Top Minnow (*Gambusia holbrooki*) in Relation to Mosquito Control."

Old travelers may remember that Hawaii, 20 and more years ago was cursed by mosquitoes. In my first visit to the islands (1900), large ones brought from Alaska by whalers in their water tubs, in the days when Hawaii was their chosen winter resort, ruled the islands by day, and a smaller form, probably from California, was heard at night. Neither of these carry malaria, but both were excessively annoying.

Mark Twain, at the old Hawaiian Hotel felt this grievance, and in a characteristic way set out to remedy it. Everyone in Honolulu then slept under a mosquito canopy and each night some of the smaller insects crept through the meshes. Mark waited until all the mosquitoes came in through the netting and then slipped out and slept on the floor.

But even this shrewd device often failed. At last, in 1904, the City of Honolulu (knowing the present writer to be a fish sharp), sent a credit of about $1,500 (of which about $600 was used) asking me to discover and send to the islands a fish that would really eat mosquitoes.

A California student will tackle any problem, and so I sent out Alvin Seale (then a senior at Stanford, now superintendent of the Steinhart Aquarium in San Francisco). He was instructed to go to Louisiana and secure from the bayous three species which might meet the demand. Each of them would eat mosquitoes, but in no case had their efficiency been tested. New Orleans was then once more in the throes of yellow fever, so Seale moved across to Galveston and filled his milk cans with the chosen fishes. Such fishes known as "Top-Minnows," Killifishes, and Cyprinodonts, are all very hardy if properly handled, especially if not handled at all, and very few died on the voyage to Hawaii.

Arrived at Honolulu, each species was tested out in aquarium tanks in drug-store windows, these filled with stagnant water, stocked with mosquito eggs. The largest fishes, *Fundulus grandis*, showed little interest in the matter. They were poured into a pool and have not been noticed since. The next species (*Mollienesia latipinna*) did better. This is a very handsome little fish, with high fins and varied colors, bright blue shades and spots predominating. But it is mainly a vegetable feeder, preferring "frog spittle" (*Confervæ*) to insects, and seemed not likely to be of any value in the task assigned to it. It has become very abundant in the estuaries of Hawaii. It is valued for aquaria and is largely used as bait for the Aku, or Victor-fish (*Katsuwomus*), and other predatory species.

The third set of fishes (*Gambusia patruelis*), rose at once to the occasion, and almost instantly cleared the aquarium of mosquito eggs and wigglers. This, with its twin of further east, *Gambusia holbrooki*, is no doubt the greatest mosquito killer in existence. It has lived and multiplied in all available waters in Hawaii. It swarms in irrigation ditches and in pools in the rice fields. It is so abundant that it is now gathered up in nets, baked and crushed as food for the fishes in the Waikiki Aquarium. It does not migrate to the sea and it does not attack other fishes.

In a recent visit of two months in Honolulu I saw but six mosquitoes, all of them small, no doubt hatched in rain pools, tin pans, or other small bodies of water, which the most assiduous fish can not reach.

From Honolulu the fish has been taken to Formosa by another Stanford student, Dr. Masamitu Oshima, former director of Fisheries in that island, whence specimens have been sent back to me. The fish was then brought over to Manila by another Stanford man, Dr. Albert W. Herre, director of Philippine fisheries, and it has become firmly established in Luzon. Large breeding pools have been established about Manila by Doctor Herre. From the Philippine streams and marshes about Singapore, Mandalay, and Bangkok either have been stocked by Dr. Herre, or are soon to be so. The fish is now distributed to southern Japan and China, and ultimately will be, I hope, to all the malaria-burdened world.

A native of warm regions, we are not sure how much cold it will stand. Last winter in California, the temperature dropped two or three times to about 30°, but none of the fish seemed to suffer. In early November the old fishes slip to the bottom in mud and weeds to keep warm, but the later born of the flock may be seen near the surface on any of the so-called winter days of central or southern California. The director of the Illinois pond at Carbondale reports that a foot and a half of ice did not kill any of them last winter, as they were all hibernating at the bottom of the pond. In their native regions, snow and ice are unknown, but they do not seem to mind moderate cold if they are allowed to lie still and are not expected to function. As to heat, Hildebrand reports that in nature he has found *Gambusia* in water having a temperature of 102° F. When held in containers they usually die when 100° F. is reached. They feed on flies and mosquitoes by choice, rejecting wasps, beetles, butterflies, or larger insects. I have seen them leap out of the water to seize an incautious fly alighting on the edge of their pond.

These fishes are light greenish brown in color, the fins speckled, but no conspicuous markings anywhere. In the adult there is usually a black shade or bar under the eyes, and the gravid females develop a black area on the side under the skin. The female is 2½ inches long, the male about an inch shorter. About 10 females are born to 1 male. The eggs are hatched in the body of the female, 6 to 10 in a brood, there being 4 or 5 broods between March and September. This is recorded in Georgia, with *Gambusia holbrooki.* In California, with *Gambusia patruelis*, I notice but two or three broods in a season. The young when born are transparent, with big black eyes, and are about a fifth of an inch in length.

A certain number die when first caught and placed in confinement. Those that survive the first three days mostly live on indefinitely. It is therefore well to hold a consignment for a few days before taking them for a long distance. In summer time about 150 can be transferred in July in a 50-pound lard can, and in October as many as 500. In summer time a wet jacket of burlap around a can is desirable, but ice and overaeration are both risky.

Mr. Hildebrand does not discuss the artificial feeding of these fishes. The very young evidently feed on minute or tender algæ, as desmids and *Confervæ.* The adult, in default of mosquitoes, take kindly to *Confervæ.* The *Gambusias* in my own pool are fed on goldfish food. The kind which is made of rice-flour pressed into flat cakes they eat eagerly, especially if cut or torn into very small pieces. The fact that this floats and can be reached on the surface from below, they seem to appreciate. The goldfish food made from crushed shrimps they will eat also, but as this soon falls to the bottom it is not so well adapted to their habits.

The *Gambusia* is very tenacious of life. It does not, however, endure rough handling, and the gravid females are very sensitive to harsh usage. They should be taken from the water in a dip net, not a seine. According to Mr. Hildebrand "the best container for transferring and shipping *Gambusia*, undoubtedly is the Fearnow fish can, a patented device. Excellent results can be had by the use of lard cans, lard tubs and similar containers. If secondhand vessels are used, they must be thoroughly washed and scalded with hot water." The water in the container should be shallow, forcing the fish to keep near the surface. This need indicates the undesirability of milk cans. When under way the less splashing the better. "The Fearnow can successfully overcomes splashing and is very convenient, for transporting fish over rough roads."

Mr. Hildebrand further adds that it is usually advisable to confine *Gambusia* in the water from which they were caught. If this water is foul, it should not be used. It generally is best when *Gambusia* in confinement are to be transferred from pond water, for example, to water from another source, to mix the waters at first and accomplish the change more or less gradually.

In establishing the mosquito fish in a new region, it is well to prepare a shallow pond some rods in diameter, with a lining of concrete to prevent leakage. So far as my experience in California goes, this should not be over 4 feet in depth. The pond may be stocked in the middle with pond lilies and water plants, not set so densely as to smother the little fishes or to prevent them from readily getting about when hunting down "wigglers." Even *Confervæ* (frog spittle), on which young fishes seem to feed, will help, but the plants need clearing out when too abundant. The sulphate of copper (blue vitriol), sometimes used to clear the water by destroying *Confervæ* and the like, is fatal to *Gambusia.* The little fishes, however, make no objection to sewage in the water, and flourish in the gutters of Vera Cruz and other filthy cities in which open ditches take the place of sewers.

As to the enemies of *Gambusia*, I have noticed but one especially destructive. This is the large water beetle, *Dytiscus*, about an inch long and of a shining brown color. This species entered my pool, and before it could be extirpated, one had killed a mother fish and another a goldfish.

In a small pool in a garden a fungus once appeared, forming a white ring about the eye in individuals attacked. I imagine that bass and similar carnivorous fishes would attack the *Gambusia*, and that it might fall prey to ducks, coots (mud hens), king-fishers, and other like birds of prey. To what extent these creatures would do mischief I can not say.

The present writer first brought the value of *Gambusia* to public notice in the Scientific American in May, 1926. Parts of that article are repeated here. Since then he has had an extended correspondence with persons interested, in various parts of the world—London, Paris, Berlin, Florence, Rome, Buenos Aires, Salonika, Singapore, Calcutta, and especially with the American Red Cross people, who hope to redeem those parts of Russia most specially cursed. For nowhere in southern Europe, northern Africa, nor western Asia is there any species of fish devoted to the destruction of mosquitoes and their eggs and larvæ. About the Mediterranean and the Black Sea its help is most particularly needed.

I may quote from a personal letter of Dr. L. W. Hackett, of the International Health Board of the Rockefeller Foundation, director of "La Stazione Sperimentale, per la Lotta Antimalarica" at Rome. He writes me of the work in Italy:

> *Gambusia* was first introduced into Spain by Dr. Massimo Sella,[1] director of the antimalaria work. by the help of the American Red Cross. Doctor Grassi, the famous Italian malariologist, had *Gambusia* brought to Italy from Spain. They were imported first to the drainage canals at Ostia and Fiumicino at the mouth of the Tiber and in the four succeeding summers have multiplied prodigiously. This fish seems to have left behind its natural enemies and to be more at home in Italian and Spanish waters than it ever was in America. For one thing, the weaker males, which in America are always found in disproportionately small numbers, here seem to survive and in many places equal the females in number.
>
> The International Health Board of the Rockefeller Foundation has recently established in cooperation with the Italian Government an experimental antimalaria station in Rome with field laboratories in different parts of Italy. This station has made a wide distribution of *Gambusia* in all parts of Italy, in Jugoslavia and in Dalmatia as well. It would therefore be a very simple matter for Mr. (John Henry) House to obtain these fish in Salonika.
>
> These fish, owing to the enormous numbers which develop in ponds and streams are more effective against mosquito larvæ than they were in America. They will penetrate many kinds of horizontal aquatic vegetation, and will do away with from 80 to 90 per cent of *Anopheles* larvæ. There are many types of water, however, both permanent and intermittent, to which they can not adapt themselves and our judgment is that although they are a great help in antimosquito work, conditions are rarely such as to make it unnecessary to do any other kind of antimosquito work. However, as their introduction is inexpensive and their maintenance practically nil, they represent a measure of which practically any community can avail itself in mild climates.

A hopeful pond was established at Tirana, the capital of Albania, and stocked with fishes from Rome. It was washed away by a "cloud burst" and the water all leaked out through its gravel bottom.

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[1] Doctor Sella, in a recent valuable report, records the establishment of 59 pounds in Italy, Yugoslavia, Macedonia. Albania, and Palestine.

A letter from Tirana to the Red Cross Courier, thus describes this mischance, unfortunate, though no doubt the fishes will reappear in other pools nearer the sea.

You must know of the *Gambusia*, some kind of a small fish which feeds on green vegetation in ponds garnished with the larvæ of the *Anopheles* mosquito. The strange thing about the fish, according to my information, is its intelligence. It will have its salad, I believe, dressed only with *Anopheles* larvæ. Some American doctor figured it all out.

Well, our school (Tirana) pledged itself to breed *Gambusia* in phalanx. We wrote to Rome of our latest enterprise and requested that the Rockefeller Foundation there be asked to arrange to transport fishes for a breeding pool in Albania.

We had the fish transported to Tirana and during the next hectic two days succeeded in establishing at the farm the first scientifically arranged fish pond in Albania. It was especially designed with cunning weirs to form the habitat of *Gambusia*, except that it had no waterproof bottom.

Water was turned into the new pond, the fish were tenderly removed from the patent Rockefeller tin and that night we went to bed with light hearts; such are the rewards of happy labor, and were we not in the thick of malaria campaign? For my own part I dreamt that I was watching a great *Gambusia*, up on its tail like a kangaroo, chasing some kind of a gaunt *Anopheles* specter all over the salt sea marshes that circle Durazzo.

And then I awoke. It was raining one of these miserable Albanian rains that drop out of a leaden sky and smother the earth with a blanket of water. It continued to rain all day and into the night. The next morning big Kesova Bill from the farm appeared at the school, tragedy written all over his erstwhile cheerful countenance.

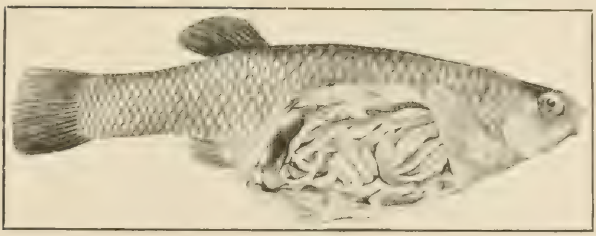
It appears that during the afternoon of the day previous he had inspected the pond and the *Gambusia*. The pond was all right. The fish were all right. The next morning early, he had an uneasy feeling that all was not well with our part of the malaria campaign. He went to the pond. Water and fish were gone; not a trace remained. No fish, no water, only bits of shiny white gravel over which they had disported themselves so confidently two days before.

Where did the fish go? Where did the water go? No one knows. We only know that they are gone and another mystery awaits solution. In the meantime we are praying the indulgence of the Rockefeller people in Rome for another consignment. Breeding time comes in the spring so that we have lost nothing and gained much in experience. Up to the present time, however, we can produce only excuses for our part in the malaria campaign. In addition to constructing a fish pond with a water-proof bottom we are also constructing a bomb-proof cellar as a matter of precaution should an expert drop into our midst with queries concerning the precious *Gambusia*.

From Manila I have an account of a home built on the shores of a pond, which the mosquitoes made uninhabitable. When Doctor Herre introduced the *Gambusia* into the water, the situation is reported as having become delightful.

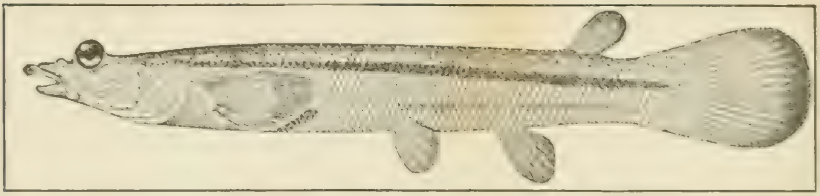
With *Gambusia holbrooki* or *Gambusia patruelis* or both, well established and active in the pools and swamps of Southern Europe and Western Asia, thousands of lives can be saved, millions of others rescued from perennial misery and hundreds of square miles now vacant, restored to industry.

1. GAMBUSIA HOLBROOKI, CHARLESTON. AFTER GARMAN

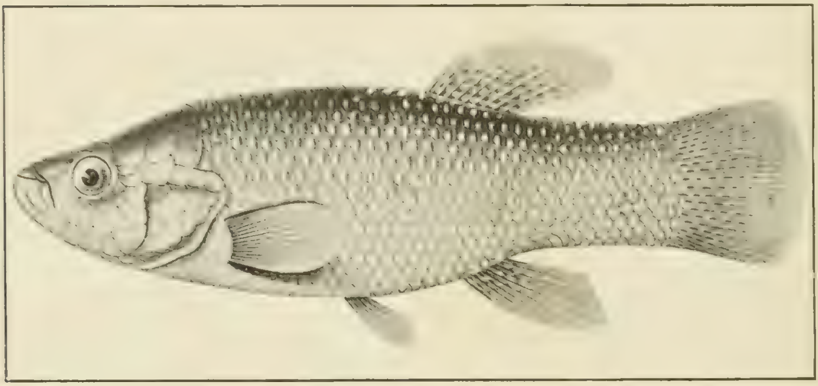


2. GOODEA LUITPOLDI (STEINDACHNER). A VIVIPAROUS FISH FROM LAKE PATZCUARO, MEXICO

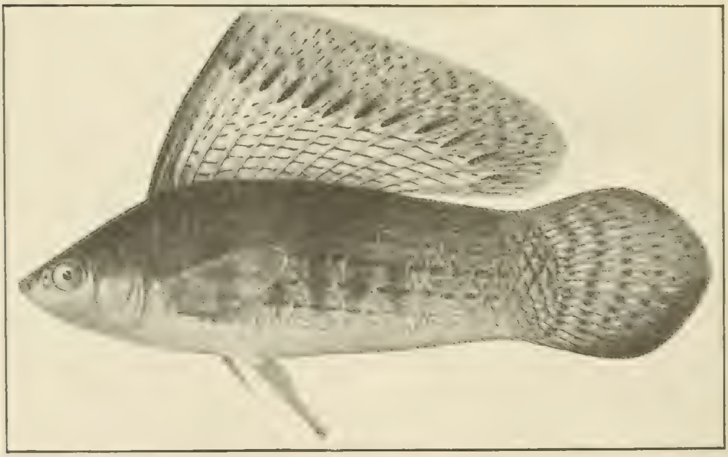
Family Pæciliidæ, showing the method in which the young are stowed away after the egg hatch. After Seth E. Meek



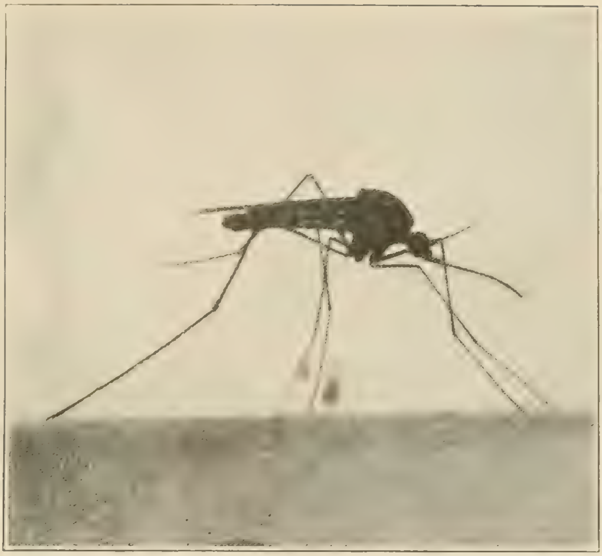
1. FOUR-EYED FISH, ANABLEPS DOVII GILL, TEHUANTEPEC, MEXICO



2. FUNDERLUS GRANDIS



3. MOLLIENESIA LATIPINNA

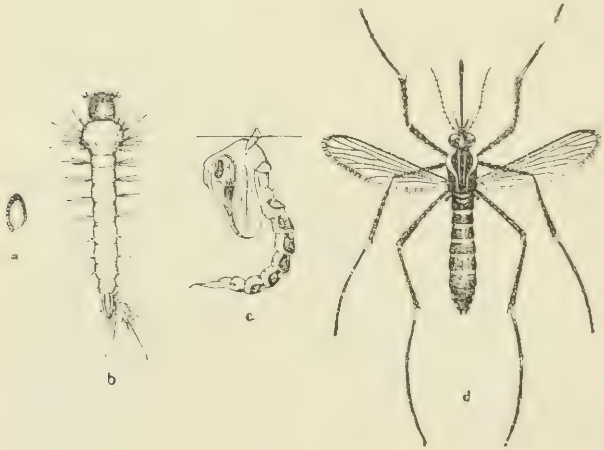


1. CULISITA INCIDENS. THE BODY OF THIS COMMON MOSQUITO IS HORIZONTAL WHEN BITING, GIVING ASSURANCE THAT IT WILL NOT TRANSMIT FEVER

2. ÆDES SQUAMIGER. A HARMLESS SALT-MARSH MOSQUITO. NO MOSQUITO THAT RESTS HORIZONTALLY WHEN IT BITES IS A BEARER OF MALARIA

1. ANOPHELES MACULIPENNES

This is the American malaria mosquito. It may be easily distinguished because it stands on its head when it bites



2. ÆDES AEGYPTI

This is the well-known yellow-fever mosquito which has caused the death of many millions of human beings

THE EFFECT OF ALUMINUM SULPHATE ON RHODODENDRONS AND OTHER ACID-SOIL PLANTS[1]

By Frederick V. Coville

[With 13 plates]

INTRODUCTION

Our native rhododendrons do not thrive in ordinary fertile garden or greenhouse soil, but they grow with great luxuriance in sand mixed with peat, or with rotting wood, or with half-rotted oak leaves. It is clear from many experiments heretofore made by the writer that, although both these types of soil contain an abundance of plant food, the rhododendrons thrive in the peat and sand mixture because the chemical reaction of the soil solution is acid, and they die in the ordinary fertile garden soil because the reaction is neutral or alkaline.[2] (Pl. 13.) Except in acid soils, most rhododendron plantings are failures. In nonacid soils the plants often subsist for a year or two on their old rootball of peat, but when that is used up they sicken and die if the surrounding soil is neutral or alkaline.

The statement had been going around among nurserymen that rhododendrons could be made to thrive in an ordinary fertile soil through the application of magnesium sulphate, commonly known as Epsom salts, and at the suggestion of Harlan P. Kelsey it was determined to try the experiment. Knowing that one of my colleagues, C. S. Scofield, had been using various sulphates in a remarkable series of experiments on the alkaline irrigated soils of the western United States, I asked his opinion regarding the probable action of magnesium sulphate in a rhododendron experiment. He replied that if magnesium sulphate would tend to bring about an acid reaction in an alkaline soil, aluminum sulphate should do it a great deal better. Aluminum sulphate therefore, happily, was included in the experiment.

[1]An account of the earlier experiments here described was published March 24, 1923, by the American Horticultural Society, as their Bulletin 1, under the title, "The effect of aluminum sulphate on rhododendron seedlings."

[2] See also "Experiments in blueberry culture," issued as Bulletin No. 193, Bureau of Plant Industry, 1910, and "The formation of leafmold," published in the Smithsonian Report for 1913, pages 333 to 343, also separately printed.

EXPERIMENTS WITH RHODODENDRON

A soil mixture was made up as follows: rotted turf loam, 1 part, by bulk; well-rotted cow manure, 1 part; and sand, 1 part. A portion of this soil was treated with a 0.6 per cent (M/20) solution of magnesium sulphate in sufficient quantity to supersaturate the soil, and this was afterward leached repeatedly with distilled water until the excess of soluble salts was removed. Another portion was similarly treated with a solution (M/60) of crude aluminum sulphate, and a third portion was leached with distilled water without other treatment.

On March 30, 1921, in each of these three portions of soil were set six seedlings of *Rhododendron catawbiense* in six 2-inch glass pots, each provided with a drainage hole at the bottom. The pots were plunged in sand in a greenhouse maintained at a temperature of 55° to 70° F., and were given uniform treatment as to light and watering. Within a month the cultures were showing pronounced differences in behavior, and after three months, on June 29, when the photographs shown in Plate 1 were taken, these differences were conspicuous. The plants in the untreated garden soil had made no growth. In the soil treated with magnesium sulphate the plants had grown a little, the increase in diameter of the rosettes of leaves being about 30 per cent. In the soil treated with aluminum sulphate the stimulation of growth had been very great, the increase in the diameter of the rosettes being about 250 per cent. In fact, these plants were almost as large as plants grown in an ideal rhododendron soil consisting of peat and sand. On May 27, 1921, when the beneficial effect of the treatment with aluminum sulphate had become clearly apparent, two of the pots were given an additional application of 1 gram of aluminum sulphate in 5 grams of water. These two plants were kept for observation in comparison with the six plants treated with magnesium sulphate and the six untreated plants. The condition of the three lots on July 28, 1922, is shown in Plate 2. All the untreated plants were dead. Of the magnesium-sulphate plants, two were alive, but they had made little growth. The aluminum-sulphate plants, however, had grown many times their original size.

When the beneficial effect of aluminum sulphate began to show itself from the first experiment, it was determined to try further experiments, in which ordinary porous earthenware 2-inch pots were to be used in place of glass pots, and aluminum sulphate was to be applied to the plants after they had been potted. The soil was made up as before, equal parts of loam, manure, and sand. The mixture was neutral or slightly alkaline in reaction and proved so injurious to the healthy rhododendron seedlings set out in it that they all stagnated and many of them died. Sulphate of aluminum was applied to similar plants in the same soil. The result, with one exception, was a definite and pronounced stimulation of growth. The exception was an experiment in which the aluminum sulphate was applied in a very strong solution, one-third gram of the ground sulphate in 1 cubic centimeter of water (M/2). This solution was so strong and the small seedlings, previously in active growth, were so delicate that about half of them were immediately killed. The surprising and significant feature of this experiment was that the seedlings that survived showed later the same stimulation of growth as those that were treated with milder solutions. The applications ranged in amount and strength from that cited above down to 10 cubic centimeters of a 0.57 per cent solution (M/60). The illustration of one of these experiments, in Plate 3, will suffice for all of them.

The next experiment to be described related to the possibility of resuscitating a sickly rhododendron in an ordinary garden soil by the application of sulphate of aluminum. On June 3, 1922, eight plants were selected from a large number that had been potted on May 3, 1921, in 2-inch porous earthenware pots in the fertile garden-soil mixture already described. For more than a year the plants had been stagnant and sickly. To each of four of the pots was applied half a gram of ground aluminum sulphate. The material was spread on the surface of the soil and dissolved and washed down with water. The other four plants were left untreated. All eight plants were plunged in sand and received afterwards the same greenhouse treatment.

After seven weeks a small amount of growth had taken place in all four of the aluminum-sulphate plants, barely enough, however, to be conspicuous in a photograph. The four untreated plants had made no growth.

As the effect of the aluminum sulphate was clearly beneficial, but slower than in the earlier experiments, it was decided to make a further application. On July 27, 1922, an additional half gram of aluminum sulphate was applied to each of the four plants to which the earlier application had been made.

On August 30, when the photograph reproduced in Plate 4 was made, 11 weeks after the beginning of the experiment, the difference between the two lots of plants was conspicuous, not merely in their size but still more in their color and texture. The aluminum-sulphate plants had made an increase of about 65 per cent in the diameter of their rosettes, and their leaves had the delicate texture and bright green color of plants in active and healthy growth. The untreated plants had made no growth. They were very sickly, their leaves a dull reddish-green color. The resuscitation of the four plants as a result of the application of aluminum sulphate is all the more remarkable because the soil in which the recovery took place had been in the pots for more than a year, subjected to the leaching action of the customary greenhouse watering.

That the aluminum sulphate had no direct fertilizing effect is evidenced by an earlier experiment, in which, when it was added to a soil composed of peat and sand, rhododendron seedlings showed no greater growth than in untreated peat and sand. The aluminum sulphate contributed no beneficial effect through the development of an acid condition, because the soil was acid already. If the aluminum sulphate had contributed plant food the rhododendrons would have made increased growth.

The plants concerned in this resuscitation experiment were repotted in the following year and the treatment of the two lots was continued as before. The plants to which aluminum sulphate had been applied remained healthy and reached the height of about 5 inches. All the others died.

The effect of aluminum-sulphate treatment when carried through a third year on rhododendron seedlings is illustrated in Plates 5 and 6. The plants in Plate 5 were from a lot that were first potted in 2-inch porous earthenware pots on May 3, 1921, in the standard neutral soil already described, equal parts of loam, manure, and sand. They remained in this injurious soil throughout the years 1921 and 1922 without repotting. Many of them died. On March 23, 1923, 21 of these plants, which were still alive, were repotted in 3-inch pots in the same neutral-soil mixture. Plate 5, from a photograph taken February 12, 1924, shows that some of these plants were dead and all the rest were sick. Plate 6 shows a lot of plants identical in origin, age, and treatment with those in Plate 5, except that they had received two applications of aluminum sulphate. The details are as follows: On May 3, 1921, after potting in 2-inch pots in a soil consisting of equal parts of loam, manure, and sand, each plant was given one-third gram of aluminum sulphate dissolved in water. They were not repotted in 1922, and not having been chilled in the winter of 1921–22 they made no new growth in the following summer.[3] On January 16, 1923, they were moved from the warmhouse (55° to 70° F.) to the coldhouse (35° to 40° F.) for chilling, and on March 23, 1923, they were repotted in 3-inch pots in a mixture of equal parts of loam, manure, and sand, to which one-half of 1 per cent, by bulk, of ground aluminum sulphate had been added. The plants grew vigorously during the season of 1923. On February 12, 1924, when the photograph used

[3] The trees and shrubs of cold climates, after becoming dormant, do not start into growth again in a normal manner until they have been subjected to a period of chilling. See "The influence of cold in stimulating the growth of plants," Smithsonian Report for 1919, pp. 281 to 291, pls. 1 to 27.

in Plate 6 was taken, they were in a healthy condition contrasting sharply with the bad condition of the plants shown in Plate 5, which had received no aluminum sulphate. The experiment shows that for this period, three years, the beneficial effect of the aluminum-sulphate treatment was continuing and cumulative.

EXPERIMENTS WITH FRANKLINIA

One of the rarest and most beautiful of trees is *Franklinia alatamaha*, a species discovered in 1765 by John Bartram on the Altamaha River in Georgia (at that time spelled Alatamaha) and named by William Bartram in honor of Benjamin Franklin. It belongs to the same family as tea and camellia and in late summer and autumn produces a succession of beautiful white, sweet-scented flowers 2 to 4 inches in diameter, with a mass of brilliant golden stamens in the center. The species has been referred by some botanists to the genus Gordonia, under the technical name *G. pubescens*, *G. altamaha*, or *G. alatamaha*, but its peculiar pods and seeds mark it as a distinct genus. All the plants have disappeared from the only place at which it has ever been found in a wild state. It is now known, therefore, only in cultivation. From experiments that I began in 1911 it was found that the tree is an acid-soil species, that it is easily propagated from cuttings and seeds, and that it grows luxuriantly and flowers profusely in the very acid soils of the pine barrens of New Jersey. Its rarity in cultivation and its reputation as a difficult plant to grow have been due chiefly to a lack of understanding of its soil requirements.

To obtain material to illustrate the behavior of franklinia in acid and nonacid soils a new experiment was begun on February 8, 1923. Ten well-rooted, dormant, leafless cuttings were potted in 3-inch porous earthenware pots in a standard acid-soil mixture consisting of two parts of kalmia peat and one part of sand. Eleven other rooted cuttings of franklinia were potted in the same manner in a neutral soil consisting of one part of rotted turf loam, one part of well-rotted cow manure, and one part of sand. Both lots were plunged in sand in a greenhouse maintained at 55° F. at night and 70° during the day. The plants varied somewhat in size, but they were selected pair by pair so that the two lots were exactly comparable except for the soil in which they were potted.

Eight weeks later all 10 plants in the acid soil were growing well, their leaves of a healthy green color, and their average height 4⅛ inches. Of the 11 plants in the neutral soil 2 were dead. The 9 that were alive had yellowish-green leaves, and their height averaged 3⅓ inches.

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Since the nine living plants in the neutral soil were evidently sick and getting worse, an experiment was undertaken to determine whether such sick plants could be resuscitated with aluminum sulphate. The nine plants were arranged in sequence, from the best to the poorest. To the second, fourth, sixth, eighth, and ninth was given 1.25 grams of aluminum sulphate each. This was immediately dissolved and washed into the soil by repeated syringing with water. Thus five of the plants made sick by the neutral soil were treated with aluminum sulphate and four were left untreated.

On May 16, at the end of six weeks, the average height of the four sick and untreated plants was 4¾ inches, their older leaves were yellowish green, some of the leaves were scalded by the sun, and the latest young leaves were nearly white. The other five plants, treated with aluminum sulphate, had resumed normal growth, with normal green leaves, though the older scalded leaves still remained pale. Their average height was 5½ inches.

Ten weeks later, on July 26, the treated and untreated plants were in the condition indicated in Plate 8. The untreated plants were small, pale, and weak. The plants treated with aluminum sulphate not only had recovered from their sick condition but had put out new leaves, shed their old ones, and grown to twice the height of the other plants.

In Plate 7 is shown, at the left, a normal healthy plant of franklinia, grown continuously from February 8 to July 26, 1923, in a naturally acid soil made up of peat and sand. At the right is a plant of the same history and treatment except that it was in a neutral soil consisting of one part each of loam, manure, and sand. It was pale, sickly, and less than a third the height of the other.

The two plates, 7 and 8, show conclusively the stimulating effect of soil acidity on this plant, whether the acidity is natural or is brought about artificially by the application of aluminum sulphate.

EXPERIMENTS WITH BLUEBERRIES

The aluminum-sulphate treatment has been applied to blueberry plants in an unsuitable soil, with the same stimulating results obtained in the experiments with rhododendron and franklinia. On February 4, 1924, 12 small seedling blueberry plants 5 months old were potted in 2-inch porous earthenware pots in an ordinary neutral greenhouse soil consisting of one part of rotted turf loam, one part of well-rotted cow manure, and one part of sand. On the following day each of them was given 1.25 grams of ground aluminum sulphate. The sulphate was placed on the surface of the soil in the pot and was then dissolved and washed into the soil by repeated syringing with water. The solution of aluminum sulphate was so strong that 5 of the 12 delicate and tender plants died within a few days. The remaining seven grew vigorously, with normal healthy color. On September 9, at the end of the season's growth, the seven aluminum-sulphate plants had an average height of 8½ inches. Growth of the stems had stopped for the year, and the leaves were of the normal size for healthy seedlings of this age, and of a healthy green color, except a few that were beginning to show their autumn purpling. The plants were of substantially the same size and vigor as other plants of the same origin which had been grown in a naturally acid soil of peat and sand. A typical plant treated with the sulphate is shown in the larger of the two figures in Plate 9. The small and sickly plant in Plate 9 is one of a lot of 24 plants having exactly the same history and treatment as the others, except that they received no application of aluminum sulphate. On September 9, 1924, when the aluminum-sulphate plants were in a normal healthy condition, with an average height of 8½ inches, the untreatd plants that were still living had an average height of 3 inches. Their leaves were small, those on growing tips pallid, those a little older pink instead of green. Growth still continued, in an abnormal and unseasonable manner, and very feebly and slowly. Three of the original twenty-four plants had died.

On April 17, 1925, both lots of plants were repotted in 3-inch pots, in the same soil as before, and the lot that had received the first application of aluminum sulphate was given another application, four grams to each 3-inch pot. At the end of the season, after the leaves had dropped, the seven plants treated with aluminum sulphate were all strong and vigorous, with an average height of 15 inches. Of the 24 untreated plants all but eight were dead. These had an average height of 3½ inches. The tips of all the stems were dead, the height of the live portion of the plants averaging only 2½ inches.

On March 31, 1926, both lots of these blueberry plants were again repotted in 4-inch pots, in neutral greenhouse soil as before. Each of the seven plants that had previously received the aluminum-sulphate treatment was given a new application of 8 grams. The ground sulphate was placed on the surface of the soil and each pot was watered four times, half an inch of water being applied each time. On the following day five additional waterings were given, in order to leach out any lime that may have been released, in the form of calcium sulphate, as a result of the application of the aluminum sulphate.

On April 12, 1926, the seven aluminum-sulphate plants, all of which were healthy, and six of the untreated plants, all of which were sickly, were placed in a chilling frame at 35°–40° F. Both lots of plants had been in a warm greenhouse all winter and were completely leafless and dormant. A chilling was necessary to bring them out of their dormancy. After 11 weeks in the chilling frame they were transferred to a greenhouse maintained at an ordinary summer temperature. On September 23, after three months' exposure to a temperature highly favorable to growth, the plants treated with aluminum sulphate were all in full leaf and in a healthy, vigorous condition. Of the six untreated plants four were dead. The better of the two remaining plants and the best of the seven aluminum-sulphate plants are shown in Plate 10. The aluminum-sulphate plant was 18 inches high, and its healthy condition was indicated not only by its appearance of general vigor but by the flowering buds that had been formed in anticipation of its next year's fruiting. The untreated plant was 5 inches high and the live part had a height of only 2¼ inches. Such leaves as were present were small and pallid, and it was evident that death could not be far away.

This experiment shows conclusively that potted blueberry plants, which die in an ordinary fertile but neutral soil, can be made to thrive in such a soil after it has been acidified by a suitable application of aluminum sulphate. The plants used in this experiment were highbush blueberry, *Vaccinium corymbosum.*

To determine whether a blueberry plant that is near the death point in a fertile but neutral soil can be resuscitated through the acidification of the soil with aluminum sulphate, 8 grams of this substance was applied on March 31, 1926, to each of two sickly plants in 4-inch pots. One of the plants was already so far gone that it afterwards died. The other plant, 4½ inches high at the beginning of the treatment, responded to the acidification, started into active growth, and by September 23 had reached the condition of health and vigor shown in Plate 11. The old stems, although their tips were dead, had put out new lateral branches, and a new shoot from the base of the plant had grown to the height of 8 inches. The resuscitation was definite, complete, and unmistakable.

EXPERIMENTS WITH HYDRANGEA

An experiment was made by the writer in 1923 and 1924 to determine whether the change in color of the flowers of the house hydrangea, *Hydrangea opuloides*, from pink to blue can be brought about by growing the plants in an acid soil. The experiment showed that this could be done and that soil acidity was the cause of this curious and conspicuous color change. While the experiment was in progress, however, C. H. Connors, of the New Jersey State Agricultural Experiment Station at New Brunswick, published similar results from experiments that he had undertaken earlier and independently.[4] An account of my own experiment, therefore, has never

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[4] "The control of color in hydrangea," Florists Exchange, vol. 57, pp. 1563 and 1564, May 17, 1924.

been published, but a brief description of it will be instructive in its relation to the present subject. On May 26, 1923, 13 small plants of the Japanese variety of hydrangea known as Otaksa were potted in 5-inch porous earthenware pots in a soil consisting of rotted turf loam 1 part, well-rotted cow manure 1 part, sand 1 part, and pounded crocks 3 parts. On July 18, 1923, one of the plants bloomed. Its flowers were pink. Ground aluminum sulphate was applied to the surface of the soil in each pot at the rate of 1 part, by bulk, to 200 parts of the soil. In the fall the plants were placed in a coldhouse for chilling, and on January 12, 1924, they were repotted in 6-inch pots in the same soil mixture as before, and moved to a warmhouse, 55° to 70° F. Two days later an application of aluminum sulphate was made, in the same proportion as the first, and washed into the soil by repeated sprinkling with water as at the first treatment. Other plants were given the same soil and treatment, except that no aluminum sulphate was applied. Others were given the same treatment, but in a soil consisting of 2 parts of kalmia peat, 1 part of sand, and 3 parts of crocks, or instead of crocks soft-coal cinders.

Plate 12, from a photograph made May 14, 1924, shows two plants typical of the lots they represent. The flowers at the left, of a pink color, were grown in the loam mixture without aluminum sulphate; those at the right, deep blue in color, were from the loam mixture treated with aluminum sulphate. The pink flowers came from a neutral soil, the blue from an acid soil. Blue flowers were produced also on the plants in a peat and sand soil, which was acid, although no aluminum sulphate was used.

The use of druggists' alum, placed in chunks in the pots to make pink hydrangeas produce blue flowers, is an old practice of florists, but the interpretation of the cause as a change in the soil reaction from neutral or alkaline to acid appears not to have been made until the outcome of the New Brunswick and Washington experiments in 1924.[5]

NATURE OF THE ACTION OF ALUMINUM SULPHATE

The nature of the fundamental action of aluminum sulphate on a neutral soil or an alkaline soil appears to be the replacement of the lime in the soil by aluminum, and the leaching away of the released

[5] It now appears that the same conclusion was reached a year earlier, by still another investigator. After the present paper had been sent to the printer, a colleague directed my attention to a paper by W. R. G. Atkins entitled "The hydrogen ion concentration of the soil in relation to the flower colour of *Hydrangea hortensis* W., and the availability of iron," published in June, 1923, in the Scientific Proceedings of the Royal Dublin Society, vol. 17, new series, pp. 201 to 210. The author concluded that in acid soils the house hydrangea produces blue flowers, and in alkaline soils pink flowers, and that the cause of the blue coloration is the presence, in the flower, of an unusual amount of iron, dissolved from the soil by reason of the acidity of the soil solution, absorbed by the plant in excess of its ordinary iron requirements, and therefore present in the state of "inorganic" iron, the direct effect of which is to turn the pink coloring matter of the flower blue.

lime in the form of calcium sulphate. Repeated tests show that after the application of aluminum sulphate to a soil of this type, the first leachings contain only a trace of aluminum but an abundance of calcium sulphate. The change in the soil reaction from neutrality or alkalinity to acidity is doubtless due at first to the acidity of the aluminum sulphate itself, but the continuation of the acid reaction is due apparently to the fact that the calcium and other substances that could neutralize soil acidity arising from aluminum salts or other causes, have been removed by the treatment described. The resulting condition is substantially that which occurs in a peat soil, the particular characteristic of which is acidity caused by the presence of organic substances. In the two lots of plants illustrated in Plate 4 the soil of the healthy plant at the right, seven weeks after the last application of aluminum sulphate, had an acidity of 10 on the Wherry scale,[6] while the soil of the untreated and sickly plant at the left was neutral. To summarize the matter, the application of aluminum sulphate may be regarded as an effective and rather inexpensive means of changing the reaction of a soil from neutral or alkaline to acid.

APPLICATION OF THE EXPERIMENTS

The aluminum-sulphate experiments described in this paper have not yet been extended by the writer to large plants growing in the deeper soils of outdoor plantings. For such situations amounts of aluminum sulphate up to a pound per square yard may be applied advantageously and safely if the soil is a loam of the ordinary fertile type, the application being repeated if the soil is not made acid by the first application. In applying ground aluminum sulphate to an outdoor bed the material should be distributed evenly over the ground, and mixed into the surface soil with a rake. The bed should then be watered thoroughly with as much as 2 to 3 inches of water in order to dissolve the sulphate and carry it deeply into the soil. The water should be so applied that it will not run off the surface but will sink through the bed past the roots, and leach out underneath. For greenhouse experiments 1 part of aluminum sulphate to 200 parts of soil, by bulk, may be taken as a standard experimental mixture. Persons desiring to experiment with sickly outdoor rhododendrons or other acid-soil plants are advised to apply the aluminum sulphate to only a portion of a planting, always leaving another portion untreated for comparison.

If a soil is already sufficiently acid, the application of aluminum sulphate is useless.

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[6] Edgar T. Wherry, 1922, "Soil acidity—its nature, measurement, and relation to plant distribution," published in the Smithsonian Report for 1920, pp. 247 to 268. Also, by the same author, "Soil reaction in relation to horticulture," published in May, 1926, as Bulletin 4 of the American Horticultural Society.

Outdoor experiments with aluminum sulphate should not be tried in mixed plantings unless it is known that all the plants are suited to a strongly acid soil, because the ordinary plants of horticulture, which require a soil with a neutral or alkaline reaction, are likely to be severely injured, or killed, by the aluminum sulphate.

Crude aluminum sulphate, such as was used in these experiments, is commonly known in the trade as sulphate of alumina. It is employed extensively in the chemical industries and is not expensive. In large quantities it can be purchased at about $30 a ton.

Experiments that have been in progress for several years have shown that soil acidity is required not only for rhododendrons, franklinias, and blueberries, but for azaleas, kalmias, heather, trailing-arbutus, wintergreen, and practically all the plants of the heath family, besides pink ladyslipper, sweet ladies-tresses, and many other orchids, and numerous other plants of ornamental horticulture that are commonly regarded as difficult of cultivation, such as bunchberry, vernal iris, birdsfoot violet, painted trillium, galax, pitcher-plant, and Venus flytrap. There is every reason to expect that these other plants also can be made to thrive in ordinary soils through the use of aluminum sulphate, provided the soil does not contain too much clay, for a heavy clay soil is unsuited, for other reasons, to most acid-soil plants even after it has been acidified. A knowledge of the usefulness of aluminum sulphate in the culture of acid-soil plants is likely to be of importance at the present time when the importation of these plants has been greatly curtailed through the plant-quarantine laws, and nurserymen are now trying to grow the needed plants inside the United States. Before the aluminum-sulplate treatment is applied extensively to ericaceous plantings, however, it remains to be determined whether the treatment if long continued may not lead to the development of unforeseen difficulties, such as the formation of compounds of sulphur injurious to ericaceous plants. For the present the aluminum-sulphate treatment should be regarded as experimental.

NATURALLY ACID SOILS PREFERABLE

Readers of this publication are especially asked not to conclude from these experiments that the best way to grow rhododendrons and other acid-soil plants is to put them in a neutral or alkaline soil and then apply aluminum sulphate. The best way to grow such plants is to remove the neutral or alkaline soil and put in its place a bed of naturally acid soil, such as sand mixed with peat, rotting wood, or half-rotted oak leaves. (Pl. 13.) Detailed directions for the preparation and maintenance of such acid soils are given in other publications. The following restatement, however, will be useful here:

In nature acid nourishment is provided by the accumulation, on the surface of the ground, of a layer of half-rotted leaves, twigs, and rootlets. Such an accumulation when it occurs in a sphagnum bog is called bog peat, or simply peat. On well-drained sandy or gravelly soils it is called upland peat. Under good conditions upland peat is laced into a tenacious mat, a few inches in thickness, by the roots of the ericaceous plants that accompany it, and this mat persists year after year, continually renewing itself through each year's leaf-fall and the penetration of new roots into the decaying mass. Upland peat is normally brown, but is often blackened by ground fires. On limestone soils or on soils which for any reason have an alkaline chemical reaction upland peat does not form. The lime and other alkaline substances in the soil greatly hasten the decomposition of the leaves. Each year's leaf-fall is decomposed, much of it passing in liquid form into the underlying soil, prior to the leaf-fall of the following year. Fully decomposed leaves form a true leafmold, black in color and neutral or alkaline in reaction, in which rhododendrons and other acid-soil plants will not grow. In soils derived from granite, sandstone, sand, and gravel, acid conditions are usually maintained with little difficulty by the addition of upland peat, half-rotted oak leaves, or decayed wood or bark.

Sawdust and spent tanbark are acid materials useful as mulch for acid-soil plants. They should be applied experimentally at first, however, to test the safety and suitability of the particular kind that is available. Some kinds of sawdust, notably redcedar and pitch pine, contain, when fresh substances that are directly injurious. Other kinds, such as basswood, maple, and birch, are free from these substances. In general it is best to use sawdust that is weathered and somewhat decayed.

When an attempt is to be made to grow rhododendrons or other acid-soil plants in a place in which the soil is neutral or alkaline, such as a limestone soil, the bottom land of a river valley, the ordinary fertile garden, or a prairie or arid-region soil, it is necessary to prepare holes or trenches and make up a special soil mixture. This should consist of 1 part of clean sand to 1 or 2, or even 4 parts of upland peat or its equivalent. To keep earthworms from bringing up the underlying soil the bottom of the hole should be lined with a 2-inch layer of soft-coal cinders. The depth of the peat and sand mixture need not be more than 8 to 12 inches. If the materials for the mixture are available in quantity a bed may be laid down over the whole surface of the ground. A permanent mulch of oak leaves will help maintain a proper degree of moisture and by decomposition will add to the peat supply.

In choosing peat for the culture of acid-soil plants two mistakes should be avoided. First, certain swamps contain a deposit that looks like peat but is neutral or alkaline in chemical reaction. The soil of such swamps, to which the name muck should be applied, is well suited to the culture of onions, celery, and lettuce, but altogether unsuited to the culture of rhododendrons and other acid-soil plants.[7] Second, the much decomposed peat in the submerged lower layers of deep bogs, such as is used for fuel in Europe, or the lighter kinds for stable bedding, is not suitable, by itself, for acid-soil plants. It is many years, often centuries, old and although it may furnish the needed

[7] For a further discussion of the opposing characteristics and uses of peat and muck, see "The agricultural use of acid peats," published in January, 1925, in the Journal of the American Peat Society, vol. 18, pp. 5 to 7, pls. 1 to 4.

acidity it is deficient in plant food. When such a peat is used, nourishment for the plant must be supplied in some other component of the soil mixture. A very light peat of this kind, imported from Europe, consisting chiefly of brown fragments of sphagnum moss, is much used in the United States as a mulch, as an ingredient of potting mixtures, and in cutting beds, for acid-soil plants. It is well suited to these purposes, but being deficient in plant food it should not be used alone, or with sand only, as a potting soil.

A sharp distinction should be made between half-rotted oak leaves and the ordinary compost of leaves with manure, garden soil, and garden trash. Such a compost is neutral or alkaline in reaction and should not be used on acid-soil plants. Sugar maple, elm, and linden leaves rot rapidly and so soon reach the alkaline stage that they also are not desirable for application to an acid-soil planting. Oak leaves, especially red oak leaves, rot slowly, and in two or three years, if the pile is turned over several times, make a good substitute for upland peat.[8]

No manure, lime, or wood ashes should be applied to rhododendrons or other plants that require an acid soil, for all these substances tend to neutralize the necessary acidity. Cottonseed meal, ground soybeans, and spent malt, all of which contain a large amount of nitrogen in organic and acid form, are excellent fertilizers for acid-soil plants. Experiments made by the writer in the spring of 1926 show that skimmed milk and buttermilk are useful as fertilizers for acid-soil plants.[9] Undoubtedly the partially dried forms of these products now marketed for poultry feed are also serviceable as fertilizer for such plants. The warning should be given, however, that skimmed milk contains about ten times as much lime as cottonseed meal and that the possible cumulative effect of repeated applications may require remedial measures, such as the application of aluminum sulphate to remove the excess lime. In very sandy soils for which so little peat is available that the plants suffer for nourishment the following special acid fertilizer devised for blueberries and cranberries will probably do well for rhododendrons, applied at the rate of an eighth to a fourth of a pound per square yard.[10]

	Pounds
Cottonseed meal	10
Acid phosphate	4
Sulphate of potash	2

Hard water, which is alkaline in reaction, will ultimately injure an acid-soil planting. Rainwater or some other water that is neutral or even acid in reaction should be used if practicable. If only alkaline water is available for sprinkling purposes it can be made neutral or slightly acid by dissolving in it a suitable amount of aluminum sulphate. The proper amount can be determined by adding to a teaspoonful of the treated water in a white dish a fraction of a drop of the dye known as bromthymol blue. If the amount of aluminum sulphate added to the water was just sufficient to make it neutral, its color under this test will be green; if it has become acid, yellow; if it is still alkaline, blue.

Ornamental plants vary in the degree of soil acidity or alkalinity to which they are best adapted. The preparation of authentic lists of species on this

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[8] For a more extended discussion of the decay of leaves and its relation to acid soils see "The formation of leafmold," Smithsonian Report for 1913, pp. 333 to 343.

[9] "Buttermilk as a fertilizer for blueberries," Science, vol. 64, pp. 94 to 96, July 23, 1926.

[10] For a discussion of fertilizer experiments see pp. 19 and 20 of "Directions for blueberry culture, 1921," Bull. 974, U. S. Department of Agriculture, 24 pp. and 29 pls.

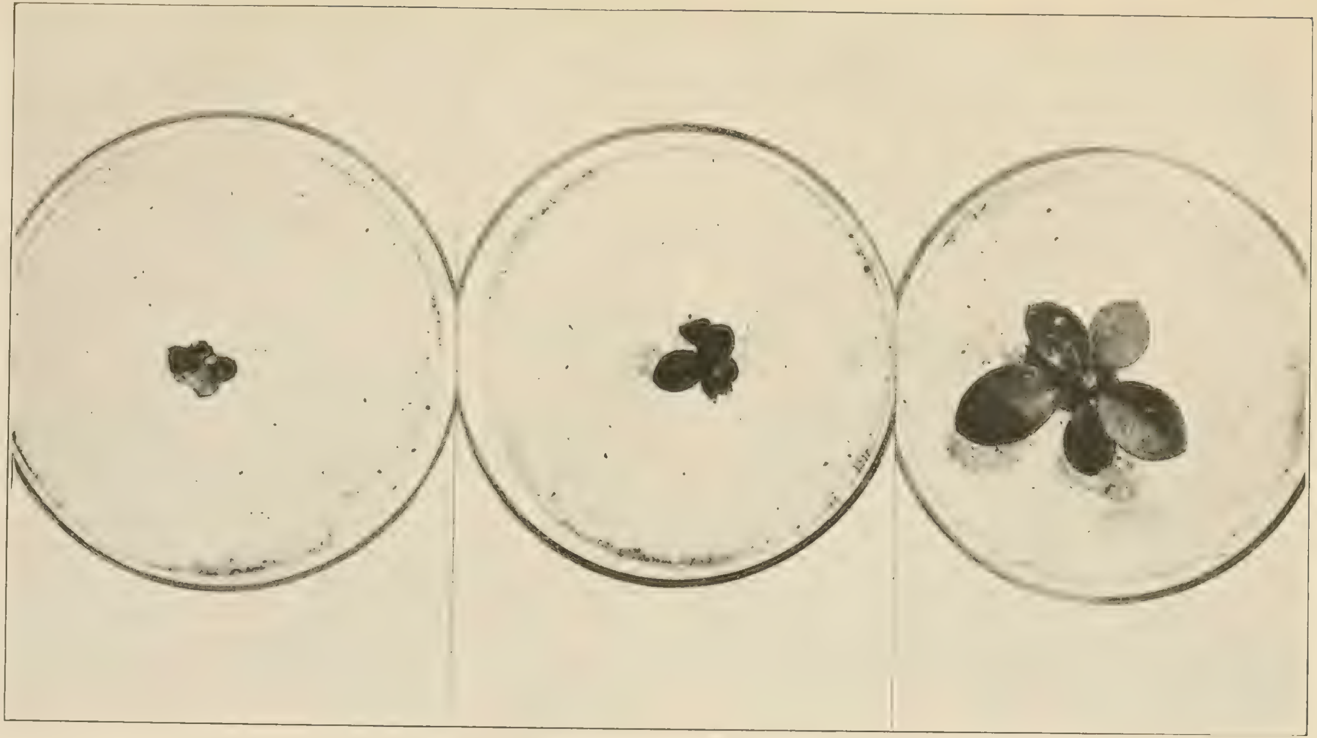
basis will necessarily be a slow procedure, the outcome of careful experimentation, but fortunately a general though not infallible guide to the need of soil acidity for a particular species is already in existence in such well-known works on gardening as Nicholson's Illustrated Dictionary of Gardening and Bailey's Standard Cyclopedia of Horticulture. European gardeners have learned from long and cumulative experience that certain plants thrive best when supplied with peat, and this knowledge has been handed down to us in garden literature, and in garden practice when conducted intelligently, but never apparently with any suggestion that the essential quality of the peat was its acidity. The statement in any reliable work on gardening that a particular species requires peat may be taken as good evidence that this species is an acid-soil plant. In very many cases, however, especially in American works, even this evidence is lacking. Fortunately there has been published very recently (May, 1926) by Dr. Edgar T. Wherry a paper that contains lists of plants classified according to the degree of soil acidity at which they thrive best.[11] [12]

CONCLUSION

If, contrary to the advice in the preceding paragraphs, a planting of acid-soil plants has been made in a nonacid bed, the plants can probably be saved by proper applications of aluminum sulphate. If an acid-soil bed has become neutral as a result of the use of hard water, or by reason of the excessive decomposition of the peat or the leaves originally placed in the bed, or from any other cause, treatment with aluminum sulphate will probably prove beneficial. If the cost of preparation of an acid-soil bed is prohibitive, in a locality in which the necessary materials are not easily available, then the acid-soil plants may be tried in an ordinary fertile neutral soil after it has been acidified by means of aluminum sulphate.

[11] "Soil reaction in relation to horticulture," 1926, Bull. 4, American Horticultural Society, 14 pp.

[12] Much of the information contained in the eight preceding paragraphs has been used for several years past, under the title "Experiments in rhododendron culture," to answer letters of inquiry on this subject addressed to the United States Department of Agriculture. It was published in 1923, so far as the experiments up to that date permitted, on pages 336 to 341 of L. H. Bailey's "The cultivated evergreens," under the heading "Acid soils for certain broad-leaved evergreens."



ALUMINUM-SULPHATE TREATMENT OF RHODODENDRON CATAWBIENSE FOR THREE MONTHS

The three plants were set in an ordinary fertile garden soil on March 30, 1921, in glass pots. When the photograph was taken, on June 29, 1921, the plant at the left had made no growth; the plant in the middle, treated with magnesium sulphate, had increased in diameter about 30 per cent; the plant at the right, treated with aluminum sulphate, about 250 per cent. The whiteness of the soil is due to a thin covering of white sand put on just before the photographs were taken. Natural size

ALUMINUM-SULPHATE TREATMENT OF RHODODENDRON CATAWBIENSE FOR 16 MONTHS

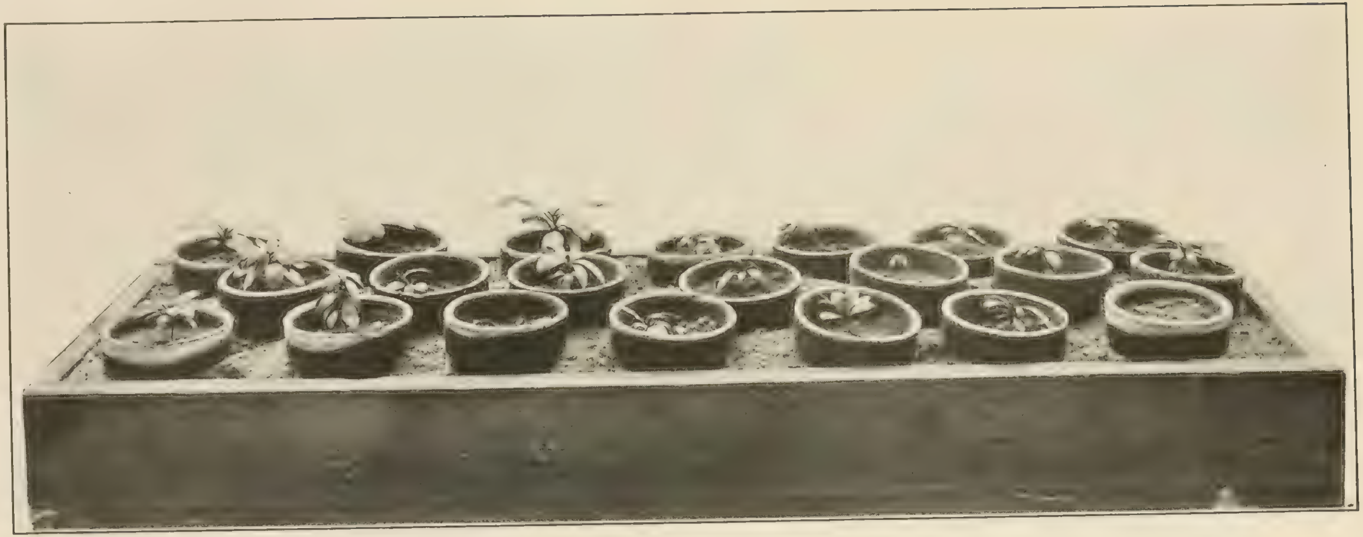
The plant in the glass pot at the left, in an ordinary fertile garden soil, died before the end of the 16 months; the plant in the middle, treated once with magnesium sulphate, is alive but sickly; the plant at the right, treated twice with aluminum sulphate, as described on page 370 has made luxuriant growth   Natural size

ALUMINUM-SULPHATE TREATMENT OF RHODODENDRON MAXIMUM FOR ONE YEAR

The plant at the left, potted on May 3, 1921, in a fertile garden mixture, which is not suited to rhododendron culture, had made no growth when it was photographed on June 3, 1922. The plant at the right, similar to the other in history and treatment except that it had received one-third gram of aluminum sulphate in 10 cubic centimeters of water on May 27, 1921, made luxuriant growth, almost as good as the plant in the acid peat-and-sand soil illustrated in Plate 13

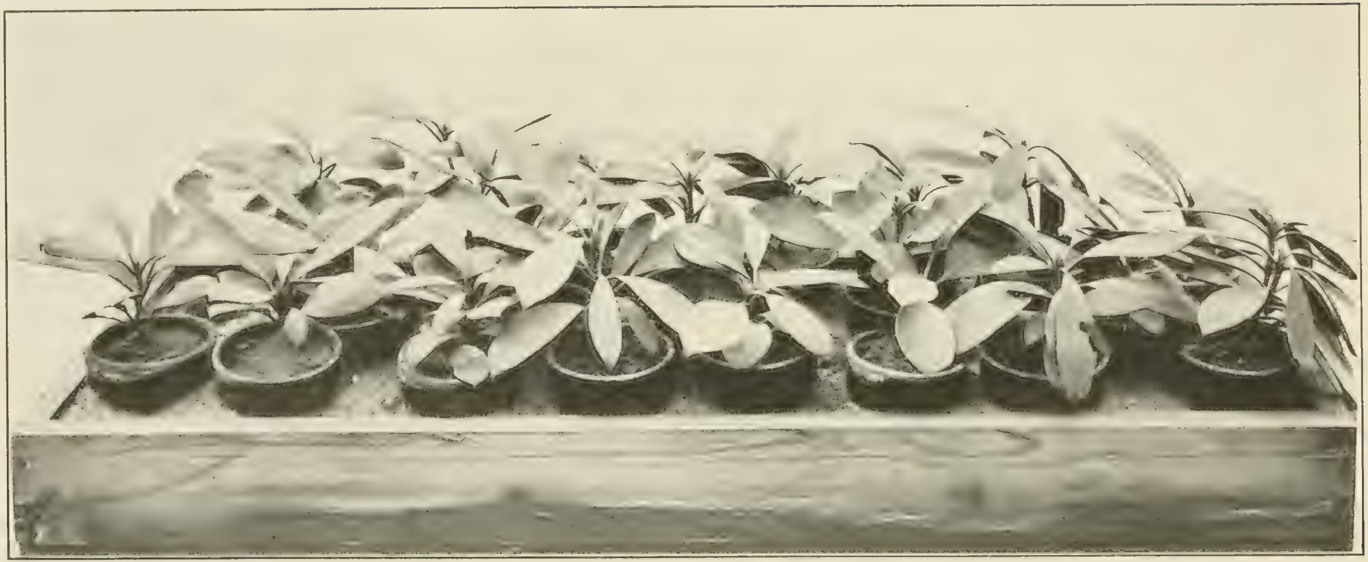
RESUSCITATION OF A SICKLY RHODODENDRON THROUGH TREATMENT WITH ALUMINUM SULPHATE

Both these plants had stagnated and become sickly after May 3, 1921, when they were potted in an ordinary fertile garden soil, which is injurious to rhododendrons. On June 3, 1922, half a gram of aluminum sulphate was applied to the plant at the right, and on July 27, 1922, another half gram. On August 31, 1922, when the photograph was taken, this plant was in active and healthy growth, while the untreated plant at the left, was still stagnant and sickly. Natural size



RHODODENDRONS SICKLY OR DEAD AFTER THREE YEARS IN ORDINARY FERTILE SOIL

Plants of *Rhododendron maximum* which had survived for two years in fertile garden soil were repotted March 23, 1923, in 3-inch pots in the same kind of soil. On February 12, 1924, when the photograph was taken, some of the plants were dead and all the rest were sickly. These plants, which were in a neutral and therefore injurious soil, are to be compared with those in Plate 6, which were grown in the same soil after it had been acidified with aluminum sulphate. About one-fifth natural size



HEALTHY RHODODENDRONS GROWN THREE YEARS IN ORDINARY SOIL MADE ACID WITH ALUMINUM SULPHATE

These plants, photographed February 12, 1924, had been growing for three years in a fertile garden soil made acid with aluminum sulphate. Their healthy condition contrasts sharply with the sickly condition of the plants in Plate 5, which were in exactly the same soil, except that no aluminum sulphate had been applied. About one-fifth natural size

INJURIOUS EFFECT OF ORDINARY RICH SOIL ON FRANKLINIA

At the left is a typical healthy young plant of franklinia grown in a standard acid soil. The plant at the right which, at the beginning of the year, was a healthy well rooted young cutting like the other, had been for five months in a fertile but neutral garden soil. In this soil it had become sickly and on July 26, 1923, when the photograph was taken, it was nearly dead About one-third natural size

RESUSCITATION OF A SICKLY FRANKLINIA THROUGH TREATMENT WITH ALUMINUM SULPHATE

The plant at the left was almost dead from five months' contact with an ordinary fertile but neutral garden soil. The plant at the right was in the same soil for the first eight weeks and became sickly like the other. It was then given an application of aluminum sulphate, which changed the soil reaction from neutral to acid. After three months' contact with the acid soil the plant had recovered its health and resumed normal growth ,as shown in the illustration. About one-third natural size

ALUMINUM-SULPHATE TREATMENT OF THE BLUEBERRY FOR SEVEN MONTHS

Both the plants shown in this illustration were small healthy seedlings of the same size on February 4, 1924, when they were potted in a fertile but neutral garden soil known to be injurious to blueberry plants. The plant at the left was given a heavy application of aluminum sulphate. On September 9, when the two plants were photographed, the beneficial effect of the aluminum sulphate was conspicuous. Two-thirds natural size

ALUMINUM-SULPHATE TREATMENT OF THE BLUEBERRY FOR THREE SEASONS

The plant at the left has been in an ordinary rich garden soil for three seasons. It is small, pallid, and half dead. The plant at the right, healthy and ready to bear fruit the coming year, is in the same soil as the other, except that it received each year, at the time of repotting, an application of aluminum sulphate, which changed the soil reaction from neutral to acid About one-third natural size

BLUEBERRY PLANT RESUSCITATED WITH ALUMINUM SULPHATE

On March 31, 1926, this plant was in a sickly dwarfed condition after two years in an ordinary fertile but neutral soil, and it was getting worse. Aluminum sulphate was applied Six months later, when the photograph was taken, the plant had recovered its health completely and had nearly doubled in height. About three-fourths natural size

ALUMINUM-SULPHATE TREATMENT OF THE HOUSE HYDRANGEA

Both plants were potted in a fertile garden soil, made up of loam, manure, and sand. In this nonacid mixture the plant at the left produced pink flowers. The soil of the plant at the right was acidified by applications of aluminum sulphate. It produced flowers of a deep blue color. Blue flowers were produced also on plants grown in a naturally acid soil of peat and sand, without the use of aluminum sulphate. About one-fourth natural size

STIMULATING EFFECT OF A NATURALLY ACID SOIL ON A RHODODENDRON

In early May healthy seedlings of *Rhododendron maximum* were set in 2-inch pots in an ordinary fertile garden soil composed of equal parts, by bulk, of loam, well-rotted cow manure, and sand. Other similar plants were potted in 2 parts of upland peat to 1 of sand. In June of the following year, when the photograph was made, the plant at the left, in the neutral garden soil, had made no growth, while the plant at the right, in the strongly acid peat soil, had made normal and luxuriant growth. It is better, whenever practicable, to give acid-soil plants a naturally acid soil than to put them in a neutral soil and then acidify it artificially with aluminum sulphate. Natural size

EASTERN BRAZIL THROUGH AN AGROSTOLOGIST'S SPECTACLES

By Agnes Chase, *United States Department of Agriculture*

[With 9 plates]

The flora of eastern Brazil is of especial interest to the student of tropical North American plants. Except for a limited amount of botanical exploration in Jamaica and in Santo Domingo before the revolution at the close of the eighteenth century, but few botanical collections were made in the Tropics of North America until after an important scientific expedition to Brazil had made known much of the flora and fauna of eastern Brazil and part of the valley of the Amazon. Brazil, the West Indies, and Panama have many species of plants in common. In working on a family of plants of the North American Tropics, therefore (in my case, grasses) it is necessary to have a fairly detailed knowledge of the family as found in Brazil.

The Brazilian expedition referred to in the preceding paragraph was sent by Francis I of Austria as an honorary escort to his daughter Leopoldina on her voyage to Brazil to marry the crown prince of Portugal and Brazil, the man later known as the "Liberator," Pedro I of Brazil. This Francis was a grandson of Maria Theresa and he was the grandfather of Maximilian, the short-lived "emperor" of Mexico and of the late Francis Joseph of Austria. Francis I was a patron of science and an opportunist in politics. In 1810 he gave his daughter Marie Louise to Napoleon, then at the height of his power; and in 1817, Napoleon being out of power, he gave his younger daughter Leopoldina to the royal family that had fled before Napoleon from Portugal to Brazil. Poor Leopoldina seems to have been as reluctant a bride as was Marie Louise. She delayed her departure so long that some of the eager scientists of the honorary escort set sail without her. Martius, the Bavarian leader of the scientific expedition, together with Spix, Mikan, and others set out for Brazil and arrived at Rio de Janeiro in July, 1817, while Leopoldina did not arrive until November. She lived but eight years longer. Dom Pedro, the last emperor of Brazil, was her son.

Pohl, Natterer, and Schott of Vienna, Raddi of Tuscany, and other botanists and zoologists accompanied the bride or followed, so that young Brazil for a time swarmed with naturalists. Publication of their results began to appear as early as 1823 when Raddi's Agrostographia Brasiliensis, a little volume of 58 pages, the earliest work on South American grasses, was published.

Except Pohl, who went as far as Goyaz, most of the naturalists remained in the vicinity of Rio de Janeiro or traveled short distances southward, but Martius and Spix, after a few months about Rio de Janeiro, went to São Paulo and from there made their way northward through Minas Geraes and Bahia to the city of Bahia. From there they went by boat to Ilheos and returned by land, then traversed Bahia, Piauhy, and Maranhão to the north coast, crossing Rio São Francisco at Joazeiro. They then traveled up the Amazon to some distance beyond Teffe (or Ega).

The Amazon and other parts of Brazil have since been explored by Germans, Swedes, Swiss, English, Brazilians, and in recent years by Americans, and the United States National Herbarium has, by exchange, come in for a share of the plants collected, but there was no United States National Herbarium at the time of Martius and but little since has been collected, at least of grasses, in the region he traversed in the interior; wherefore the grasses of that region were known to us only (or chiefly) from the specimens preserved in the herbaria at Brussels, Munich, and Vienna.

I reached Rio de Janeiro late November 1, 1924. The entrance to the bay has been described many times, and we are all familiar with pictures of it, but the reality is almost overwhelming. As we neared Sugar Loaf with peaks in all directions I had the sensation of sailing into the tops of a mountain chain on a flood.

The following afternoon I spent on Corcovado. As I clambered along a narrow trail on a steep slope I seemed to be following Raddi's footsteps, for I collected several of his species of grasses described from this mountain.

In spite of the dense population in the lowlands the mountains about Rio de Janeiro have not been spoiled for the botanist. Except for the invasion in places of *Melinis minutiflora*, called capim gordura (molasses grass by us), an African species early introduced into Brazil, the steep jungly slopes, I imagine, are not greatly changed from what they were a hundred years ago. As elsewhere in the Serra do Mar (the coast range) there are great bare slopes and knobs of dark granite or gneiss.

Rio de Janeiro is very healthful now. In the last three years a great hill in the city has been cut down, letting the sea air across to the back, and a tidal marsh is being filled with the material removed. The city is built in and out of the hollows between the hills, only a relatively few houses, mostly hotels for foreigners, being in the hills.

It is wonderfully lovely with trees and gardens, and everywhere hills for background.

Four days after my arrival I left for Pernambuco in order to reach that region before the dry season was much advanced. (Ships from the United States do not stop at any Brazilian port north of Rio de Janeiro.) Pernambuco, or Recife as the city is commonly called, lies on flat ground built up by coral reefs and mangroves (both *Rhizophora* and *Avicennia*). Extensive mangrove marshes surround the city and Rio Capiberíbe flows slowly through it. The city is cut into by tidal lagoons into which the mangroves are advancing. Recife is full of beautiful trees and flowering shrubs, royal palms, mangroves, caju (or cashew, *Anacardium occidentale*), breadfruit (*Artocarpus incisa*) and its next of kin, Jackfruit (*A. integrifolia*), *Carica papaya*, and coconut palms being the most conspicuous.

The surrounding region is densely populated. Wooded hills which at a distance showed no signs of being inhabited turned out to be full of huts and goats and children. In little clearings were patches of maize and beans, and a few banana trees and sometimes oranges. Vetiveria was planted about many of the huts. This is one of the oil grasses introduced from the East Indies. In the West Indies, the roots are used to scent clothing and to keep moths away, but here the grass is used to thatch huts. The caju is everywhere, a beautiful wide-spreading tree bearing multitudes of fragrant small maroon flowers, buzzing with bees, and fruit in all stages of development. These trees are a blessing to a blistering botanist. Whenever I sat down in their grateful shade to write up my notes and arrange the plants there was an excited squeaking in the tree above. I could see nothing through the dense foliage, and could not guess what sort of creature was worried by my invasion. I was told that it was the marmoset; then by patient and quiet watching I caught glimpses of little gray faces and bright eyes peering down with an expression of the most intense interest.

The low land is even more thickly settled than the hills, mud huts occupying little peninsulas in the mangrove marshes, the bit of land swarming with naked children, and the mud with fiddler crabs. The margins of fresh-water streams, ditches, and ponds are occupied by washerwomen while their children swarm in the water like tadpoles. The Brazilian lavandera is a worker of miracles. She washes clothes in muddy water, spreads them along the dusty roadside, and then brings them home glistening white.

Loads of capim da planta, *Panicum barbinode* (Pará grass, we call it) are continually being carried cityward on the backs of horses, less commonly in carts. This grass, which is the universal hay in Pernambuco, occupies practically all the low land. It is cut by hand.

The wet meadows and stream borders offered the best botanizing. Here were great paspalums and panicums higher than my head, tangled with aroids, ferns, and brush. I was surprised to find a bog that quaked even more than do Maine bogs. This was about half a mile long, and billowed under my feet in a way that made me gasp.

I wanted to see something of the sertão, the interior arid region. I had letters to missionaries in Recife, and from them I secured much helpful information. Here and elsewhere I found the missionaries to be the best sources of information. They travel everywhere, and like the botanists do it on a limited amount of money, and can direct one anywhere and give information about baggage and the numerous details that are so troublesome to a stranger unprepared for them.

Bello Jardim, 186 kilometers to the west in the Serra da Genipapo, at an altitude of 600 to 650 meters, was chosen as representative of the sertão. At about 50 kilometers west the arid region begins, and the land becomes higher and drier as we go.. Giant agaves, at the end of blooming, were falling or ready to fall. Agave seems to be cultivated to some extent for rope making. This plant after flowering assures a second crop of offspring by producing leafy shoots all along the horizontal old flowering branches, these ready to take root as soon as the parent stem falls to the ground.

The hills are covered with scrub or low trees, the "caatinga," consisting of *Mimosa*, *Acacia*, thorny shrubs, and semiarborescent cactus, except where it has been cleared for planting. Ground is cleared by burning, and cotton, sugar cane, castor plants, mandiocca, or tobacco are planted, sometimes here and there among the shrubs or tussocks of sedge that refused to burn down. There seemed to be little or no cultivation. Mandiocca, or cassava, from which the staple food farinha is made, was the only clean crop seen, except small patches of tobacco. There are no plows or other agricultural implements, planting and cutting being done with heavy hoes and large knives. When a field becomes overgrown with weeds or brush it is abandoned and a new place is burned. Land, I was told, is very cheap. The result is that cultivated spots are scattered, hit or miss, through the scrub, which is overgrazed by cattle, horses, donkeys, sheep, and goats, till only inedible shrubs and herbs, *Jatropha*, *Capparis*, and the like flourish.

The poor skinny animals eat everything bare except where a bit of soil is protected by thorny or bitter shrubs. I searched such spots for remnants of the original ground-cover, but most of the poor little refugees were introduced weeds. Bermuda grass (*Capriola* *dactylon*) clings to earth even when reduced to mats no larger than a 5-cent piece. If given the least chance it would cover the desolate earth; not a thing for the agrostologist to rejoice over, but it would benefit the poor animals. The bare ground is eroded more or less, but is held by the shrubs, except in the little villages where powdery dust fills the air. When the rains come the water runs off at once carrying the surface soil with it.

No forage crops are grown in the sertão except for little patches of Pará grass here and there along a stream. In November the dry season had only begun, yet every edible plant in the sertão seemed to have been consumed, and there were some eight months more to endure before the rains. A large thrifty looking milkweed (*Asclepias*), a low temptingly green herb growing in dense patches, and scattered plants of *Capparis* were not even nibbled. Palatable plants, overgrazed and not allowed to seed, have been exterminated and only such inedible herbs remain. The shrubs were mostly leafless, but many were in bloom, glowing patches of yellow of *Chamaefistula* and *Cassia* being conspicuous. A species of *Ruellia* with lovely mauve flowers was common in the scrub.

Garanhuns, 850 meters high in the sertão, 271 kilometers to the southwest of Recife at the end of the railroad, is much less barren and more progressive, with fairly good sugar-cane fields and with bullock carts in common use. From Garanhuns, accompanied by two missionaries, Mrs. Thompson and Miss Kilgore, I visited Paulo Affonso Falls in the Rio São Francisco, difficult of access until recently and not heretofore visited by a botanist. We made the trip, some 200 kilometers, by automobile over a newly cut road, leaving at dawn. About an hour from Garanhuns we dipped into the valley of a small river with fairly dense woods, then, reaching the hills again, the country became drier and drier. We were now in the true sertão in the basin of Rio São Francisco. The country was less desolate than that about Bello Jardim. Though the grasses and herbs were dead and bleached, many of the shrubs and small trees composing the caatinga were in gorgeous bloom, some leafless, some with brilliant green glossy foliage. Cashews and other large trees were met with here and there, and in two places where the road dipped to lower altitude were rather thick groves of trees hung with a *Tillandsia* like our Spanish moss. Small birds of astonishing colors—green, yellow, and raspberry pink in the same flock—flew up in an explosion of color. Doves, much like our ground dove of Florida, were common; also parokeets and the red, white, and blue (slate blue) "gallo das campinhas," seen before at Bello Jardim. This "cock of the fields" is a handsome bird about the size of our cardinal.

We reached Pedra, about 25 kilometers from the falls, just before sunset. There is a thread factory here, with light and power transmitted by a turbine station at the falls, both the property of the Gouveia family. Permission was secured from the factory manager to visit the falls, and a little after dark we set out. As we sped along, the headlights showing cactus and the pale gray stems of leafless shrubs, I waited breathlessly for the plunge into tropical forest. Finally we saw lights ahead and were met by a little crowd of men and boys. (The factory manager had telephoned that we were coming.) The automobile could go no farther; they would take us and our baggage on a tiny trolley on a narrow track. A man ran behind and pushed the car. The new moon had set but there was enough starlight to see that we were crossing deep places. We could hear the roar of the falls and, alighting after a ride of about half a kilometer on the trolley, we could see a wild turmoil of tossing waters. We clambered about a little to get a starlight view of the falls while Antonio, who had pushed the trolley car and who was our devoted friend till we left, hung our hammocks in an empty house and carried in our baggage. How could there be such mighty falls and such spray without verdure? Morning would reveal some dripping cliffs, I was sure, with trees and the climbing bamboos and tropical grasses I had been looking forward to. But at early dawn I left my hammock to view the greatest waterfall and the most lifeless desert I have ever seen.

At this time, early in the dry season, the falls were about 81 meters high. (Niagara is about 49 meters high.) In the rainy season in this region (June and July), and again in the rainy season at the headwaters of Rio São Francisco in Minas Geraes (December to February) the river is much higher, sometimes 15 meters or more above its present level below the falls. The Paulo Affonso is not one straight fall, as is Niagara, but is, rather, a stupendous cascade.

The power plant and a few small houses are on an island cut off from the mainland by two rocky channels, one of which was dry at this season. These channels are bridged by a trolley line about two and one-half feet wide, with planks down the middle for crossing on foot. At the falls a high island of dark rock (Secret Island) divides the river, the main falls being the left branch (looking down stream). The right branch (on the Bahia side of the island) can not be seen from the left bank. At the top of the main falls the river is divided by a great mass of rock, forming two falls which pour toward each other. Below this the waters pour in three divisions into a great plunge basin, into which also pour the waters of a lovely twin falls and, a short distance farther, of the great Bahia Falls, which subdivide Secret Island. At the base of the Bahia Falls all the waters come together in the wildest turmoil, creamy brown, and explode against both rock walls. From here the whole mass falls into a second plunge basin, with spray which shoots up in spires, rising higher than the top of this lower fall, and obscuring all but the summit, as in Horseshoe falls at Niagara. There is a deep vibrating roar with a high continuous clashing above it, like endlessly shattering glass.

The river below is the wildest clash of waters, the bed slanting downward probably 15 to 20 meters to a sharp turn where the end of the island and the high wall of the left bank approach, forming a whirlpool and cutting far into the wall. At the head of this recess, several meters up the cliff, is an enormous cave and down the side falls the water of the stream crossed by the trolley. The cave is about 150 meters in depth with a lofty ceiling at the entrance. The floor toward the back is covered thick with manure from bat roosts. In front of it are piles of driftwood. The river here makes a sharp turn to the right. Following the wall to the south, the falls called Agua de Venta on the Bahia side of Secret Island can be seen.

I never saw any region so nearly devoid of vegetation. It is astonishing how the cliffs can keep so dry and bare with so much mist rising from the falls. The perpendicular wall of the canyon was dark-brown rock, smooth and polished. In clefts were a few small trees and shrubs and an entire-leaved fern. On the opposite cliff (the face of Secret Island) is a vertical zone of verdure where the spray waters it, with scrub and cactus and bare rock on either side. I explored the channels crossed by the trolley and then struck up river. All was bare rock, smooth and polished or black and cindery, without even a lichen, and hot to the touch in the blazing sun. Back from the river in a desert of loose dry sand was sparse scrub, the shrubs mostly leafless but some in bloom. A woody Bignoniaceous vine (a species of *Arrabidaea*) clambering over a low tree bore gorgeous yard-long sprays of large rose-purple flowers. Parrots flew screaming and hawks and vultures wheeled and soared. Doves were common, as everywhere in the more arid sertão.

From Garanhuns I went to Maceio, Alagoas, and took a Brazilian boat for Bahia. The boat left at night, so I had a day in the low, wooded, sandy region back of the mangrove zone.

The city of Bahia is on the inside of a small peninsula between the bay and ocean. Towns in Brazil, like plants with us, have frequently an official and a common name. The city of Pernambuco is called Recife (for the reefs which form a breakwater); Bahia is São Salvador, and the bay is Bahia dos Todos Santos; but both the city and the bay, as well as the State, are called Bahia.

The peninsula is a succession of hills and hollows, and my field book began to fill rapidly. This was what I had expected of Brazil.

I had the good fortune to be the guest of a family of American missionaries, the Andersons, whose veranda and lawn I spread with plant driers. Mr. Anderson knows more about Brazil than anyone I met, and gave me information that saved endless time and worry.

One of the Martius localities I wanted to visit was Joazeiro, on Rio São Francisco. At Pedra I was not far from there. A narrow-gauge railroad runs from Piranhas, on the Rio São Francisco, about 50 kilometers below the Paulo Affonso falls, to Jatoba, about as far above them. The river above and below is navigable. But the journey from Pedra to Joazeiro, around the great bend to the north, would have taken over two weeks. From Bahia to Joazeiro, 575 kilometers, a shorter distance than from Washington to Pittsburgh, took two days each way, the train stopping overnight at Santa Luzia. After half a day's ride it seemed to be the journey to Bello Jardim over again, the same dry scrub land, the same sorry agriculture and miserable animals. The second day was still worse, and my heart sank as we neared Joazeiro.

This old city is an important center of trade in hides, dried fish, and bark for tanning. The produce from the upper river is here shipped overland to Bahia. Noisome stacks of hides towered far above one's head at the railway station, and piles of bark bordered the track. Water for household use is carried from the muddy river by women and children and in kegs on the backs of donkeys, a continual stream of water-carriers coming and going. The water is filtered through large earthen pots into tall graceful water jars.

The region is as desolate as Yuma, Arizona. It is obvious that long-continued overgrazing has changed the character of the country. There is nothing to hold the rains and the overflow from the river. The soil is alluvial and ought to support a good growth of plants. The few trees, not tall, but sturdy, seem to thrive, but the ground is absolutely bare in large patches, deeply gullied and in same places exposing very coarse gravel, the latter, because it does not blow, forming low flat hillocks. A hundred years ago when Martius was there it must have been beautiful semiarid scrub and alluvial savanna, for the plants he collected there are those of brushy savannas.

While botanizing some ten kilometers to the west I saw an excellent demonstration of wind erosion. Hearing a roaring like fire I looked to see what it was. At some distance was a whirlwind which came with a cloud of red dust so thick it obscured the brush as it went by, less than 100 meters from me.

In the river margin was a large colony of *Echinochloa polystachya*, a gigantic relative of our barnyard grass. This, I was told, is eagerly eaten by cattle, but while feeding on it they are sometimes attacked by piranhas, the blood-thirsty fish which makes bathing in the river risky. I saw this fish only on the table, where it is excellent eating.

I made a day's trip to the Rio Salitre about 45 kilometers to the west. The scrub (or caatinga) is much denser and near the river are trees, but the earth is badly eroded. I found some interesting grasses here, one known as *Paspalum denticulatum* var. *ciliatum* (but a good species), which is very rarely represented in herbaria and which I found nowhere else, being abundant in low wet ground.

At Joazeiro there is a Horto Florestal, about what we would call an agricultural experiment station. It looked very promising with fine mango and orange trees, plantations of *Eucalyptus*, and some good Duroc-Jersey and Poland China swine for breeding.

From the train I saw a stretch of promising sandy savanna at Parafuso, a few miles north of Bahia. Returning there I had one of the richest days of my entire stay in Brazil. I found several little-known grasses I had been hoping for and many more I knew in the herbarium but had never seen growing.

I made a trip across the bay to the little town of Cachoeira at the head of navigation of Rio Paragassú. If the Bay of Rio de Janeiro were not so famous for its beauty we would hear more of Bahia. The bay and its steep surrounding hills, with mangrove marshes filling the indentations, is indescribably lovely.

A giant aroid (*Montrichardia arborescens*—what Beebe calls "muckamucka") grew in the water at the base of the hills as we entered the wide mouth of Rio Paragassú. I hired a man with a dug-out canoe to take me out to a dense growth of this in the river between Cachoeira and São Felix, to get an enormously tall grass (*Panicum rivulare*) growing in it.

I spent a day in the dry region about Feira Santa Anna and another walking back from Serra to Cachoeira, about fifteen kilometers. A little stream full of rapids and falls kept me company much of the way. Here I found *Hymenachne condensata*, the type of which I had seen in Raddi's herbarium at Pisa and which was represented in the United States National Herbarium by a single fragmentary specimen. I afterwards found it plentiful in a single locality west of Rio de Janeiro.

I had two more good days in marshes and sandy savannas between Alagoinhas and Matto de São João, about 125 kilometers northwest of Bahia, and sailed on January 6 for Rio de Janeiro.

I reached Rio de Janeiro a second time January 9, midsummer. The next day, in company with Dr. Horace Williams, the chief of the geological survey, I visited Pão de Assucar. The summit is reached by an aërial trolley, the first section of which runs from the base to Morro de Urca, the second from the other end of Morro de Urca to the summit. This enormous block of dark brown granite is 380 meters high. The perpendicular west side is bare for more than half its height. Toward the summit small bromeliads and grasses cling to the rock, the aggressive intruder, capim gordura, being the most abundant. The clouds that hang around this isolated peak supply moisture for a surprisingly dense vegetation. The summit is fairly covered with vegetation, a dense colony of *Paspalum coryphaeum*, masses of a sterile bamboo, *Olyra micrantha*, the largest of the olyras, reaching a height of three to four meters, a beautiful large-flowered bean (*Phaseolus grandiflorus*) and tall composites, occupy the summit and the rocks just below, while trees and vines form dense thickets on the eastern face, extending nearly to the very summit.

From the summit there is a wide view out to sea, over the city, and up the bay. This island-dotted sheet of opalescent water, with the blue peaks of the Serra do Mar rising beyond it, is enchanting. The most striking peak is called Dedo de Deus, the finger of God, from the resemblance to the uplifted forefinger of a closed hand, so common a feature in images of Christ.

I had letters to officials at the Jardim Botanico and received many courtesies from them. Miss Maria Bandeira, educated in England and the daughter of a prominent physician at Rio de Janeiro, who is working on mosses at the Jardim, was a delightful companion on my first full day on Corcovado. We took an early train (cog-road) to the summit and walked down to Paineiras, no great distance, the collecting being so good. At the summit, 720 meters altitude, the pretty little international, *Poa annua*, greeted me, as it did at sea level the first minute I set foot on European soil two years before. Corcovado is the "type locality" for a large number of grasses, and from *Paspalum obtusifolium* Raddi (now referred to *Axonopus*) and *P. corcovadense* Raddi at the summit, to *Olyra glaberrima* Raddi at 480 meters, they still lived where they were discovered over a century ago, as well as many since described by Nees and by Hackel from this beautiful mountain. I spent several more days on Corcovado, along the Aqueduct Trail, beloved of Martius, and up and down the jungly slopes or rocky cliffs.

At this time the quaresma (a species of *Tibouchina*) was in bloom, and masses of richest rose-purple glowed on the slopes. These gorgeous trees are called *quaresma*, which means Lent, because the trees bloom during the lenten season. But I saw different species of it, trees and shrubs, in bloom in various places until May. At this time the city was aglow with *Cassia fistula*, its pendent clusters of golden flowers a foot long.

Through the kindness of Dr. Campos Porto, Miss Bandeira and I were able to visit Itatiaia, the great mountain that rises where the

States of Rio de Janeiro, São Paulo, and Minas Geraes touch. The journey from Rio de Janeiro, to Barão Homem de Mello (Campo Bello—the nomeclature of Brazilian towns being like that of plants, with numerous changes of names and consequent synonyms) was through jungle-clad mountains and across rocky streams. From Barão Homem de Mello we started on horseback toward the towering mountain mass to the north, our collecting outfit following on a pack horse. We had charming views of Rio Campo Bello far down the narrow valley below and could hear its tumbling waters. The slopes were mostly forested with different species of palms, especially a very slender one that grows in clumps, suggesting gigantic clumps of sugarcane. We reached the Florestal on Monte Serrat about 4 o'clock. From Monte Serrat (816 meters altitude) to the summit of the mountain and for some miles beyond on the Minas Geraes side the country is a Federal reserve under the charge of the Jardim Botanico. The Florestal is a sort of forest station and experiment station combined, where scientific work is carried on under the direction of Dr. Paulo Campos Porto. The station is a long low building, with pleasant living rooms, a laboratory, library, and dark room, surrounded by gardens. There are great groves of *Araucaria brasiliensis*, beautiful against a background of blue mountains or white mist. From the Florestal there is a vast outlook up the mountains and down over a sea of lower hills.

The next morning we left shortly after 8 o'clock with two pack animals bearing camping and collecting outfits. It had rained during the night and masses of white mist hung between the mountains, the nearby araucarias outlined against them. The trail was difficult, up over stones and through deep mud or across streams. It was necessarily slow going so I did not have to give much attention to the horse, but could keep my eyes on the forested slopes above and below, with their palms, tree ferns and great masses of hanging bamboo, and on the trail border where *Panicum*, *Ichnanthus* and a silvery *Paspalum* promised rich collecting on the way back. Once we saw down the steep slope below a dark brown monkey up a palm tree so slender that it swayed under his weight, and a second running up the trunk. They looked at us and chattered—then one climbed down, while the upper one spread his little arms and sprang from the tree, sailing down (it must have been forty or fifty feet) into the top of another palm. A third, then a fourth monkey ran up the same palm, turned to look at us and made the same leap, while one, just glimpsed lower down, kept calling or scolding.

We stopped at a mud-hut resthouse at a place called Macieiras (the place of apples) because the Jardim has planted an apple orchard on the hillside here. It was a grassy and a mossy place and Miss Bandeira and I collected until called to supper at about dark.

Macieiras is about 1,900 meters altitude and the grasses were northern or alpine genera, *Agrostis*, *Calamagrostis*, *Danthonia*, *Bromus*, and the like.

About 7 in the morning we started up the mountain on horseback, and in less than an hour were above timberline. We passed glowing gardens of a big red *Hippeastrum* (an ally of *Amaryllis*), three or four flowers in a cluster, often all open; lovely meadows of an *Erigeron* that comes out white and turns rose pink, and masses of a yellow composite. At Itatiaia Alta, a great stretch of gentle slope, full of boulders and with great clumps of *Cortaderia modesta*, we left the horses near two tiny lakes.

Above Itatiaia Alta the peak, called Agulhas Negras (the black needles), rises abruptly, composed below of steep, bare granite cliffs, deeply furrowed vertically. We climbed up the furrows on all fours and crossed from one series to another over steep slopes covered with a low bamboo (*Chusquea pinifolia*) most convenient to cling to. At the top of these furrowed cliffs is a great overhanging rock that seemed to stop all progress, but the way led through a crevice to one side and over and between boulders wedged in the crevice. The worst place was like a chimney flue, which we ascended with the help of a rope.

The view from the summit was magnificent, mountains everywhere, in all directions, from dark granite or green slopes near to wonderful blues in the distance. From under a cloud we looked out on the Minas side on mountains glowing in sunshine, as far as the eye could reach, like looking into the sunshine from under a vast parasol.

At the summit was dwarfed *Chusquea pinifolia*, the only grass, a pink *Oxalis*, a tiny cactus (*Epiphyllanthus candidus*), a little fern, bromeliads, an ericaceous plant resembling *Gaultheria* with lovely pink flowers, two carices, and a composite. In wet mossy rocks coming down I collected *Poa*, *Agrostis*, and *Bromus*.

Reaching Itatiaia Alta again an excellent hot meal awaited us by a clear cold streamlet—this was mountaineering de luxe. Here, above timberline, grasses were abundant. I made the return journey afoot, collecting as rapidly as possible, for night shuts down quickly in the Tropics.

The next morning I started down afoot with my portfolio. The way was long and grasses many, so I had to walk and collect at top speed, reaching the Florestal just before dark with bulging portfolio, a big handkerchief tied around a bundle, and an armful besides.

It rained hard during the night and in the morning the mountain tops were hidden by the mist, but the araucarias are at their best with white mist for background. I started again immediately after café to collect on the way down to Barão Homem de Mello, where we were to take the noon train.

Baggage regulations on Brazilian railroads are the despair of a foreigner. One's clothing goes on the train with the passenger, but other baggage follows on a later train. My clothing was of no consequence, while my precious collections would spoil if I could not take them with me to dry. By some kind of magic Dr. Campos Porto got all my collections on our train, and I heartily wished that I had more Portuguese than *muito obrigada* and *agradecida* at my command to thank him for the wonderful trip and for this crowning favor.

A few days later there was a terrific storm in Rio de Janeiro, retaining walls giving way in places, with tons of rock and earth and trees across the street-car tracks. The next morning was misty, with clouds pouring over the shoulder of Corcovado, but it was not raining, so I started about 6 o'clock for an all-day tramp from Alta Boa Vista (about 450 meters altitude), on the slope of Tijuca, to Silvestre, on the slope of Corcovado. It was drizzling by the time I reached Alta Boa Vista, but I went on, hoping it would clear. It rained gently or in sudden torrents all day, and yet was one of the most joyous day I had in Brazil. There was a dense mat of a little *Paspalum*, apparently new, of which I had found but two specimens on Corcovado, and a colony of *Panicum latissimum*, 6 feet tall, with great clasping blades, 6 inches broad and 12 to 15 inches long. It grew on an almost vertical slope, in a jungle of trees and shrubs and tangled vines. In the United States National Herbarium there were fragments only, nothing to give a hint of the beauty of the plant. The rain continued the next day, so I took my collection to the Jardim Botanico to be dried in the drying oven, and then had to succumb to an attack of grippe. I convalesced in the home of kind missionaries on the island of Paquetá, toward the north end of the bay, botanizing with the children.

There were a few more trips in the vicinity of Rio de Janeiro, to Jacarepaguá, in low land toward the south coast to the west; in the sands at Ipanema by the seacoast; a day along the Camino dos Macacos, which runs from the Jardim Botanico to Alta Boa Vista; about Merity, in the low land to the west of the bay; and a glorious day climbing the Pico de Tijuca. On the last three trips I enjoyed the companionship of Mr. Cuyler, naturalist on the *Blossom*, of Cleveland, a little three-masted sailing vessel exploring particularly the bird islands on both sides of the southern Atlantic. The *Blossom* was undergoing repairs in the harbor of Rio de Janeiro. On a steep wooded slope above Camino dos Macacos I found the eagerly sought *Streptochaeta spicata*, one of the strangest grasses known, with broad oval blades and slenderly conical spikelets hanging loose (at maturity) by fine spiral awns to the top of the slender axis, a sort of Maypole-dance arrangement. On this trail I saw for the first time the rain tree (*Samanea Saman*) raining, the mist falling in a stream of sunlight striking through the trees.

Pico de Tijuca is the highest peak in the vicinity of Rio de Janeiro. It was cloudy or misty most of the day, glimpses of the city or the bay occasionally showing below us. At the top of the steep granite Pico was a bamboo (*Chusquea sclerophylla*) in flower, rich reward for the climb, and *Panicum latissimum* again, in a mossy thicket, as well as many lesser grasses.

February 19 I left Rio de Janeiro on the early train for Juiz de Fóra in Minas Geraes. In the valley of Rio Parahyba, beyond the Serra do Mar, the silk-cotton trees (*Ceiba* sp.) were coming into bloom, forming masses of lovely pink on the mountain sides. These magnificent trees, one with great buttresses at the base, another with the trunk beset with conical spines, were blooming in Minas until the last of April.

Juiz de Fóra lies in the narrow flood plain of Rio Parahybuna. Dense colonies of giant species of *Paspalum* and *Panicum* bordered the river. Their blades have edges like razors and hands and arms are slashed in collecting them. A golden-rod (*Solidago microglossa*) on the red clay slopes looked out of place in the tropics.

This region is in the Zona de Matta or wooded country, the hills mostly covered with second-growth forests. The grass flora was very different from that before encountered and I remained a week, the guest of a family of American missionaries.

Above the town rises a steep hill, Morro do Imperador, 975 meters high. At the summit is an image copied from the "Christ of the Andes." There is a road up the more sloping side, and a trail up the steep face. The trail is used by the devout for penitential pilgrimages. The town was celebrating carnival (before the beginning of Lent) with processions and noisy crowds. The processions looked like moving pictures of African dances, both in costumes and movements. They were led by gigantic black women (or men dressed as women). Juiz de Fóra has about the same proportion of Negro blood as has Washington, but the whites have adopted African methods of jubilation. No doubt the trail up the peak was worn deeper during the weeks that followed. The sloping sides of the Morro afforded a good day's botanizing.

The next stop was at Barbacena, 1,120 meters altitude, just across the Serra de Mantiqueira. This was the beginning of the Zona de Campo, with high rolling hills covered with grasses, herbs, and commonly, scattered shrubs, and there were quantities of grasses not before seen. This was the only place in Brazil where I saw our dandelion.

After four days about Barbacena I had an all-day journey to Lavras in the valley of the Rio Grande. Most of the distance the railway followed the south side of Rio Dos Mortes flowing west, full of rapids, rocks, and low islands, and bordered by giant *Paspalum*, *Panicum*, and *Erianthus*. Minas Geraes is fine cattle country. After seeing the interior of Pernambuco, Alagoas, and Bahia, it was good to see the ground covered with plenty of forage, though it was mostly capim gordura, better liked by cattle and their owners than by botanists. The foliage is sticky, difficult to walk through, and soils one's clothes. Worse than that is the way it spreads, taking possession of everything and killing out the native vegetation. But cattle thrive on it and it holds the steep red clay slopes that otherwise would be eroded. It has been tried in Florida, but has not found favor either with cattle or farmers. It is a beautiful grass, forming soft billowy mounds, and when in flower, covers the hillsides with soft glowing purple. Maize was the principal cultivated crop through this region, with rice and sugarcane in small patches.

Martius and Spix write of the gold washing at Lavras, which they visited on their way from the southwest, but the Lavras of a century ago was some 7 kilometers north, near the Rio Grande. Gold washing is no longer carried on there. Agriculture is more advanced here than in any other part of Brazil I saw, due doubtless to the leadership of Dr. Benjamin Hunnicutt and the Escola Agricola, which he has developed, part of the Instituto Evangelico. The Ceiba trees which surround the plaza at Lavras were in bloom, the great pink flowers not only covering the trees but carpeting the earth beneath them, the thick petals remaining fresh and beautiful long after falling.

The grass flora was rich at Lavras, but collecting was hampered by rain. Minas Geraes was suffering for want of water, the rainy season having been niggardly this year. Doctor Hunnicutt declared the rains were worth a million dollars apiece to Minas so I could not begrudge them, though I returned drenched from my tramps. The red clay hills are terribly eroded in places here, as elsewhere, in Minas. In slavery days ditches were used in place of fences, and these ditches have eroded into great gulches. To the south of Lavras the hills are cut into bad lands.

March 13 I left Lavras, stopping for three days at Oliveira, and then went on to Bello Horizonte, the clean and beautiful capital of Minas Geraes. To the south lies the Serra do Curral, typical campo.

Trachypogon, *Mesosetum*, and *Thrasya*, genera characteristic of the campos, and many species of *Axonopus*, *Paspalum*, and *Panicum* were a joy to an agrostologist. Species long known in the herbarium are often surprising when met in the field. One especially so was a species of *Paspalum* I found climbing trees. This had a simple cane 2 or 3 meters tall, erect among low trees by a rocky streamlet. When it reached the branches of a tree it sent out numerous horizontal or recurved branches and clambered on up the tree, branching in all directions, with broad racemes of white spikelets against a dark purple ribbon-like rachis at the ends of the branches. My annotated manuscript list of Brazilian grasses showed it must be *Paspalum phyllorhachis* Hack., but who ever dreamed of such a habit for a grass known from specimens we now see were but ends of ultimate branches. I found it again higher up the Serra, with nothing to climb on and forming a tangled thicket on a little shelf of rock. This species was known from a single collection by Glaziou, the locality given as "Minas Geraes," only. I found it only in Serra do Curral, and that is probably the type locality.

Collecting was so good I went back several times before I reached the submit of the Pico, 1,400 meters, on the stony slope of which waved the little silky white banners of *Paspalum blepharophorum*.

At Bello Horizonte I was the guest of Miss Christine, principal of the Collegio Isabelle Hendrix. The grasses of the region alone would have made this place a delight, but the companionship of interesting women, the little children who helped me spread my driers in the sun, even the kindly cook who tolerated my plant presses behind her stove, made it about the best-loved spot in all Brazil.

One of the most interesting finds of the entire Brazilian trip was made in low ground west of Bello Horizonte. This was a new species of *Lithachne*, a monoecious genus of which but two species were known, one in tropical North America and southward to northern Brazil, the other known only from eastern Cuba. This was strikingly different from either. The culms bearing the pistillate spikelets are very slender, vinelike, running along the moist ground a meter or more under other vegetation. It was a delicate task to untangle them without loss of their few hood-shaped white spikelets.

A few hours north of Bello Horizonte is Lagoa Santa made classic by Pedro Lund, the Danish botanist and anthropologist, and by Claussen, Warming, and others who visited him. Lund was a consumptive who went to Brazil for his health. After a few years he returned to Denmark cured, but the disease again attacked him and he returned to Lagoa Santa to die. Being a Protestant he could not be buried in the cemetery, so he bought a piece of ground about 5 kilometers from the village for his grave. He lived 40 years after that, and buried Claussen and another friend and his two Danish servants in his little cemetery before he himself was buried there in 1880 at the age of 79. The few acres inclosed form a precious preserve of the original campo. Except for four immense clumps of bamboo, the ground is left wild—the best kind of memorial to Pedro Lund. He was dearly loved by the Brazilians and women still come to the cross to pray for the soul of the Protestante. There are all manner of legends about the curative properties of the lake.

One of the localities cited by Trinius and others is Serra da Lapa. Through Doctor Rolfs I learned that this locality, unknown to-day, is part of Serra do Cipo, of which Itambe is the highest peak. At Lagoa Santa I arranged to go into this range on a freight truck, or caminhao, which makes the trip as far as Vaccaria, 110 kilometers from Bello Horizonte. I had hoped to visit Itambe, but it would have required outfitting for about 100 miles of travel by horseback, too costly in time and money.

The ride over the undulating hills and hollows with the blue mountains hour after hour as far off as ever reminded me of a trip by stagecoach from Sheridan to Buffalo, Mont. But the plant cover, except in small areas, was not short grass, but more like that of the flat woods of Florida minus the woods. Only the river valleys are wooded. Not far northeast of Lagoa Santa the road crosses Rio das Velhas, the large branch of Rio São Francisco, then Rio Jaboticatubas. After that for 40 or 50 kilometers it was all open tall-grass campo, *Trachypogon* and *Aristida* the dominant grasses. *Trachypogon macroglossus* shone in the sun like silver, edged with the pinkish awns not yet spread. From Rio de Cipo, near the foot of the mountains, to Vaccaria the campo is brushy with small patches of woods. At a turn in the road the falls of Rio Peixa came into view, a slender stream pouring over the mountain wall. Vaccaria is a store, a watermill, and house all in one, owned by a Portuguese. It was the most picturesque place I saw in Brazil. This little place was rude and primitive with earth floor in the dining room, but there were orange trees about it and a little vineyard in the back.

The mountains, called Chapeo de Sol (Portuguese for parasol), rose abruptly, the rocks of light-gray limestone with much pale crumbling sandstone. The soil of the region is nearly white, very fine, sand. An old rocky trail led up between peaks to Rio Peixa. Along this trail and on the peaks above it (up to 1,400 meters) were more species of *Axonopus* than I had ever seen together before. The next day, following the road now being built, I reached wide, high, open campos with rounded peaks in all directions and palm groves far down in the valley. It was a day of blue and silver, blue sky overhead, blue mountains in the distance, and silvery grasses all about me, *Trachypogon*, *Andropogon*, and the *Ceresia* group of *Paspalum*, with spikelets clothed with silvery hairs, characteristic of the high, open campos. Loveliest of them, *Paspalum splendens*, waved its pair of glittering silver banners above the other grasses. Even the best find of the day, *Panicum arnacites*, had silver spikelets, hung like pendants on hairlike pedicels. A striking tall species of *Paepalanthus* (probably *P. speciosus*) was common on the upper rugged slopes and also a little one growing on hummocks of its own making. A terrestrial orchid with a single beautiful large pink flower and composites with purple, pink, or yellow heads dotted the campos.

On a cliff by a little waterfall in a shady ravine I found plenty of the dainty little *Raddia nana* with filmy ferns and mosses.

Early the fourth day I took the road to Lagoa Santa, to be picked up by the caminhão when it overtook me. The collecting was so good that, though I hurried, I had gone only 10 kilometers when the caminhão appeared. The kindly driver stopped for me, however, when I glimpsed some grass I wanted.

On April 6 I left Bello Horizonte for Ouro Preto, the old capital of Minas, the "Villa Rica" of Martius and other early travelers. Though only about 100 kilometers to the southwest the country was very different, being granite and red clay. One day in the Ouro Preto hills and the next by horse to Itacolumi, the high peak (1,752 meters) to the southeast, where again I had a rich harvest on high open campos and rocky slopes, and then I left the Zona do Campo for Viçosa in the Zona da Matta. Dr. P. H. Rolfs, formerly director of the Experiment Station at Gainesville, Fla., is building up a school of agriculture for the State of Minas Geraes at Viçosa. The country is much more fertile and more densely populated than the Bello Horizonte country. Here Ceiba and quaresma (*Tibouchina* sp.) were in bloom. I had missed them in Serra do Curral and Serra de Cipo. I was fortunate here in being the guest of the Rolfs family. The swampy places and borders of the second growth forests (chaparão) that clothed the hills afforded good collecting. Two days were spent at Anna Florencia to the northeast, and then with Doctor Rolfs and his daughter I made a trip to Serra da Gramma, some 60 kilometers east of Viçosa, in the Serra Sebastião. We stayed at a fazenda, two days' journey on horseback from São Miguel, stopping over night, going and returning, at Araponga. (This musical name is that of the anvil bird of the region.) The trail led through forested hills often hung with bamboos. We reached the fazenda in the middle of the afternoon and had time to botanize for a few hours. The third day we rode to the base of

Serra da Gramma, then proceeded afoot—a man to cut the trail, the old fazendeiro to help him, the guide, three men from Viçosa, Doctor Rolfs and his daughter, and I. For some distance we followed the rocky bed of a stream then struck into the virgin forest. This was the real tropical jungle of the school geographies, dense and dark, with palms, tree ferns, vines, and bamboos all tangled together, with brilliant bromeliads up the trees, and multitudes of ferns. From about 1,500 meters altitude the bamboos made the climbing difficult and fatiguing. The very steep trail was cut but there was no time to clear it, and we tripped and stumbled or sank into soft humus, up and up, then slipping and sliding down into a deep ravine, then climbing up again. We were nearly exhausted when light appeared ahead and we knew we were nearing the open summit. But the "campo" we were expecting was composed for some distance of dense brush up to our waists—almost what we would term chaparral. It was nearly dark when we passed the brush and came to open, grassy ground. It was too dark to go down hill for water, so we made camp without it. When streaks of scarlet appeared in the sky I was glad to get up and start collecting. Everything was wet with dew and it was like working in ice water, but there was too much to collect to wait for the sun.

There are three peaks; we had camped on the lowest. We ascended the second through dense chusqueal (tangled *Chusquea*), but did not have time for the third, which appeared to be very like the second. On the way down the trail through the forest I found a single *Chusquea* in flower—it is always cause for rejoicing when one finds bamboos in flower—and a few other grasses.

On the return journey to Araponga and the following day to São Miguel the cavalcade halted when I wanted to collect, and it was frequently, for there were two bamboos with flowers, one a beautiful slender vine, *Chusquea capitata*, besides numerous other grasses.

A few days after our return from Serra da Gramma, Miss Rolfs and I left for a trip to Pico de Bandeira, the culminating point of Serra da Caparao, the mountain range which separates Minas Geraes and Espirito Santo to the east. It is claimed by recent topographers to be the highest point in Brazil, 2,884 meters in altitude. The village of Caparao, the railroad station nearest the peak, lies only about 150 kilometers east of Viçosa, but to reach it we had to spend two days on the railroad, stopping over night at Uba and again at Santa Luzia Carangola, covering two long sides of a triangle to reach the other end of a short base. It was this paucity of railroads that prevented me from carrying out the extended itinerary I had planned in Brazil. Doctor Rolfs sent with us a reliable youth from the school farm, and at Caparaó we hired three riding mules, a pack mule, and a guide, who had to go afoot, because another animal could not be procured. We bought food to last three or four days, and next morning, May 1, we started about half-past 10.

Caparaó is only 814 meters in altitude, lying in a hollow between two ridges. For an hour or so the trail led up through partly cultivated or pastured hills, then, as we rose higher, through virgin forests with palms and an occasional *Araucaria* standing out alone. A high-climbing leguminous vine, with brilliant scarlet flowers about 2 inches long in loose pendant racemes 6 to 10 inches long, was frequent in places, and the gorgeous purple quaresmas (*Tibouchina* sp.) were still in bloom—the last I was to see of them. The trail became obscure, and Miss Rolf's questioning brought out the fact that the "guide" sent with us had never been this far on the trail. There was a resthouse below the peak where we expected to spend the night; this we had been told we could reach in three hours and a half, but darkness came on with no resthouse in sight, so we camped on a shoulder of the mountain, with plenty of down timber, which enabled us to keep a big fire going all night—a great comfort, as it rained till midnight and then cleared and turned very cold. The barometer showed that we were at about 2,100 meters altitude. In the morning a herder hunting stray horses put us on the trail to the resthouse.

The resthouse was a low hut of upright sticks, partly chinked with mud, the roof a combination of wooden shingles and sheets of zinc. Horses had been in the hut so we had to clean it out; then we floored it with shingles we found outside, made a fire in the stone and clay mound designed for that purpose, and had dinner. It drizzled all afternoon but this mountain meadow was rich in grasses and compositae, so I collected, bringing armfuls into the hut to put in press and write up.

The night in this "resthouse" was less comfortable than the preceding night in the open, for the roof above the "stove" was of shingles, and in my efforts to warm the hut I had nearly set fire to it, so we had to discourage the fire and nearly froze. In the morning, leaving the useless "guide" at the hut, Miss Rolfs, José, the boy from Viçosa, and I started for the Pico. *Chusquea pinifolia* began some distance below our first camp and continued up the mountain, the plants becoming dwarfed at higher altitudes. This species was abundant on Itatiaia, but here I found it in flower for the first time. A second species of *Chusquea* (*C. tenuis*), with tall arching culms and narrow blades, was also in flower.

From the resthouse and for some distance below we had seen a high pyramidal peak, much the highest in sight. The trail led through a saddle between this peak and a ridge opposite, obscured in clouds. We deliberated as to which side we should climb (there is no detailed map of the region) and decided in favor of the towering pyramidal peak. It was a hard climb but presented no such difficulties as those encountered on Agulhas Negras, and this agreed with accounts of Pico de Bandeira. But at the summit the clouds lifted for a few minutes from the opposite ridge and it was higher than we were. We learned later that we had climbed Pontão Crystal, 2,798 meters high, instead of Pico de Bandeira, 2,884 meters high. There was no time to ascend the other ridge, nor food enough to allow us to remain another day. The botanizing on Pontão Crystal was probably as good as on the Pico so I probably did not lose much, still it was disappointing. We reached the resthouse about 2 o'clock, packed at once, and started back down the mountain.

At the clean little hotel at Caparaó the following day I got my great stacks of plants in press ready for the train at 3. After a night at Santa Luzia Carangola, where the hard beds seemed soft by comparison with our recent ones, we parted in the early morning, Miss Rolfs and José returning to Viçosa, I bound for Rio de Janeiro. When I reached my pension about 11 that night, I rejoiced to find my trunk and duffle sacks sent on from Viçosa.

The flowering season was almost as definitely past as if it were late fall in the Temperate Zone, and a few trips about Rio de Janeiro and in the mountains north secured little additional material. So I made one more trip into campo country, to Campos do Jordão in northern São Paulo. The hill are open campos rich in grasses, the hollows between filled with *Araucaria* woods. In one of these moist ferny ravines I found another *Chusquea* (*C. sellowii*) in flower.

May 31, rejoicing in what I had found and regretting what I had not (Doctor Rolfs says a botanist is never satisfied), I sailed for home. A compiled list of grasses known from Brazil contains about 1,100 species. In the few points of eastern Brazil visited I collected between 500 and 600 species. The grass flora of Brazil must be far greater than at present known and would well repay further exploration.

1. TYPICAL CAATINGA AT THE BEGINNING OF THE DRY SEASON

In the sertão .near Bello Jardim

2. ZEBU BULLOCK

1. DRY CHANNEL CROSSED BY TROLLEY LEADING TO POWER PLANT

2. PAULO AFFONSO FALLS

Top of the main falls

1. TWIN FALLS ON SECRET ISLAND

2. PAULO AFFONSO FALLS

Showing the main falls, Secret Island to the left

1. ANTONIO

A typical coboclo or inhabitant of the sertão. The leather hat, held on by a leather band at the back, is universally worn in the interior, as is also the knife at the belt

2. BAHIA FALLS

Seen from the stairway leading to the turbine station

PÃO DE ASSUCAR

Seen from Morro de Urca, the entrance to Rio de Janeiro Bay in the middle background. Photograph by Kollien, Rio de Janeiro

ASCENT OF ITATIAIA

Between the Florestal and Macieiras, showing palms, tree ferns, and climbing bamboos

1. ITATIAIA ALTA

The large tussock grass is *Cortaderia modesta*

2. AGULHAS NEGRAS

The altitude is in dispute. It was generally given as 2,994 meters, but later measurements give 2,841 meters

1. CLOSER VIEW OF VERTICALLY FURROWED CLIFFS

2. GRAVE OF PEDRO LUND

1. ESCOLA SUPERIOR DE AGRICULTURA E VETERINARIA AT VIÇOSA

2. REST HOUSE BELOW PICO DE BANDEIRA

OUR HERITAGE FROM THE AMERICAN INDIANS [1]

By W. E. Safford

[With 12 plates]

The nature of the arts and industries of primitive tribes is determined primarily by their environment. In forested regions the materials employed are furnished in large part by the trunks, bark, and roots of trees; in the neighborhood of lakes and streams, by the reeds that grow along their banks; on the treeless prairies, by the grasses and rushes; and in certain cultivated parts of deserts, by the shells of gourds and calabashes.

The dwellings and clothing of people and the character of their food are influenced by climate. Similar conditions in regions widely separated have brought about parallel developments. In some cases there is a resemblance so striking that one is led to believe that a relationship exists between races which really have not had any means of intercommunication. The natives of Virginia, those of Louisiana, those of the northwestern United States, and those who lived along the great rivers of South America hollowed out canoes from the trunks of large trees by means of fire. The tribes living along the shores of the lakes of Nevada and California constructed rafts with bundles of reeds or rushes like those of the treeless regions of Peru and the shores of Lake Titicaca, situated on the elevated plateaus which formed the ancient kingdom of the Incas.

Certain types of baskets made by the tribes of the west coast of the United States had a remarkable resemblance to some of those made in the Old World. Likewise certain kinds of ancient Peruvian cloth, woven of cotton or of the wool of llamas and alpacas, are almost facsimiles of oriental forms as to both design and mode of weaving. These exquisite products of an art developed and perfected in the Western Hemisphere are as independent of the oriental fabrics which they resemble as are the llamas and alpacas of their relatives, the camels, of the Old World. I found superb examples of them in the great prehistoric cemetery of Ancón on the coast of Peru near Lima.

There I opened a large number of graves which contained seated mummies surrounded by terra cotta jars, in which there were foodstuffs still well preserved: Indian corn or maize (*Zea mays*); beans

[1] Translated by permission from Annaes do XX Congresso Internacional de Americanistas realizado no Rio de Janeiro, 1922, vol. 1, pp. 173–178, 1924.

or frijoles (*Phaseolus vulgaris*) of several varieties; lima beans (*Phaseolus lunatus*); peanuts (*Arachis hypogaea*); dried pods of cayenne pepper or *ají* (*Capsicum frutescens*); white and yellow potatoes (*Solanum tuberosum*); sweet potatoes or *camotes* (*Ipomoea batatas*); manioc (*Manihot utilissima*), from which cassava is prepared; and fruits of various kinds of trees and shrubs, such as chirimoyas (*Annona cherimola*), pepinos (*Solanum muricatum*), and locumas (*Lucuma obovata*). There were also spindles of cotton (*Gossypium peruvianum*) thread, and of yarn spun from the wool of the llama and alpaca.

Farther north along the same coast, near Trujillo and Chimbote, there are other prehistoric cemeteries, where we found funerary vases of different sorts, fashioned in the form of squashes and pumpkins (*Cucurbita pepo* and *C. maxima*) and calabashes (*Cucurbita lagenaria*), achira roots (*Canna edulis*), potatoes, and manioc roots. There were other vases having the forms of gods or idols, evidently consecrated as objects of worship, like the image of the god of agriculture, a masked monster holding in one hand a stalk of maize and in the other a manioc plant with its pendent tubers; the corn god, surrounded with ears of corn; and a third image seated on a warty squash. There were also vases covered in relief with peanuts in terra cotta, and still others with decorations in the form of lima beans.

Some of the mummies were wrapped in elegant robes decorated with beautiful borders resembling Gobelin tapestries, whose colors were perfectly preserved.

It was the discovery of these interesting objects in the prehistoric tombs that inspired me with a desire to study the plants employed as food and in the arts and industries of the indigenous tribes of other parts of America, both north and south of the Equator. I read carefully in the originals the accounts of the voyages of Columbus, Cieza de León, John Smith, Jacques Cartier, Champlain, the Jesuit fathers, and other explorers and colonizers, likewise the accounts of the conquests of Brazil, Mexico, and Peru written by the Portuguese and Spaniards.

Then I asked myself: What was the origin of all these valuable plants utilized by the Indians of our continent? After having read attentively the works of Piso, Father Feuillée, Oviedo, and Hernández, the great work of Alphonse de Candolle, "The origin of cultivated plants," and other books of the same nature, the answer to this question was not a very difficult one. The aborigines of America did not find upon the continent a single economic plant of Europe, Asia, or Africa. Even the cotton in the cloth of the ancient Americans came from a *Gossypium* quite distinct from the species of the Old World. The only exception, perhaps, is the calabash (*Cucurbita* *lagenaria*), whose dried fruit furnished the aborigines with bottles, pots, and dishes. The ancestors of the Indians were not acquainted with any cereal, legume, or fruit of the Old World. They had to begin by eating the fruits, nuts, seeds, and roots of wild plants growing in the prairies, forests, mountains, and swamps. They soon learned to choose the best kinds, to reject the harmful ones, and to preserve fruits, nuts, and even edible roots for use in winter. This practice of storage is not surprising, since squirrels, beaver, and many other animals make stores of different provisions for winter. The most interesting thing is that the first inhabitants of America learned not only to gather wild plants for their food but, in addition, to sow, cultivate, and develop the kinds most agreeable to their taste. This primitive cultivation was the true beginning of agriculture in America.

The aborigines learned by experience that certain plants were poisonous; that others had purgative or constipative or stimulant or calmant qualities, or were even intoxicating, but without being able to explain the reasons for the intoxication. They therefore attributed to these plants a virtue or divine power, and in certain instances they even worshipped these plants as deities.

Among their divine plants were the tobaccos and Daturas; in Peru the *floripondio* (*Datura arborea*) and *tonga* (*Datura sanguinea*), intoxicating plants employed by the priests in the Temple of the Sun at Sagamoza; and, in the Antilles, a certain tree of the Mimosa family which produced seeds from which they made snuff that caused a form of delirium. It was Fra Ramón, a friar companion of Columbus, who left us a description of this snuff, called *coxoba* or *cohoba*, which the Indians of the island of Hispaniola were accustomed to inhale, employing for the purpose a forked tube whose two ends they placed in their nostrils. In Mexico the priests and medicine men of the ancient Aztecs gave themselves up to practices of magic and necromancy after they had become excited or tipsy by means of some of these plants, especially a species of *Datura* and a little spineless cactus called *peyotl*. Even to-day this *peyotl* (*Lophophora williamsii*) is worshipped and employed by several Indian tribes of Mexico and the United States in their religious rites. Many of the priests of the ancient Mexicans were prosecuted by the authorities of the Catholic Church in the seventeenth century. I have had the good fortune to read the minutes of trials of this sort, and I have found in them information that has enabled me to identify a number of the plants used by the Mexican Indians in their religious rites.

It was from the Chichimeca Indians of northern Mexico that they learned the use of this intoxicating cactus, called by them *teonanacatl* (" divine mushroom ") and by the Spaniards " devil's-root." It is interesting to learn that some of these intoxicating plants figured in ceremonies of divination which resembled the practices of the priestesses of the ancient oracle of Delphos. What is more interesting is that these same beliefs and practices existed in regions widely separated, like Cuba and Haiti, Mexico and Peru, Florida and California, and Virginia and the pueblos of the Zuñi Indians.

It is equally remarkable that all these peoples employed incense in their religious ceremonies. In certain regions, like the Antilles, the incense was composed of fragrant balsams, in Mexico of resinous copal or of odorous herbs, while other tribes used tobacco for the same purpose. One reads that the Indians of Canada, before tapping sugar-maple trees, to collect the sweet sap, were accustomed to offer a sacrifice to the spirit of the tree, burning tobacco before it, and apologizing to the tree for robbing it of its blood. The Mexican Indians, thousands of miles away from the Canadian tribes, practiced the same rite before felling a tree to make a bridge, burning fragrant copal, and explaining to the spirit of the tree why they were going to cut it.

Among stimulants, the most important discovered and employed by the ancient Americans were the *yerba maté* or Paraguay tea, the coca of Peru, the guaraná and *caapí* of Brazil and Venezuela, the cacao of Mexico, the tobaccos of the Antilles, Mexico, and North America, and the *coxoba* or *cohoba* of Haiti, of which I have just spoken.[2]

While speaking of yerba maté, I should like to call attention to a species of *Ilex* of the United States, which resembles closely *Ilex paraguariensis.* This plant, used by the Indians of Carolina and Florida in certain religious rites, was adopted by the Spaniards as a substitute for Chinese tea. It has been found that the leaves contain caffeine, like that yielded by yerba maté and Chinese tea.

The coca, *Erythroxylon coca*, in use by the Peruvians before the discovery of America, is a strong stimulant which is used even at the present time in South America. From its leaves is extracted the alkaloid cocaine. In the Peruvian graves which I have mentioned nearly all the mummies had about their necks sacks filled with coca leaves, with little *matés* or gourds of lime, which the Indians of Peru chewed with the coca leaves.

Among the tobaccos used by the ancient Americans the most important species were *Nicotiana tabacum*, of the Orinoco and the Antilles, the kind observed by Columbus and his companions upon their arrival; and *Nicotiana rustica*, of the Mexican plateau, Virginia, and Canada. *Nicotiana tabacum* was the *petun* of the

[2] Safford, W. E., "Narcotic plants and stimulants of the ancient Americans." Smithsonian Annual Report for 1916, pp. 387–424, 1917.

Brazilians, and the *quauhyetl* of the Mexicans. *Nicotiana rustica* was the *picietl* of the Mexicans, and the *uppowoc* of the Virginians; it was the sacred tobacco of the Iroquois. West of the Mississippi the most important tobacco was *Nicotiana attenuata*.

It was believed formerly that the *cohoba* of the ancient Haitians was a preparation of tobacco for smoking. I have learned that it was not a smoking tobacco but a kind of snuff, made of the seeds of *Piptadenia peregrina*, which I have identified with the *niopa* or *curupa* of South America, in use to-day among certain tribes as a stimulant or excitant.[3]

Among the medicines discovered by the ancient Americans there were several precious balsams, such as the balsam of Peru (*Myroxylon pereirae*), Tolu balsam (*Myroxylon toluifera*), copaiva balsam (*Copaiva langsdorfii*), and that of the sweetgum (*Liquidambar styraciflua*). There were also bitter barks, like the Cinchonas, from which quinine is extracted, and the quassias, of the Simaruba Family. The virtues of some plants used medicinally by the Indians were purely imaginary, but the efficacy of others, like the Cinchonas, coca, the balsams, and ipecac, has been demonstrated by experiment and practice and they have been adopted by modern physicians.

Some of the dyestuffs of the Indians produced beautiful and durable colors, but thanks to the discovery of synthetic dyes derived from coal tar, their use is constantly diminishing. Even the use of logwood and Brazil wood as dyes is decreasing; and the culture of the little insects that furnish cochineal (*Coccus cacti*) is almost extinct in Mexico, even in the district of Nochiztlan, whose name signifies "Place where cochineal insects abound."

Among the textile plants of the ancient Americans there were several distinct species of cotton: *Gossypium barbadense*, the sea-island cotton of the Antilles; *Gossypium hirsutum*, the upland cotton, planted in the United States, Mexico, and Central America; *Gossypium hopi*, cultivated by the Indians of Arizona and New Mexico; *Gossypium brasiliense*, the *aminiiú* of the Indians of Brazil; and *Gossypium peruvianum*, of various colors—white, brown, and purple, found in the graves of which I have already spoken. I should remark here that in discussing the Brazilian cotton, Piso unfortunately made use of an engraving of *Gossypium arboreum*, an Old World species so distinct from ours that it is not possible to make hybrids between it and any species of *Gossypium* found in the New World. The same statement may be made of *Gossypium herbaceum* of the Old World, a species formerly taken to be our *Gossypium hirsutum*, to which the *Ichcaxijuitl* of Mexico, illustrated in 1575 by Hernández, is closely related.

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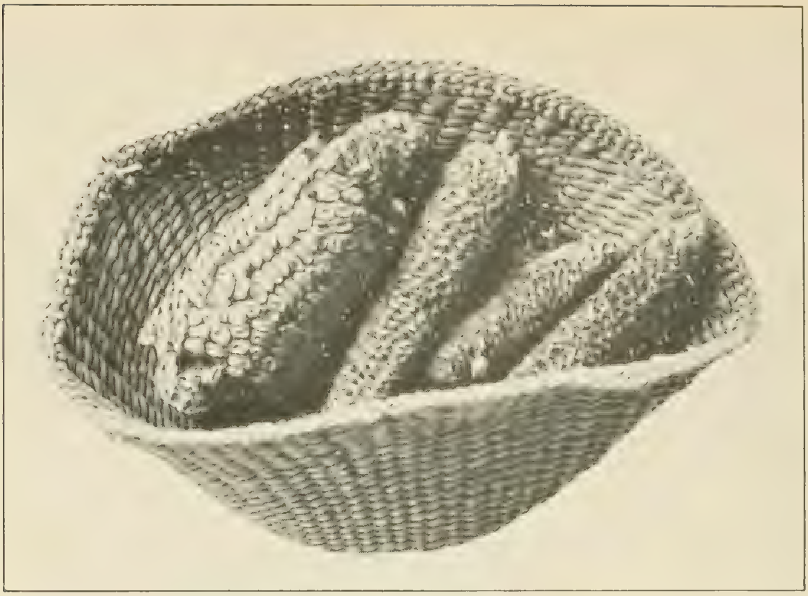
[3] Safford, W. E., "Identity of cohoba, the narcotic snuff of ancient Haiti," Journ. Washington Acad. Sci., vol. 6, pp. 547–562.

I should also like to mention that it was the American Indians who discovered the properties of rubber and were the first to utilize it. The first *conquistadores* of Mexico noticed that the inhabitants employed a large elastic ball for playing certain games. In some places there were huge courts surrounded by high walls in which were fixed large rings through which the ball was thrown. The elastic substance from which the ball was made came from the latex of a tree bearing the technical name of *Castilla elastica*. But the most important source of rubber at the present day is *Hevea brasiliensis*, from whose latex certain tribes used to make elastic syringe-like bottles. The trees are known to-day in Brazil under the name of *seringueiras*. Pear-shaped bottles made of this substance by certain Indian tribes of South America were described by the explorer, Condamine, in his interesting report published in 1745 in the Memoirs of the Royal Academy of Sciences.

It is impossible within the limits of this paper to enumerate all the important plants used as food, medicine, and dyes, and the textile and other economic plants discovered and introduced into cultivation by the American aborigines before the time of Columbus. Some have proved to be of great benefit to humanity. The cultivation of maize, beans, tomatoes, potatoes, sweet potatoes, cayenne pepper, squashes, manioc, and pineapples is to-day widely spread. The Jerusalem artichoke (*Helianthus tuberosus*), noticed by Champlain in the gardens of the New England Indians before the arrival of the English, is grown to-day in France; and sunflower seeds (*Helianthus annuus*), from which our Indians extracted an excellent oil, are produced in large quantities in Russia. The yellow-flowered *Nicotiana rustica* of the Aztecs and North American Indians also is cultivated in Russia, where it is known under the name of "peasants' tobacco." The pink-flowered *Nicotiana tabacum*, which has replaced it in our own country, has penetrated to the most remote regions of the earth. Cacao, from which the ancient inhabitants of Mexico prepared their chocolate, is one of the most important plants cultivated in all tropical countries

During the late war some of the greatest comforts supplied to our soldiers in the trenches came from vegetable products which are a heritage from the American Indians—cigars, cigarettes, chocolate, cocoa, peanuts, preserved pineapples, maple sugar; some of the most nourishing foods, such as potatoes, maize in the form of popcorn, canned corn, corn bread, corn cakes, dried and canned beans, sweet potatoes, and tapioca. We owe all these products and many others to the American Indians. In the hospitals the elastic tubes of the surgical instruments were made of rubber; but the greatest blessing of all was the cocaine, which permitted the performance of surgical operations without pain, and this is a direct heritage from the Indians of Peru.

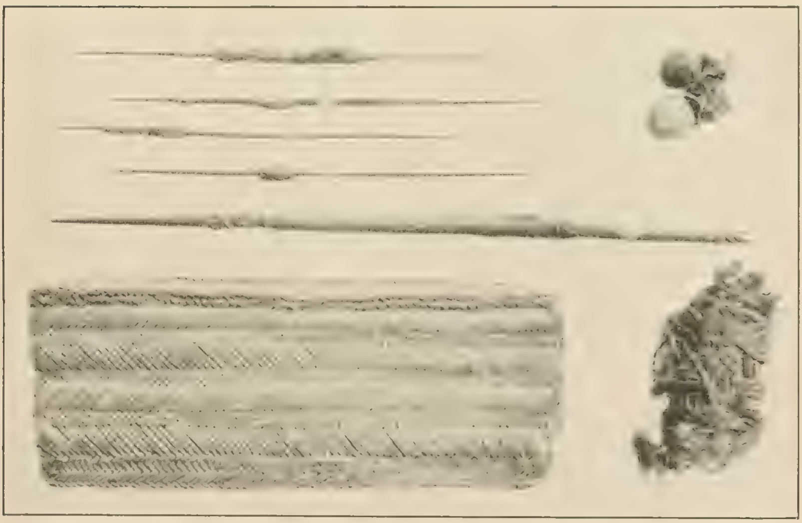
MAIZE GOD OF THE ANCIENT PERUVIANS, FUNERARY VASE BURIED WITH THE DEAD; FOUND AT CHIMBOTE, COAST OF PERU. U. S. NATIONAL MUSEUM



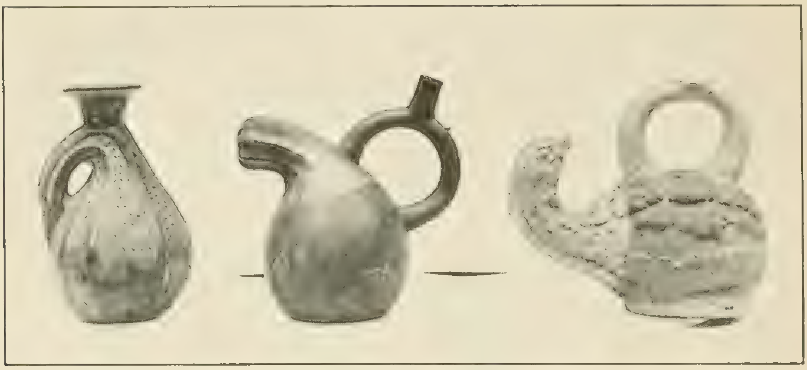
1. MAIZE FOUND WITH A MUMMY IN A GRAVE AT ANCÓN, NEAR LIMA, PERU. NATIONAL MUSEUM, WASHINGTON

2. BEANS (PHASEOLUS VULGARIS) AND LIMA BEANS (PHASEOLUS LUNATUS) FROM AN ANCIENT GRAVE. COAST OF PERU. NATIONAL MUSEUM, WASHINGTON

1. PEANUTS (ARACHIS HYPOGAEA) IN A CALABASH, FOUND AT ANCÓN. NATIONAL MUSEUM, WASHINGTON



2. SPINDLES OF COTTON THREAD; BROWN AND WHITE PERUVIAN COTTON FROM AN OLD GRAVE, ANCÓN. FIELD MUSEUM, CHICAGO



1. FUNERARY VASES WITH THE FORMS OF CROOK-NECK SQUASHES, FOUND AT SECHURA AND CHIMBOTE, COAST OF PERU. FIELD MUSEUM, CHICAGO

2. FUNERARY VASE, REPRESENTING A WARTY SQUASH, VALLEY OF SANTA, PERU. U. S. NATIONAL MUSEUM

FUNERARY VASE DECORATED WITH PEANUTS. COAST OF PERU. AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK

FUNERARY VASE OF BLACK CLAY, DECORATED WITH TWO PEANUTS. COAST OF PERU. NATIONAL MUSEUM, WASHINGTON

FIG. 1. INTOXICATING CACTUS, LOPHOPHORA WILLIAMSII, THE PEYOTL OF THE CHICHIMECA INDIANS OF MEXICO. A FLOWERING PLANT. DEPARTMENT OF AGRICULTURE, WASHINGTON

FIG. 2. DRY PEYOTL BUTTONS (LOPHOPHORA WILLIAMSII) EMPLOYED IN RELIGIOUS RITES BY CERTAIN AMERICAN TRIBES

SACK CONTAINING DRY LEAVES OF ERYTHROXYLON COCA, AND A SMALL GOURD OF LIME, FOUND IN AN OLD GRAVE, COAST OF PERU. NATIONAL MUSEUM, WASHINGTON

LEAVES, FLOWERS, AND FRUITS OF ERYTHROXYLON COCA, PHOTOGRAPHED BY O. F. COOK, DEPARTMENT OF AGRICULTURE, WASHINGTON. COCAINE IS OBTAINED FROM THE LEAVES OF THIS PLANT

PINK-FLOWERED TOBACCO, NICOTIANA TABACUM, OF THE ORINOCO AND ANTILLES, WHICH HAS REPLACED THE YELLOW-FLOWERED TOBACCO OF THE INDIANS OF MEXICO AND VIRGINIA. EXPERIMENT STATION, ARLINGTON, VA.

YELLOW-FLOWERED TOBACCO, NICOTIANA RUSTICA, OF THE AZTECS AND THE ANCIENT INDIANS OF NORTH AMERICA; AT PRESENT CULTIVATED IN RUSSIA UNDER THE NAME OF "PEASANTS' TOBACCO." EXPERIMENT STATION, ARLINGTON, VA.

PERUVIAN COTTON, GOSSYPIUM PERUVIANUM, WITH WHITE AND BROWN FIBER. ECONOMIC COLLECTION OF THE DEPARTMENT OF AGRICULTURE, WASHINGTON

THE PARASITE ELEMENT OF NATURAL CONTROL OF INJURIOUS INSECTS AND ITS CONTROL BY MAN

By L. O. Howard, *Chief Bureau of Entomology, United States Department of Agriculture*

When the economic entomologist confronts an emergency problem it is his duty to bring measurable relief as speedily as possible. At the same time he must begin studies looking forward to natural and therefore comparatively costless control. No one at all broadly familiar with the insect complex can doubt the importance of the insect enemies of insects. So important does their work appear to me that I am inclined to rank it the main factor in the preservation of the so-called "balance of nature." Surely it is one which demands our most careful attention.

The food necessities of the rapidly growing human population of the world make it necessary for us to grow enormous and increasing food crops. As we do this, we make equally enormous and increasing opportunities for the multiplication of certain insects. And does it not occur to you that this in turn should give the insect enemies of those certain insects such unprecedented food supplies that they should increase beyond all previous experience and become of the very greatest help to us in the fight to avoid starvation?

All this seems logical, and in the long run it will happen in just that way. But we want to hasten the process. In the case of crop enemies brought in from another part of the world we can not wait for the relatively slow adaptation of native parasites to the new host. We must bring to the new country the parasitic forms already accustomed to and adapted (in the course of centuries) to the crop pest accidentally imported.

This is the theory on which so much work has already been done, and it is safe to say that, failing some startling discovery which is likely to be made at any time, such work is still in its infancy. We have seen some strikingly successful results, and some workers have been overencouraged. Many instances will occur to you in which, carried away by the wonderful success of certain introductions into California and Hawaii in the closing years of the last century, highly intelligent men, like the late Elwood Cooper, of California, for example, have made claims which to-day seem preposterous and which even then were discounted by the trained entomologists.

But even all the trained entomologists did not see clearly. The great master, David Sharp, of England, when I met him one day, in 1902, in the British Museum, told me that in his opinion the economic entomologists should abandon every other kind of work and devote themselves exclusively to the parasites and predators. Even Doctor Sharp's brilliant son-in-law, Frederick Muir, in spite of his remarkable successes in Hawaii, would not have made so sweeping a statement.

While it is true that the introductions of *Novius cardinalis* into California and other parts of the world have been followed by almost immediate results of enormous value, and while it is true that some of the Hawaiian work has given speedy and striking results, and that both of these instances did much to start and encourage the prosecution of the biological control idea, it is almost unfortunate that these results were so speedy and so perfect, since it has encouraged many people to expect equally speedy and perfect results in all cases. In fact, many people are disappointed and discouraged when work of this kind is not successful almost immediately.

As a matter of fact, complete control by parasites and predators is rarely gained by such work. The success of the Australian Novius is almost unique. Only the success of the sugar cane leaf-hopper parasite in Hawaii and that of the parasites of the sugar cane borer in the same islands approach it in simplicity, efficiency, and speed. Immediately following these comes the introduction of *Prospaltella berlesei* from America into Italy, where, after a few years, it virtually controlled the mulberry scale. And at the present time there is reason to hope that *Aphelinus mali* will approximate this record in the control of the woolly apple aphis in New Zealand and parts of Australia, although the same insect in France, Italy, and South Africa seems to be less efficient.

As opposed to these speedy beneficial results, we must remember the rapidly growing list, not of failures, but of parasitic insects of slow establishment and of only partial control of the crop pest. Many differing conditions in different countries operate favorably or unfavorably on introduced species, and these species themselves vary in their susceptibility to different conditions.

With many species of parasites the normal environment is complicated. Years ago, in discussing the spread of land species by the agency of man and the liability of an introduced species to accommodate itself to a foreign territory, I formulated the idea that "It is upon the degree of simplicity of its life—the degree of simplicity of its normal environment as a whole—that the capacity of a species for transportation and acclimatization, even in a parallel life zone, depends." I had in mind when I wrote this only injurious insects, but it holds equally well for their parasites. Now, as it happens, with very many important parasites life is not simple—it is vastly complicated—and it results that an almost complete knowledge of its normal environment must be gained before we can expect successful introduction and acclimatization.

The question has been proposed to me by Doctor Metcalf as to what proportion of an appropriation should be used for parasite work. This question necessitates a complicated and somewhat devious reply. A great deal of money has been spent uselessly; and, again, good results have been gained with little money. The introduction of *Prospaltella berlesei* into Italy cost the Italian Government nothing. It was sent over by our Federal Bureau at Washington. The introduction of *Aphelinus mali* into France, Italy, New Zealand, Australia, several countries in South America, and South Africa cost these countries nothing; all were sent there directly or indirectly from Washington, with the exception of the South African introduction, which was made by a South African student at Cornell University.

The Hawaiian work has been very expensive in actual outlay. The Sugar Planters' Association must have spent some hundreds of thousands of dollars in this productive work. But this expenditure has been very well worth while, since the continuation of profitable cane growing on the islands has been the direct result.

But no part of the earth which does not have the very simple native fauna and flora of Hawaii, which does not have its equable tropical or subtropical climate, and which does not consist of islands rather limited in size, can expect with any degree of certainty to achieve results at all closely approaching these. And even from Hawaii many expensive expeditions have been fruitless.

California has spent in years past large sums of money with no appreciable results; not only that, but in at least one instance has hurt herself by introducing and liberating a parasite which proved to be hyperparasitic upon a beneficial primary introduced and established at a much later date. In fact, insect control in California was greatly hampered for nearly 20 years by a general reliance on the expected success of much work which was carried on by unscientific enthusiasts. It may as well be placed on record that all California parasite importation work as it was then carried on would have been stopped by Secretary of Agriculture James Wilson, under the Federal law of March 3, 1905, had not Harry S. Smith, a highly-trained expert of the Bureau of Entomology, taken charge of the work for the State under Prof. A. J. Cook, Commissioner of Horticulture.

The complications of work of this kind on a large continental area in the temperate zone have been shown vividly in the work carried on and now under way in the Bureau of Entomology, and the bureau has been able to devote as much money to it as its promised success from time to time seemed to warrant. It is probable that the men engaged in its prosecution have been as well fitted as any to be found. Some of them have grown up with the work as it has grown. It will not be necessary to attempt to estimate the sum the bureau has already spent in this direction in toto, but our experience over many years led us to spend $10,000 on alfalfa weevil parasites in 1923, and last year $15,000 on corn-borer parasites, $2,700 on Mexican bean beetle parasites, $28,000 on Japanese beetle parasites, and $50,000 on gypsy moth and brown-tail moth parasites. These sums include the salaries and expenses of traveling experts and foreign assistants and laboratory expenses abroad as well as similar expenses at the receiving end in the United States. In the case of the corn-borer parasite work, something over $3,000 of the $15,000 was spent last year in the home end of the work.

Down to the present time nothing spectacular has resulted from the prolonged efforts of the bureau. Very many beneficial insects have been imported and have become acclimatized, and the present excellent condition of the New England woodlands as a whole must be attributed in large measure to the work of the bureau importations. But it must be remembered that these importations have been coming in since 1905 (except for the five years of war time), and that we are still continuing. This fact in itself shows that the problem is a big one with very many ramifications, and it indicates further that immediate results are not to be expected, except under certain conditions, in a country like ours. Congressional committees and the Budget Bureau say to us, about our various parasite projects, "You say 'the work is promising,' but how about definite results?" It is difficult to make them understand our unwillingness to make definite promises; but the subject undoubtedly greatly interests these hard-headed, practical men.

The number of trained entomologists is increasing so rapidly almost all over the world that it is becoming an inexpensive matter to secure the introduction of promising parasites, on a comparatively small scale, by correspondence—almost at the cost of postage. It is a sample of the mutually helpful feeling that exists to an extraordinary degree among entomologists—an early instance of the true international spirit that is coming. Practically all of the later shipments of Novius have been from California rather than from Australia, and the great work that this insect has done in Egypt, Portugal, and many other countries was made easy by the courtesy of California.

In a thoughtful and important paper just published in Nos. 6 and 7 of the Revue de Zoologie Agricole for 1925, B. Trouvelot has listed the principal attempts made in sending beneficial insects from one country to another from 1873, when Riley and Planchon introduced *Tyroglyphus phylloxerae* into France from the United States, down to the present year. Thirty-four such efforts are listed, of which 17 were made at a cost so slight as to be inappreciable, while I estimate that the others cost in the neighborhood of $150,000. Of the 34 attempts listed, more than half (18) have not as yet shown beneficial results, and the majority of these will never show such results.

In this list there is no mention of many efforts, costing large sums of money, which have been absolutely fruitless, notably the world travel for many years of one of the California agents; the journey of two South African experts to Brazil to investigate one of the announced finds of the Californian; circumnavigation of the globe by an Australian expert, and, I fear, some of the more recent work of traveling agents of California, Hawaii, Italy, and the Bureau of Entomology at Washington.

Wherever there is actual waste of money in parasite work, it must usually be laid to ignorance or incompetence. Only the best-trained experts must be allowed to take part. It becomes a matter of danger to the country in other hands. It is for this fact that the United States Bureau of Entomology, with its large corps of men who have made such work their especial study, wishes to control in a way all such importation work for the United States; and it is, in fact, so empowered by law. It is for this reason that we have charged ourselves with the establishment of the parasites of the European earwig in the Northwest, although the city of Portland is apparently willing and able to undertake the work.

There are many things which will be brought out in this symposium, and many more which might be discussed to great advantage, but I can touch on only a few, although I could talk on the general subject all day long for several days.

Passing over the well-known subject of hyperparasitism, we may well devote a few words to superparasitism or coparasitism. The possible introduction of too many parasites—that is, too many kinds of parasites—has been seriously considered by workers for a number of years. Beginning with the strenuous controversy between Berlese and Silvestri concerning the parasites and predators of *Aulacaspis pentagona*, and strengthened by the studies of Pemberton and Willard of the parasites of the Mediterranean fruit fly in Hawaii, the different aspects of the subject have been more or less theoretically considered by several writers, notably by Thompson, by Wardle and Buckle, and Trouvelot in his recent papers.

A case in point is just now under consideration. It is proposed to bring to Bermuda from Hawaii the parasites of the Mediterranean fruit fly. Shall the four species now working in Hawaii all be sent to Bermuda, or shall only one—*Opius humilis*—be sent? In the work of Pemberton and Willard referred to, the conclusion was reached that the four parasites working together do not destroy as many fruit-fly larvæ as the Opius working alone. The Opius larva is destroyed by two of the others when working in the same fruit, while alone it is more prolific than the others. But the Hawaiian entomologists do not agree perfectly. Some believe one way, while others think that the more species of parasites introduced the nearer we come to actual control, thus backing up the stand made by Silvestri in his long controversy with Berlese. Mr. Willard, I believe, is of the opinion that the Opius should be sent on first and tried out.

Among the many things that persons in charge of such operations must remember is the normal food of the adults of the parasitic forms. We have during the past few years been learning more and more of the habits of adult parasitic Hymenoptera of feeding by suction at the holes made by the ovipositor in the body of the host insect. It seems, in fact, to be a widespread habit and in itself is probably responsible for a considerable mortality among the hosts. But with the Scoliid wasps, whose work against underground Scarabaeid and Cetoniid larvae seems so important, we must study the botanical food of the adults—the flowers they visit by preference—and we must be sure of the abundance of at least closely allied plants in the countries into which these parasites are introduced. This also holds, although perhaps it is not so important, with the Tachinids and the Dexiids. Is it not a prerequisite with some of these that they visit the flowers of umbelliferous or other plants before pairing or before oviposition?

The expense at the receiving end must not be stinted, and the most expert ingenuity and care must be exercised. In many cases, where the parasitic supply has come from some foreign country without cost, all necesary expenditures must be made by the receiving entomologists. In no case will it suffice to turn the imported material loose, even under the most apparently favorable conditions. The original supply must be multiplied by breeding, and experimental loosings must be made.

Again and again valuable importations have been lost through carelessness, lack of forethought. One very promising experimental sending was lost to an European country, for example, for the reason that the man in charge went away on vacation, leaving the work in untrained hands. And on another occasion an expert went half way around the world, and after infinite care and trouble brought back to his home country a good supply of healthy, living parasites of an important imported pest, only to lose the results of this costly and laborious journey through inadequate provision and care at the home end.

Great ingenuity has been exercised in the multiplication of parasites at the importing end. The development of the potato sprout idea for the rapid rearing of mealybugs to serve as food for Cryptolaemus in confinement in California laboratories is a marked example, and other novel and effective methods have been worked out at Melrose Highlands, at Riverton, and in France. And a better and most varied technique will be developed as time goes on.

The latest attempt to sum up the complications and the difficulties in parasite introduction has been made by Dr. B. Trouvelot of Doctor Marchal's laboratory, in a paper to which we have already referred. He brings out in clear form many of the points that had already occurred to most of us engaged in active work of this kind and summarizes in a concise way the factors that should be comparatively studied both in the importing and exporting countries. These, he thinks, are (1) the climate (humidity or drought) of certain months modifying both the activities of the species and their rapidity of multiplication; (2) the distribution of plants, both wild and cultivated; (3) the fauna, its composition and distribution; (4) the cultural methods followed (the size of the fields, character of the soil, period of harvest, and the amount of cultivation); (5) finally a factor dependent upon all of the others—the life history of the host, its local and regional distribution and its vulnerability.

After general consideration has been given to the points specified above, Trouvelot again considers other points which must be studied before a choice of parasites can be gained. These may be listed as follows:

(1) Synchronism of the life round between the parasite and the host.

(2) Parasite activity.

(3) Possibility of superparasitism and coparasitism.

(4) Tendency to hyperparasitism.

(5) Variations of the parasitic activity according to the climate.

(6) Possibilities of hybridization with related species belonging to the importing country.

(7) Power of dispersal of the parasites compared with that of the host.

We have already hinted at the popular appeal which parasite work always carries. Last September there were two striking instances of this. There was a conference of State experiment station directors and agricultural officials in Ohio, Michigan, and southern Ontario to review the corn borer situation. At Bono, Ohio, on the 29th, the visitors saw two of the European parasites of the corn borer in action under laboratory conditions, and the unanimous opinion was that this exhibition was a revelation of a phase of entomology of which they had had but the haziest conception. All were enthusiastic.

The next day this party went to Chatham, Ontario, and visited the corn borer parasite laboratory there. In one cage they saw thousands of fertilized females of *Exeristes roborator*, and this cage was carried to a near-by field in which every stalk was infested by the borer. The parasites were liberated in full view of the whole party of more than 100 persons. Although it was a cold, raw, windy, overcast day, the parasites began at once to search for larvae hidden in the stalks and to lay their eggs through the tough epidermis of the stalks. This delighted the observers. Some of them, incredulous that the parasites could locate the borer from the outside, dissected the stalks, only to find that in all cases the parasite had unerringly deposited its eggs on the hidden caterpillars. At the conclusion of this demonstration one prominent educator, the dean of the school of agriculture in a great corn State, is reported to have remarked that the demonstration had given him an entirely new conception of the significance of economic entomology.

Three years ago I published a paper entitled "A Side Line on the Importation of Insect Parasites of Injurious Insects from One Country to Another" (Proceedings of the National Academy of Sciences, June, 1922), in which I called attention to the extraordinary way in which some of the imported gypsy moth parasites have taken to native hosts. One of the most extraordinary of these parasites for its general adaptability is the Tachinid, *Compsilura concinnata*. Since its introduction in 1906 it has attacked 92 species of native insects, and it has established itself in New England in such a way as to act as automatically as any native species.

Lately a significant thing has occurred which intensifies the value of this species, and in fact has a bearing upon all such importations. The European satin moth appeared in New England recently. It multiplied in a most remarkable way, and there was apparently no attack upon it by native Tachinids. But the European Compsilura had become acclimated, and at once attacked the new European invader. Webber and Schaffner have shown in Bulletin 1363 of the U. S. Department of Agriculture, now going through the press, that in certain last-stage-larva collections a parasitism of 78 per cent by this species has been noticed and that in their aggregate of all collections parasitism averages 50 per cent.

The latest experiment of an international character and one which offers many possibilities and comparatively few complications is the effort made by the Government of Fiji to find effective parasites for the so-called levuana caterpillar which damages the leaves of the cocoa palm to such an extent as to cause great alarm. Several men have been engaged in this work, notably Mr. John D. Tothill, of Canada (trained partly, by the way, in the Gypsy Moth Parasite Laboratory of the Bureau of Entomology), Mr. A. M. Lea, of Adelaide, Australia, Mr. Hubert W. Simmonds, and Mr. C. T. McNamara. Here it was impossible to find immediately the native home of the pest, but expeditions were sent to the Malay Archipelago and the parasites of allied species were studied with the result that, after one or two unsuccessful attempts were made, three enemies of the allied *Artona catoxantha* were secured and bid fair to become established. One of them, a Tachinid (*Pychomyia remota*) immediately began to attack the levuana caterpillar "as if it had been attacking it from time immemorial" (Tothill in lit.). Then there was a Clerid beetle (*Callimerus arcuper*) which in both larval and adult stages attacked the pests with enthusiasm. There was also a single female of a species of Mesostenus, from which a rearing has been made. In this work the question is arising as to the relative value of the Tachinid and Braconid and as to the possibilities of bad results from the rivalry of the two species.

I have several times urged the wisdom of a large-scale attempt to import from abroad all parasitic and predatory insects which may be of help to us in our efforts to control imported pests. We could probably add to our fauna some hundreds of species which would be of positive assistance to us. We are really spreading out into such a scheme in many directions, and are learning, in some cases through mistakes and wasted effort, how it can be done most efficiently and economically.

It is true that some admirable results have been obtained in the old, more or less haphazard way, and we have nothing but praise for Koebele and his Novius work and for the Hawaiian explorers. But it is now very evident that, in order thoroughly to exhaust the possibilities of success in the majority of cases, especially where continental areas are concerned, detailed studies, which may in general be called ecological, must be made both in the importing and exporting regions.

All sorts of conditions will arise, some of which may be grouped as follows:

(a) Where the insect and its parasites are well known in its home country and where competent entomologists are anxious to assist.

(b) Where the original home of the pest is not known.

(c) Where the original home is known, but its parasites and their interrelations are not known.

(d) When there is a close morphological relative to the injurious form in some other country, whose parasites may be expected to take readily to the species aimed at or whose mode of life is so similar as to excite an oviposition impulse from its parasites.

In 1911, in recounting the original plan for the introduction of the parasites of the gypsy moth and the brown-tail moth, I wrote (Bulletin 91, Bureau of Entomology, pp. 13, 14)—

> It seemed to the writer that by attempting to reproduce in New England as nearly as possible the entire natural environment of the gypsy moth and the brown-tail moth in their native homes, similar conditions of comparative scarcity could surely be reached, and this view he still holds with enthusiasm.

In this statement, I think to-day that I well expressed the fundamental idea, and that the study of "the entire natural environment" is essential in most of these problems. This is only another way of expressing the need for extended ecological work.

A final word in regard to the too optimistic predictions of enthusiasts: We have seen in California the unfortunate results of too much optimism. We have seen also, within the past few years, the sudden discovery of the descendants of importations of parasites which had been here unnoticed but gradually increasing for from 20 to 25 years; which means that, not only must we not be overconfident, but also that we must not be too easily discouraged. I like to remember, in regard to the first point, the concluding words of Froggatt after his tour around the world in 1907 and 1908, in his report on his expedition—

> Let the whole question be judged on its results. Allow that one or two experiments have shown perfect results * * * that can be no reason why the parasite cure alone should be forced upon any one. Its admirers should be perfectly honest. * * * The wisest can never be sure of the results of any experiment. * * * Those at work for its (economic entomology's) far-reaching interests could do it no greater harm than by misleading or unproved statements.

As to the place of parasitism in plans for insect control:

It should receive consideration in all cases of imported pests just as soon as it is decided that extermination is likely to be impossible. Studies of the parasites in the native home of the pest should be begun at once, and, in the case of serious loss, no expenditure consistent with rigidly scientific methods should be begrudged. Work of this kind is in its infancy, and its possibilities are great.

FRAGRANT BUTTERFLIES

By Austin H. Clark

[With 13 plates]

CONTENTS

PREFACE

Surprisingly few naturalists seem ever to have noticed that the males of many butterflies give off a pleasant fragrance similar to and rivaling in attractiveness that of the scented flowers. This is the more remarkable since some of the most fragrant sorts are among the commonest species almost everywhere.

There are two reasons why we know so little of the odors of our butterflies. In the first place, most people interested in the butterflies regard them more as natural works of art than as the insects that they are, and therefore pay but slight attention to anything further than the form and color and the seasonal occurrence and general habits of the adults.

In the second place the adult nose is a quite uncertain organ, especially in men, and the testing of a butterfly often results in nothing more than a fit of sneezing caused by the irritation of the loosened scales.

The sense of smell in children is much keener than in adults, and they easily detect faint odors that escape their elders. It is also more exact, and if their previous experience with odors has been adequate their comparisons are likely to be closer.

The information on our native butterflies in the following pages was brought together with the assistance of my two young sons, Austin B. J. Clark and Hugh U. Clark, whose assistance in experimenting with some scores of captured butterflies was of the greatest value. On our various excursions in the field it fell to them first to investigate the butterflies we caught. In most cases I could myself confirm their observations, but in some I was quite unable to perceive an odor which both of them assured me was quite strong.

Ordinarily the testing of the butterflies for odors is an interesting and a pleasant task, but one must always be prepared for surprises sometimes most unwelcome as in the case of the females of the fritillaries.

SOURCES OF THE MALE FRAGRANCE

The flowerlike odors of male butterflies usually have their origin in hairs or scales of a peculiar type called androconia found only in the males, grouped in special "brands" or patches in various locations on the wings, distributed along the veins, or scattered widely on their upper surface. In the males of a species of *Melete* from Brazil, Fritz Müller found that a rather strong odor was emitted by a pencil of nonretractile hairs protruding from the ventral side of the abdomen. In the skippers the scent-emitting hairs are sometimes placed upon the tibiæ of the hindmost legs.

In our common milkweed butterfly (*Danaus archippus*) the males possess, besides the scent scales in the little sack on the hind wings, an extensible brush of hairs on either side of the last segment of the body which when fully extended radiate in all directions. In various related species these hairs are borne upon the inner end of a more or less long tube extending into the body within which the hairs form a compact tuft ensheathed by the tube walls. This tube can be everted or pushed outward in such a way that the inner end now becomes the tip of a more or less elongate fingerlike process bearing a tuft of radiating hairs.

Similar organs are found in the *Euplœas* (fig. 44, pl. 9; fig. 55, pl. 12) of the Old World regarding some species of which de Nicéville says: "The males may often be observed patrolling a small aerial space, with the end of the abdomen curled under the body toward the thorax, and with the two beautiful yellow anal tufts of long hair distended to their fullest extent at right angles to the body." The males of the related *Itunas* and *Lycoreas*, and the gorgeous males of *Morphos* and of their more somber eastern representatives, all have similar extensible appendages. In some forms it has been determined that a strong odor is given off by these.

DELAYED APPEARANCE OF THE PERFUME

Various observations giving negative results have been recorded on butterflies remarkable for their strong fragrance. It some cases it is stated than the examination was made on males recently emerged from the chrysalis. Very fresh butterflies appear always to be nearly, often indeed quite, odorless, while very ragged individuals sometimes are very fragrant. It appears to take some time after the wings are fully formed and functional for the odoriferous secretion to become diffused sufficiently to give the characteristic perfume.

OTHER ODORS EXHALED BY BUTTERFLIES

Besides these pleasant odors arising from the hairs and scent scales and confined, or almost entirely confined, to males, there are also other sorts of odors possessed by butterflies.

If you take a living female of any of our common fritillaries (*Argynnis cybele*, *A. aphrodite*, *A. atlantis* [figs. 57, 58, pl. 13] or *Brenthis myrina*) and gently squeeze the abdomen there will appear from between the last two segments on the upper side a double patch of soft dull light orange tissue. On further pressure there suddenly pops out just in front of this a pair of thick blunt processes like short thick horns which give off a strong and nauseating smell resembling that of the forked red or orange organ which the caterpillars of all of our swallowtails protrude from the first thoracic segment when they are disturbed.

Among the heliconians of the American tropics, close relatives of the fritillaries, the females have similar organs, though not quite so large, which also give off a disgusting smell.

The males in both these groups have a single unpaired organ of the same nature which is very small and situated between the upper ends of the terminal valves where in our fritillaries it is very noticeable because of its bright orange color.

In the females of some pierids, as *Catopsilia* (fig. 14, pl. 2) and *Melete*, there are organs like those of female fritillaries which give off a peculiar odor.

In one of the nymphaline butterflies (*Didonis*) both sexes from the upper side of the abdomen between segments four and five extrude hemispherical protuberances which have a strong and rather disagreeable smell. The male has in addition a pair of similar protuberances, white in color, which are extruded between segments five and six and give off an agreeable odor comparable to that of heliotrope.

In various forms the insects of both sexes give off a rank, mouldy, cockroachlike, or similarly disagreeable, in rare cases pleasant, odor, which is usually stronger in the females, and in the males often is combined with a wholly different sweetish scent. An example is our common milkweed butterfly.

A rank and disagreeable odor is in certain species common to both sexes when freshly dead, though not in life.

Some butterflies, like the Old World purple emperors, the various species of *Charaxes*, and certain swallowtails, which are immoderately fond of excrement or of rotting flesh, occasionally proclaim their preferences in the odors they exhale, though these do not properly arise from them themselves.

APPARENTLY SCENTLESS BUTTERFLIES

There are certain of our common butterflies with a great development of scent scales in which as yet no odor has been found. One of the most conspicuous of these is *Cercyonis alope* (fig. 35, pl. 6). This at any rate must have an odor, though I have been quite unable to find any in either sex. Mr. Scudder also was unable to find any odor in the three species of *Œneis*, of the same family, examined alive by him. So far I have found no odor in our common orange-tip (*Anthocharis genutia*, figs. 10, 11, pl. 2), though it probably has one.

THE ODORS OF BUTTERFLIES BY GROUPS

Pierids.—Of all the larger groups of butterflies the pierids are the most remarkable for the very general occurrence and the strength and uniformity of scent in males. Its presence has now been well established in about 80 different species. Furthermore it has been found among these butterflies that closely allied forms may have quite different scents. One of the best examples of this is found in our common whites.

Mr. Scudder wrote that among our common whites the males of the common cabbage butterfly (*Pieris rapæ*, fig. 1, pl. 1) "have a very faint but pleasant odor, difficult to detect. I have sometimes done so, but at other times have been unable to perceive it, on rubbing the scales of the upper surface of the wings and immediately smelling the fingers." More recently Doctor Dixey, Mr. Longstaff, and others have determined from studies made in England that the males of this butterfly have a scent, though it is neither so strong nor so distinctive as that of the green-veined white (*P. napi*, fig. 2, pl. 1). Originally Doctor Dixey compared the scent to that of mignonette (*Reseda odorata*), but Mr. Longstaff says that Prof. Selwyn Image's comparison to sweetbriar is better, though that is not exact.

Mr. Scudder found that the males of our native gray-veined white (*P. oleracea*) have a more distinct odor than those of the imported European white, though it is still faint. It is, too, quite a different odor, and he compared it to the fragrance of syringa blossoms. Mr. Longstaff, who examined this species at North Bend, B. C., compared the odor to that of lemon verbena.

Quite a fragrant little butterfly is our common sulphur (*Eurymus philodice*, fig. 7, pl. 1; figs. 20, 21, pl. 3), the males smelling like dried "sweet grass" or like sweet hay. This odor is fairly strong, and apparently it is constant and quite uniform, as I have noticed it in all examined both in Massachusetts and at Washington.

In the little sulphur (*Eurema euterpe*, fig. 13, pl. 2) the males have a pronounced fragrance which is somewhat similar to that of the males of the preceding, but is sweeter and more flowery, and is very easy to perceive in spite of their small size. My observations were all made in the vicinity of Washington. All but 8 out of 39 males of *E. euterpe* taken by Mr. Longstaff in Jamaica had an odor varying from very slight in some to strong in 17. Mrs. Longstaff described it on various occasions as "a slight pleasant smell," "strong, like syringa," "a very soft gentle smell, might be jasmine," and "very slight, sweet, jasmine or syringa." Mr. A. P. Ponsonby suggested gorse. In Mr. Longstaff's judgment the scent resembled rather the clove pink, but was still more like pink bindweed. There was no scent in the 21 females studied.

Among the southern relatives of this little butterfly *Eurema delia*, which is common in the Gulf States, was examined by Mr. Longstaff in Jamaica, Panama, Colombia and Venezuela in 1907. The results were conflicting, but in the large majority of cases negative. Of *E. westwoodii*, which is found sparingly in Texas and Arizona, three males taken in Jamaica all had a scent, described in one as a "spice odor, not quite the same as in *E. euterpe*."

The large clear yellow butterfly so common in the Southern States (*Catopsilia eubule*, fig. 14, pl. 2) according to Miss Murtfeldt has a slight violet odor in the male. From observations in Brazil, Fritz Müller described the perfume of this same butterfly as faint and musklike. In no less than 32 out of the 33 males tested by Mr. Longstaff in the West Indies and on the northern coast of South America in 1907 "a distinct scent was readily perceived, indeed in the great majority of cases it is noted as strong, twice as very strong. In quality the scent was agreeable and was compared by me to *Stephanotis*, or *Freesia*."

Mr. Longstaff records that two large males of the form *sennæ* taken at Savanilla, Colombia, had a strong scent, like that of *Freesia*. Of one of each sex taken at Cartagena the male had the usual strong *Freesia* scent, the female a disagreeable, but somewhat sweet, odor.

Of 22 females examined by Mr. Longstaff 9 proved negative, but in the remaining 13 a scent was detected which, though usually described as very slight, or slight, and never as strong, was often distinct enough. In quality the scent of the female *eubule* was disagreeable; somewhat sweet, but recalling bad pomade, or rancid butter, or butyric acid. In the female of this species Fritz Müller found a very strong peculiar odor in which some volatile acid seemed to predominate.

In a related species (*C. agarithe*) which occurs in the Gulf States and is common throughout tropical America, Mr. Longstaff found that of three males examined in Tobago two yielded a scent noted as being "sweet, neither strong nor pleasant."

In Brazilian specimens of another form (*C. argante*) which is found in Florida and Texas, Fritz Müller detected a very distinct musklike odor. In the females of this species he found an odor resembling that of female *eubule*.

In *Appias ilaire*, which ranges southward from southern Florida and Texas, Müller observed an odor in the male which he recorded both as faint and rather strong.

In *Dismorphia melite* (fig. 23, pl. 3), which occurs in New Mexico, Müller found in the male a faint disagreeable odor; but a single male taken by Mr. Longstaff in Venezuela had a scent like mignonette.

This is all we know about the odor of our native pierids. Let us now review the information on the foreign species.

The scent found in the European cabbage butterfly (*Pieris rapæ*, fig 1, pl. 1) was also found by Mr. Longstaff in the related *P. canidia* in China and in India.

The European species corresponding to our gray-veined white (*P. oleracea*), the green-veined white (*P. napi*, fig. 2, pl. 1), has long been known to be a fragrant butterfly. The odor of its wings has been compared to thyme, to lemon verbena, to orange and to balsam, and apparently is always present in the males, or rather can always be detected. Mr. Longstaff says that out of 46 examined all had the scent, and that many times he has known by the scent alone the moment he had it in his net that a small white was a male green-veined. This is no exaggeration, as I can testify from my experience with this form in Europe. Mr. Longstaff says that besides the green-veined white there are but two other butterflies known to him with the lemon verbena fragrance, our gray-veined white, and the related *P. melete* of Japan.

It is curious that the scent of the large white of Europe (*P. brassicæ*, fig. 6, pl. 1) is more difficult to detect than that of either the common cabbage (*P. rapæ*) or the green-veined white (*P. napi*), but neither Doctor Dixey nor Mr. Longstaff have the slightest doubt of its existence. Doctor Dixey compared it to that of scarlet geranium petals, and Mr. Longstaff to the flowers of rape. But the latter thinks that orris root is the best comparison.

Among the close relatives of our common sulphur the following observations are recorded. In *Eurymus hyale* (figs. 3, 4, pl. 1) var. *marnoana*, Mr. Longstaff found in the Sudan a very slight odor in both sexes which he doubtfully compared to chocolate candy or to cloves. In *Eurymus edusa* (figs. 17–19, pl. 3) caught in England, Doctor Dixey determined the existence in the male of an odor which he compared to heliotrope. Mr. Longstaff failed to detect any odor in this species in Algeria. Doctor Dixey found in a male of *Eurymus electra* in South Africa a scent like that which previously he had found in *E. edusa;* Mr. Longstaff found a somewhat less agreeable odor. The latter suspected a slight scent in two males of *E. nilgiriensis.*

Observations by Mr. Longstaff on *Eurema phiale*, like those on *E. delia*, gave results which were conflicting, but in the large majority of cases negative. The results were uniformly negative in the case of *E. albula.* Five out of eight males of *Eurema nise* had a scent varying from very slight to very strong, which was compared to that of the pink bindweed (*Convolvulus arvensis*); a slight scent, confirmed by Mrs. Longstaff, was detected in a female.

In *Eurema messalina* a scent was noted in 6 males out of 10. Mr. Longstaff described it as distinct or strong, and compared it to pink bindweed and to spice. It is also noted as distinct from that of *E. euterpe*, more dusty and less specific, and in another specimen as more spicy than bindweed. The bindweed odor was detected by Mr. Longstaff in several males of *E. libythea* in Ceylon. He failed to detect any scent in *E. hecabe* or in any of the allied forms.

Among the relatives of our *Catopsilia eubule*, Mr. Wood-Mason noticed in Assam that the tufts of hair on the wings of the males of *Catopsilia pyranthe* smell like jasmine. When in India Mr. Longstaff confirmed this observation, but thought a closer comparison was with the tuberose (*Polianthes tuberosa*). After his second visit to Ceylon in 1908 he wrote "The number of specimens taken was very much smaller than of *pomona*, but the scent was more easily detected in the male, and more decided in the female, than in that species. In both sexes the scent was compared to *Stephanotis*, but in one male to *Freesia*, and in one female Mrs. Longstaff thought the odor was 'a little bit hair-oily.'"

On stroking the scent tufts on the hind wings of the male of *Catopsilia pomona* Mr. Longstaff detected a slight jasminelike scent; later he compared this to *Freesia* or to *Stephanotis.* Out of 27 females examined the result was negative in 18; but in the other 9 a slight, usually very slight, sweet scent without other special character was noted.

On exposure of the tufts of hairlike scales on the hind wings of males of *Catopsilia florella* in South Africa a very strong scent was found to be emitted. This Doctor Dixey compared to jasmine, and Mr. Longstaff to tuberoses or to *Freesia*. Mr. Longstaff confirmed this later in the Sudan, and also there suspected a faint odor in the female.

In Brazil, Fritz Müller found a musklike odor in the males of *Metura cipris* (fig. 12, pl. 2) and of *Rhabdodryas trite* (fig. 15, pl. 2); it was unusually strong in the former but faint in the latter.

Müller observed that during courting the female of *Appias lycimnia* in Brazil emitted from the genitalia an odor which he described as rather faint, though quite distinct, and very different from that emitted by the male's wings. This last he found to be very delicious, but rather faint and often hardly distinguishable. Mr. Longstaff records that the three males caught by him all had a strong sweet flowery scent suggesting *Freesia*. Of three females one had a rich, sweet scent.

The male of *Dismorphia thermesia* was found by Müller in Brazil to emit a very strong odor disageeable to human noses. In the male of *D. astyonome* there is a similar, but much fainter odor.

No examination has been made of either of our dog-face butterflies (*Zerene cæsonia* and *Z. eurydice*), but one out of three females of *Z. cerbera* (fig. 26, pl. 4) examined by Mr. Longstaff was found to have a slight very sweet scent like (?) clover.

I have found no odor in our native eastern orange-tip (*Anthocharis genutia* [figs. 10, 11, pl. 2]), but I have had little opportunity for testing it. In England, out of many tested of the European orange-tip (*A. cardamines*), Mr. Longstaff found a fairly distinct, though faint, scent, sometimes described as musky, once as "very sweet."

A very interesting case of two different odors occurring in two closely related butterflies is afforded by the European brimstones (*Gonepteryx rhamni* [fig. 32, pl. 5] and *G. cleopatra*). While a slight scent has occasionally been detected in the males of the common brimstone butterfly (*G. rhamni*), though most of the trials have given negative results, the males of the allied southern form (*G. cleopatra*) have a scent uniformly distinct and often strong which Mr. Longstaff, who discovered it, described as "sweet, rich, thick—suggesting *Freesia*," later hesitating between *Freesia* and syringa.

Of other pierids, seven males of *Leptophobia aripa* out of eight examined by Mr. Longstaff in Venezuela had a distinct or even strong scent which he compared on various occasions to orange, *Freesia*, and mignonette.

Three males of *Itaballia calydonia* from Venezuela, all that he captured, were found by Mr. Longstaff to have a distinct flowery scent, in one described as like that of *P. brassicæ*, in another as somewhat sickly. In another undetermined species, near *P. sevata*, the only male examined had a faint, sweet, flowery scent.

In Assam Mr. Wood-Mason noted that both sexes of *Delias hierte* var. *indica* have a strong and grateful smell of musk. Of 18 males of *Delias eucharis* examined by Mr. Longstaff a scent was detected in 17. In 4 of these the scent was very slight or indefinable, but in 12 it was strong, or very strong, and compared by him to that of sweetbrier. In 6 females out of 9 there was more or less scent, but in no case was it strong; it was described as sweet, dusty or musky, and faint sweetbrier. In *D. nigrina* a male was thought by Mr. Longstaff to have a very slight scent.

The males of *Catophaga paulina* in Ceylon were found by Mr. Longstaff to have a scent which was variously described as "like sweetbrier, but sweeter and more luscious," "sweet," "very sweet (?) *Freesia*," "flowery," "decided meadowsweet," "decided *Stephanotis*," and "extremely sweet."

In *Huphina nerissa* Mr. Longstaff found that the males have a distinct sweetbrier scent.

Nine males of *Ixias cengalensis* (fig. 36, pl. 6) examined by Mr. Longstaff all had a sweet, but only moderately strong, scent, which reminded him of meadowsweet (*Spiræa ulmaria*). Four females were scentless.

Ten African species of *Teracolus* have been examined, with the following results. In *T. achine* Doctor Dixey found in the males an odor like that of honeysuckle. In *T. ione* he found the scent not always easy to detect, but sweet and flowery. In *T. annæ* he sometimes found the scent of the male strong, like syringa; Mr. Longstaff found it faint and like that of *Pieris brassicæ*. A dead male of *T. phisadia* had a sweet luscious scent, but another of *T. halimede* a somewhat disagreeable odor.

Mr. Longstaff says that the male of *T. protomedia* has a distinct scarcely agreeable scent hard to describe, while a female of *T. daira* had a scent like clove pink, both in the field and in the house. In *T. omphale* both Doctor Dixey and Mr. Longstaff found in the males a "white flour perfume," but the former usually found a musky constituent in addition. In *T. auxo* they both found a scent in the males, and in *T. eris* a sweet flowery scent.

All of the nine males of the giant orange-tip (*Hebomoia australis*) examined in Ceylon by Mr. Longstaff had a heavy sweet scent which was strong in most, and in all decided. It was compared to that of the flowers of the mango or to cinnamon. In three females out of four there was a similar scent.

In *Belenois gidica* (cf. fig. 27, pl. 4) from South Africa, Doctor Dixey and Mr. Longstaff found in some of the males a flowery scent which the former compared to that of roses. In *B. mesentina* in India Mr. Longstaff found the male to have a faint sweet flowery scent which did not appear to him to be quite like that of any other insect. In South Africa Doctor Dixey found in a male a scent much like that of *B. gidica.* In the Sudan Mr. Longstaff found the males to have a slight scent, sometimes described as musky, but once as luscious. In *B. severina* in South Africa both Doctor Dixey and Mr. Longstaff found much individual variation in the males. The former compared their scent to sweetbrier, the latter thought it like that of *Pieris brassicæ*, but stronger and more luscious. In *B. thysa* they agreed that the males have a strong distinct odor which Doctor Dixey compared to that of roses, Mr. Longstaff rather to the bluebell (*Scilla nutans*), but sometimes to *Freesia.* In *B. teutonia*, examined in Australia, Mr. Longstaff suspected a slight scent in sundry males, but nothing at all definite.

Mr. Longstaff found in the male of *Nepheronia ceylanica* in Ceylon a more or less distinct scent which he compared to *Freesia.* A female had a similar scent which Mrs. Longstaff compared to frangipani (*Plumeria rubra*). A male of *N. hippia* from India had a very slight burnt-sugar scent.

Both Doctor Dixey and Mr. Longstaff found a flowery scent in the males of the South African *Eronia cleodora.*

In *Pinacopteryx charina* from South Africa Doctor Dixey and Mr. Longstaff occasionally found in the male a flowery scent which the former compared to mignonette. In *P. pigea* they both found a distinct, sometimes strong, scent like honeysuckle in the male.

Three species of *Mylothris* (cf. fig. 30, pl. 4) have been examined in South Africa. The males of *M. agathina* and of *M. rüppellii* have a strong, pleasant scent exactly like that of sweetbrier. The scent of *M. trimenia* is of quite a different nature; it reminded Doctor Dixey of sweet peas and Mr. Longstaff of clover.

Doctor Dixey compared the scent of the males of *Synchloë hellica* to that of gorse. Mr. Longstaff recorded a male as having a very slight heavy and flowery odor. Later at Cape Town he caught a single male with a sweet odor which seemed to him to have a resinous element.

Swallowtails.—Among the swallowtails (Papilionidæ) apparently the males always have an odor, but the information concerning these is often more or less indefinite, sometimes conflicting. The females commonly, always perhaps, have a musty or acid odor, and the males frequently a similar odor, though much less strong, which sometimes makes the detection of the true male fragrance difficult and apparently explains much of the confusion in the records.

Our spicebush swallowtail (*Papilio troilus*) is our most fragrant species. In this the males have a distinct and rather strong aroma difficult to describe, but exactly resembling that of Nabisco or Huntley & Palmer's honey biscuits. The odor of the female is not known.

In the black swallowtail (*P. polyxenes*, fig. 34, pl. 6) the males have a rather strong, sweet odor like that of carrot flowers, quite the same, apparently, as that of the males of its close relative in Europe (*P. machaon*, fig. 37, pl. 6). No one has investigated the odor of the females.

In our common yellow swallowtail (*P. glaucus*, fig. 45, pl. 9; figs. 46, 47, pl. 10) the males, at least in Massachusetts, all have a sweet, flowery odor, varying from faint to fairly strong, which resembles that of the males of the spicebush swallowtail, though it is never so pronounced. The yellow females (fig. 46, pl. 10) have a strong and disagreeable odor, pungent or acid in quality, resembling rubber cement or creosote, which is very strong in some, especially in the South. The odor of the black females (fig. 47, pl. 10) has not been recorded.

The males of the blue swallowtail (*P. philenor*) have a sweet flowery odor somewhat similar to that of the males of *P. polyxenes*, though not so strong. The females have a strong and disagreeable scent, pungent and penetrating, with a suggestion of acetic acid.

Mr. William Schaus informs me that the most fragrant butterfly in his experience is *P. devilliersi* (fig. 40, pl. 8) which has been found in Florida, though properly confined to Cuba, a relative of our blue swallowtail. The odor is very strong and of a most pleasing nature, resembling that of the fragrant orchids.

The male of the black and white swallowtail (*P. marcellus*, fig. 52, pl. 11) has a very faint odor resembling that of the males of our other swallowtails, but with a spicy flavor not discernible in them.

Fritz Müller examined in Brazil the males of a swallowtail (*P. polydamus*) which ranges north to southern Florida and Texas. In these the odor was very strong. In this form there appear to be, indeed, two sets of males emitting equally strong but quite different odors, a condition aptly called by Mr. Scudder diosmism. In this same species (var. *polycrates*) Mr. Longstaff found an odor resembling that of musty hay in two examples of each sex; Mrs. Longstaff compared the scent to rue (*Ruta gravolens*).

Several South American swallowtails were studied by Fritz Müller. He found that the males of *Papilio hyperion* have a very strong odor; the males of *P. scamander* (?*grayi*) have a strong and most agreeable odor; the males of *P. protesilaus* (fig. 41, pl. 8) have a very strong rather disagreeable odor; and the males of *P. nephalion* have a faint agreeable odor. Mr. Longstaff found that a male of *P. eurimedes* had a strong odor of musty straw, and a living female of *P. æneides* a similar odor which persisted after death.

In *Troides darsius* of Ceylon (fig. 28, pl. 4) the males have a scent, sometimes a strong scent, like sassafras; the females smell like musty straw.

Mr. H. Pryer said that the male of *Papilio alcinoüs* (fig. 39, pl. 7) of Japan has a peculiarly sweet musky odor when alive, and that the female also emits a faint odor which to him is as unpleasant as that of the male is pleasant.

In Assam Mr. Wood-Mason noted in the male of *Papilio aristolochiæ* a strong and slightly pungent odor resembling that of (?) bachelors' buttons, or of the rose with a trace of acetic acid. Mr. Longstaff in Ceylon found that both sexes have an odor like musty hay. Of *P. doubledayi* (fig. 56, pl. 13) Mr. Wood-Mason said that the male has a musk-scented body, while the female of *P. dasarada* has the strong scent of caged porcupines with a touch of musk, and the female of *P. astorion* has a strong and disgustingly rank musky odor.

Mr. Longstaff has studied some additional Indian species. He found that the male of *Papilo hector* has a musty odor. Two males of *P. demoleus* (fig. 31, pl. 5), one in Ceylon and one in India, had an odor like fresh straw; a female had "a slight peculiar scent in the field, stronger in the house." A specimen of *P. telephus*, sex not given, had a slight sweet scent at home. A male of *P. parinda* was noted as having a scent like tea, but nothing of the kind was found in any of the other individuals examined. A male of *P. polymnestor* (fig. 38, pl. 7) had a somewhat musty odor.

Among the South African swallowtails both Doctor Dixey and Mr. Longstaff found an odor of fusty packing straw in both sexes of *Papilio demodocus* which according to the latter was stronger in the female. Doctor Dixey sometimes found an element in the odor suggestive of cabbage water or a kitchen sink. Mr. Longstaff says that the male of *Papilio dardanus* (fig. 33, pl. 5) has an odor of the musty-straw type, and that some of the males of *P. lyæus* examined had a scent which he at the time described as "sweet, luscious, flowery." In the males of *P. leonidas* Doctor Dixey thought the scent to be like that of *Danaus chrysippus;* but Mr. Longstaff found in several males what he described as a "strong sweet 'white flour' scent, followed by something more spicy."

Lelièvre found that *Thaïs polyxena*, which feeds on *Aristolochia*, has on emergence when handled an odor like that of its food plant, which arises from a fluid left upon the hand that has seized the insect.

Nymphalids.—About 30 years ago I was much surprised to find that a strong and pleasant fragrance comparable to that of sweet flag or of sandalwood combined with Spanish cedar and with a "dusty" element was given off from the wings of a male example of one of our common fritillaries (*Argynnis aphrodite*). More recently I have examined this peculiarity more closely. Of the males of both of our common species in New England (*A. aphrodite* and *A. cybele*) some dozens were examined. All had the odor, and on the average about one in four or five was found to possess a very strong aroma. In several cases so fragrant was the butterfly that the odor could plainly be detected as the insect fluttered in the net. Some of the most fragrant of the butterflies were badly rubbed and torn, while some freshly emerged were almost scentless.

Mr. Scudder remarked that *Argynnis atlantis* (figs. 57, 58, pl. 13) has a distinct odor of sandalwood so strong that it is hardly possible to handle living specimens without recognizing it, which he has known to be retained for many weeks after death when the insect had been inclosed at capture in a paper envelope.

In the regal fritillary (*Argynnis idalia*, fig. 59, pl. 13) the odor of the male is uniformly strong, resembling that of the other species but sweeter and more flowery. It was compared to musk by Mr. Scudder.

Prof. John H. Gerould writes me that he has noticed the same odor as that in *A. atlantis* in another species (*Brenthis montinus*) which I have not examined.

Of a curious fritillary common in the Southern States (*Dione vanillæ*) Mr. Longstaff says that 13 out of 17 males examined possessed an odor varying from very faint to very strong which in character was distinctly disagreeable—like a stable.

The majority of observations made by Mr. Longstaff on our southern heliconian (*Heliconius charithonia*) in 1907 in Jamaica gave negative results, but in three males and two females a slight pleasant flowery scent was detected which Mrs. Longstaff described as "sweet."

The large and handsome *Victorina stelenes*, occasional in Florida and in southern Texas, was studied by Mr. Longstaff in Jamaica. Five males appeared to have a slight flowery scent; in one it suggested chrysanthemum.

The handsome male of *Hypolimnas misippus*, abundant in the eastern tropics and in Africa, and occurring sparingly in Florida and southward where long ago it was introduced from Africa, was found by Doctor Dixey from observations in South Africa to have a smell like coffee, though not very strong.

In our common viceroy (*Basilarchia archippus*) there is a pronounced and disagreeable odor comparable to that of the females of

Danaus archippus. It is rather curious that this butterfly should resemble the milkweed butterfly not only in its color but also in its odor.

The males of our common peacock butterfly (*Junonia cœnia*, fig. 25, pl. 3; fig. 43, pl. 9) have a rather strong sweet sugary odor which sometimes quickly disappears. The variety examined was the one with the under surface of the wings deep dull pinkish red, the commonest in the fields in the vicinity of Washington.

Mr. Scudder noticed that in the males of the milkweed butterfly (*Danaus archippus*) the scales found in the little pouch upon the upper surface of the hind wings next the lower median nervule emit a slightly honeyed odor over and above the carroty smell which all the scales possess. This odor was detected in nearly all the males which I examined. It may be described as like the faint sweet fragrance of red clover blossoms, or of the flowers of the common milkweed. With this is a fainter cockroachlike or carroty odor which is found alone, and much stronger, in the females. Mr. Longstaff's notes on the odor of this species which was studied by him in Jamaica, Tobago, Panama, and Venezuela in 1907, and in Australia in 1910, and Fritz Müller's observations in Brazil, evidently refer to the disagreeable odor, and not to the true male odor which escaped both observers.

In the group of which the milkweed butterfly is a member (*Euplœinæ*) the evidence seems to show the common or even general occurrence of two quite different scents, a flowerlike scent peculiar to the males and a more or less disagreeable mouldy or acid odor common to both sexes, often stronger in the females, as in our milkweed butterfly.

Mr. Longstaff says regarding *Danaus jamaicensis* that of two males one had a strong smell of rabbit hutches, the other a decided odor as of (?) cockroaches, scarcely disagreeable. Of two females both had a strong cockroach smell, perceptible next day. Two males of *D. eresimus* had a "(?) very slight pleasant scent," and a female a "strong (?) muskrat [? *Desmana moschata*] odor when alive."

In the common and widespread *Danaus chrysippus* (fig. 24, pl. 3) of the eastern tropics Doctor Dixey found that the scent in both sexes is of a strong and disagreeable nature like that of cockroaches, often stronger in the female. In *D. genutia* (fig. 53, pl. 12) Mr. Longstaff sometimes detected an unpleasant scent, but did not record the sex of the individuals examined. Later he found a male to have a slight muskrat odor in the field, but none at home, though still alive.

In *Danaus limniace* Mr. Longstaff found in a male a very faint scent suggesting old cigar boxes; but observations made on other occasions were doubtful or negative. Of 11 males of *D. septentrio-*

nalis (fig. 54, pl. 12) 9 yielded a scent noted as slight, moderate, or decided, and described as pleasant or sweet, and in 2 cases compared (with, however, some hesitation) to clover. In a single female out of seven a slight scent was found and compared to *Stephanotis;* but Mrs. Longstaff in the house said "(?) ginger."

Of four males and four females of *Danaus taprobana* Mr. Longstaff found an odor in two females only. In the field he called it "a slight musty scent," but on reëxamination he compared it to stale tobacco smoke. In a previous investigation he reached more positive conclusions, saying that "it has the acetylene odor of *Euplœa core* (fig. 44, pl. 9), but not so strong and with a difference."

In *Danaus aglea* Mr. Longstaff detected a distinct scent "in 15 males out of 17 and in 11 females out of 14. In the male the scent varied from very slight to strong; twice, indeed, it was so strong as to be clearly perceptible when the insect was fluttering in the net." In 13 examples he compared it to acetylene; in the other 2 it was described as acetylene plus cockroach; but these, when re-examined in the house, were described as cockroach only and slightly musty, respectively. In six individuals in which there was a decided, or even strong scent in the field, none was detected in the house; in others the scent at home was slight, or described as musty; but in one it was compared to sweet hay. In all the 11 females the scent was compared to acetylene. Two other females were said to have a musty odor. Mr. Longstaff was satisfied that in *D. aglea* the scent is more transitory, possibly more volatile, than in the majority of scent-producing butterflies.

Doctor Dixey and Mr. Longstaff both agree that the two sexes of *Amauris albimaculata* yield a similar smell of musty straw, accompanied by an evanescent sharp or pungent scent like that of vinegar. In *A. echena* Mr. G. A. K. Marshall found a strong smell, which reminded him somewhat of that emitted by many ladybirds.

In four males and two females of *Euplœa core* (fig. 44, pl. 9) Mr. Longstaff found a scent that to him suggested rancid oil or old lamps, but which he later called acetylene. In one female he described it as muskrat plus acetylene. But in two specimens he described the scent when examined in the house as like that of acetic acid, although in the same specimens he had noted in the field the odor of acetylene. He suggests that the scent has two elements, one more persistent than the other.

In *Euplœa asela* a scent was noted in the field in 32 out of 38 males and in 17 out of 19 females. In four males and one female no scent was detected; there is no record of the others. On reexamination in the hotel in 13 males and 5 females no scent could be detected; when a scent was noted in the house it was in the large majority of specimens, especially among males, much fainter than it had been in the field. Mr. Longstaff noted that in both sexes the scent varied considerably in strength; it seemed to him to be quite as strong in the females as in the males, though all three specimens in which the scent was strong enough to be obvious through the net were males. In one male Mr. Longstaff described the scent as not unpleasant. In five examples, four females and one male, it was described as pungent and compared to acetic acid. One female was noted as having a strong pungent odor of acetic acid, still pungent and distinct at home. The scent adhered to the fingers after pinching. Mr. Longstaff remarked that the scent in *Euplœa* would appear to be more volatile than in the pierids or the danaids. From a series of observations he concluded that in *Euplœa* and in *Danaus* the scent which is common to both sexes whatever its source may be is independent of the genital tufts.

In *Euplœa anymone* var. *kinbergi* Mr. Longstaff noted the acetylene scent in several males; once it was so strong as to be obvious as soon as the insect was in the net.

In *Euplœa midamus* the acetylene odor of a female was perceptible when it was in the net. Mr. R. Shelford wrote in a letter to Mr. Longstaff that he found the terminal tufts of a male of *E. mulciber* to be sweetly scented.

A male of *Euplœa kollari* examined by Mr. Longstaff had a slight peculiar and rather disagreeable scent. Of two males of the form *sinhala* from Ceylon (fig. 55, pl. 12) one had an acetylene odor, moderate in the field but slight at home, while the other had a moderate acetylene scent in the field, none in the house; but on pinching it again while it was still alive the terminal tufts were protruded, and there was a momentary strong acetylene scent. As Mr. Longstaff says, it does not follow necessarily that the scent emanated from the tufts.

Five males of *Euplœa montana* all had a strong, or at any rate decided, acetylene odor in the field, at home either no scent at all, or at most a faint musty odor. "In one case the strong acetylene odor seemed to come from the upper surface of the body or wings, while there was a suspicion of a sweet scent (compared with some hesitation to sassafras) which seemed to come from the tufts." Two living females yielded an odor of acetic acid, which in one persisted slightly after death.

Mr. Wood-Mason said that in *Euplœa rhadamanthus* the eversible caudal tufts of the males are finely vanilla scented.

Fritz Müller found a rather disagreeable odor to be extremely strong in *Lycorea*, sp., and in *Ituna ilione*.

Among the southern relatives of our fritillaries a single male of *Dione juno* taken in Venezuela was found by Mr. Longstaff to have a slight stablelike odor, like that of our *D. vanillæ*.

Neither of our two species of *Colœnis* has ever been examined. In *C. cillene* in Jamaica Mr. Longstaff found, in eight out of 11 males, a decided scent, though never strong. Its character was noted as peculiar, sweetish, pleasant, distinctly aromatic, resinous, druglike or medicinal; it suggested to him at one time or another tea, Canada balsam, and pure carbolic acid, but his wife compared it to ginger, or a mixture of ginger with jasmine. Later he thought that sassafras would probably be the best comparison.

Müller says that the heliconians possess a disgusting odor which is generally stronger in the females. Of 11 males of *Heliconius hydarus* examined by Mr. Longstaff in Trinidad, Tobago, and Venezuela, 3 gave a negative result and 1 was doubtful; but the remaining 7 had a scent which varied from slight to very strong and was described as musty, like acetylene, or like hazeline (a preparation of witch-hazel). Eight females were examined, only one with negative results; in the other seven the scent varied from slight to strong, and was described as disagreeable, or like acetylene, or like hazeline. In one male and one female the scent was so strong as to be easily discerned when the butterfly was fluttering in the net. Two males of *H. euryades* were examined by Mr. Longstaff; one had a peculiar, rather pleasant, smell, the other none. Two females also were examined; in one the result was doubtful, but the other had a slight odor like that of the preceding.

Three males of *Eueides aliphera* were examined by Mr. Longstaff in Trinidad, two with negative results; the third had a stablelike odor. Two females both had decided odors, described as a peculiar scent, (?) acetylene, strong when alive, and as a strong *Dione* (that is, stablelike) scent when living.

Among the close relatives of our peacock butterfly (*Junonia cœnia*, fig. 25, pl. 3; fig. 43, pl. 9), a male of the Indian *Junonia almana* had a slight sugary scent, and two males of *Precis iphita* out of several yielded a slight odor of molasses.

Quite a number of additional nymphalids have been studied. The European species of *Charaxes* is said by Girard to have a strong odor of musk, especially just after its emergence; but he does not state in which sex this is found, nor its point of origin. Of *C. varanes* of South Africa Doctor Dixey says that a male on being squeezed emitted an odorless juice. Another was noted by Mr. Longstaff as having an odor resembling molasses. A female was thought by him to have a smell like cow dung, but to Doctor Dixey the scent of the same specimen recalled that of *Danaus chrysippus*.

In Brazil an unusually strong odor was detected by Fritz Müller in the males of *Myscelia orsis*, *Epicalia acontius* and *Ageronia arethusa*. In *Prepona laërtes* he noted a distinct odor in the male, not strong, but unmistakable, like a bat. In *Didonis biblis* he found a strong disagreeable odor common to both sexes. The males have in addition two other scents comparable to heliotrope and musk respectively, the latter faint.

Five males of *Cynthia asela* out of eight taken in Ceylon were found by Mr. Longstaff to have a peculiar slight sweet scent, at the time compared by him to sassafras or to French polish.

In *Neptis jumba* from Ceylon a faint sweet chocolate scent was detected in a male in the house by Mr. Longstaff. A somewhat similar scent was suspected in another male and in a female. But no scent was recognized in the much commoner *N. varmona.* In *N. agatha* (fig. 51, pl. 11) from South Africa Doctor Dixey noted in three males from Natal a strong and very disagreeable scent, like that of *Danaus chrysippus*, but more intense. Three males taken by Mr. Longstaff on the Zambesi had a slight scent which he described as sweet. Doctor Dixey notes that there is a difference in the aspect of the insects from the two localities.

Doctor Dixey and Mr. Longstaff are agreed that the male of *Hamanumida dædalus* of South Africa has a smell of the burnt sugar type.

In the males of *Byblia goetzius* in South Africa Doctor Dixey found a very distinct and agreeable odor of sweet chocolate, with a suggestion of vanilla. Mr. Longstaff found a similar scent in the only specimen he examined, which was a female.

In *Salamis anacardii* of South Africa both sexes have an animal-like odor which to Mr. Longstaff suggested rabbit hutches; it appears to be stronger in the female.

Very pronounced odors are characteristic of the *Morphos* and their allies. Fritz Müller found that the males of *Morpho hercules*, *M. epistrophis*, *M. menelaus*, *M. achilles* and *M. adonis* give off a very distinct odor which in the last two is most agreeable, resembling vanilla.

In Assam Mr. Wood-Mason found that in *Stichophthalma camadeva* the gland covered by a patch of modified scales and by an erectile wisp of hairs on each hind wing occurring in the male secretes a fluid that gives out a pleasant odor distinct from, but so faint as barely to be perceptible in the presence of, a much stronger odor resembling that of a sable fresh from the furrier's shop which is common to the two sexes. Mr. Wood-Mason also noted that the scent fans of *Thaumantis diores* are vanilla scented.

Among the Brassolinæ Fritz Müller noted very distinct odors in the males of various species of *Caligo*, *Opsiphanes* and *Dasyophthalma*, the odor being particularly strong in the last named.

According to Müller all the Brazilian Ithomiinæ emit a more or less distinct odor from a tuft of long hairs near the fore margin of the hind wings. In *Dircenna xantho* he says there is a rather strong and most agreeable fragrance of vanilla. In *Ceratinia eupompe*, *Mechanitis lysimnia* and *Ithomia sylvo* he records a faint scent in the males. In *Thyridia megisto* he found an odor in both sexes, but much fainter in the female.

In *Tithorea megara* Mr. Longstaff found a very distinct, or even strong, scent which he compared to *Stephanotis*, but he thought it had in addition a spicy or dusty element. In *Athesis clearista* he noted that a male had a slight sweet flowery scent, both alive and dead, which appeared to be associated with the brushes on the hind wings. A male of *Leucothyris victorina* and another of *L. phemone* had each an offensive odor which in the latter seemed to be associated with the tufts or brushes on the hind wings.

Both of the species of Elymniinæ which have been examined are strongly fragrant. In Assam Mr. Wood-Mason noted that the males of *Elymnias undularis* emit a strong odor resembling vanilla, the females being scentless. In *E. fraterna*, which is probably an insular race of the preceding, Mr. Longstaff found in four males an odor like that of vanilla scented chocolate; once Mrs. Longstaff compared it to very strong honey or coarse brown sugar.

Among the Acræinæ (fig. 42, pl. 9) Fritz Müller noted a disgusting odor in both sexes of *Actinote thalia*. Mr. Longstaff failed to detect any odor in *A. antæas* at Caracas, Venezuela.

All of the other observations on members of this group are based on South African species. Doctor Dixey found that the green juice exuded from a male of *Planema aganice* had a by no means unpleasant odor, like that of a crushed cabbage leaf. Doctor Dixey and Mr. Longstaff concur in stating that both sexes of *Acræa alboradiata* have a distinct musty odor, like old hay or straw; they both are in substantial agreement regarding *A. anemosa* in which the males have a musty odor, which Doctor Dixey found also in a female. Mr. G. A. K. Marshall says that this is the only *Acræa* in which he has noticed a strong odor. In *A. encedon* Mr. Longstaff found a slight unpleasant odor in both sexes. In *A. doubledayi* Doctor Dixey and Mr. Longstaff concur as to a musty odor in the male, and the latter found it in the female also. Mr. Longstaff found a faint odor in both sexes of *A. atolmis*. In *A. caldarena* Doctor Dixey found a distinct smell of musty straw in the female, and Mr. Longstaff came across a similar but slighter odor in a male. Doctor Dixey found a similar musty odor in *A. atergatis*, accompanied by a strong ammoniacal scent, like that of stable litter; no sex was given.

Satyrids.—In many of the wood nymphs or Satyridæ the males have numerous and well-developed scent scales, but in only a very few of them has an odor been detected, and when found the fragrance has usually been faint. No odor has been found in any of our species.

Several European forms have been found to have a scent, though it is faint in all. Doctor Dixey and Mr. Longstaff are agreed that the males of *Satyrus semele* have a slight scent which the former compared to chocolate or to sandalwood, the latter to snuff or old cigar boxes. Both these gentlemen found that the males of *Epinephele janira* have a very slight odor; to Mr. Longstaff it appeared somewhat pungent and suggested old cigar boxes. Doctor Dixey found in the males of *Pararge magœra* a faint but heavy odor suggestive of chocolate cream which he connected with the brand on the forewings. In *P. schakra* of India Mr. Longstaff suspected the existence of a very slight sweet scent that appeared to be unlike that of any other species examined up to that time (1903). Mr. Longstaff found a slight but distinct musky scent in two males of *Melanargia galathea.* Aurivillius recorded that both sexes of the European *Œneis norna* have a musky odor.

In Jamaica Mr. Longstaff found in 10 males of *Calisto zangis*, nearly all those examined, a scent varying from faint to strong compared by him to molasses, chocolate, burnt sugar, or to caramel, but in one instance described simply as aromatic. Ten females were without scent. Fritz Müller says that the male of the Brazilian *Antirrhœa archœa* emits a strong odor, which he does not describe.

In Assam Mr. Wood-Mason found that the males of *Lethe rohria* emit a delicious vanillalike scent.

Mr. Longstaff detected in a few males of *Yphthima ceylonica*, which was flying abundantly when he was in Ceylon, a very slight scent of chocolate.

The males of the four species of *Mycalesis* which have been examined all possessed an unusually strong fragrance. Mr. Wood-Mason found in *M. suavolens* in Assam that the scent glands and fans emit a powerful and delicious odor resembling that of vanilla which continues for some hours after death. In *M. mineus* var. *polydecta*, which he examined in Ceylon, Mr. Longstaff found in two male specimens that exposure of the pencils of hairs on the hind wings produced a strong scent which he compared to burnt sugar, and his wife to coarse brown sugar or molasses. In South Africa Doctor Dixey found in the tufts of the male of *M. safitza* a very strong odor of chocolate. In *M. perspicua*, examined also in South Africa, Doctor Dixey and Mr. Longstaff are agreed that there is a strong odor distinct from that of the preceding, but they were in only partial agreement as to its character.

The most interesting of the wood nymphs in regard to odors is *Heteronympha merope* of Australia and Tasmania, which is remarkable for the striking difference between the sexes, the males being much the larger and handsomer insects. In four males Mr. Longstaff found a faint, but distinct, scent of a sweetish character, sometimes suggesting molasses, sometimes tobacco. In eight females he found a decided sweet and flowery scent. He once compared it to syringa, but in two other individuals it seemed to have rather a balsamic character. Mrs. Longstaff said that it was "sweetish, like some flower, not quite syringa—not so strong." In no other butterfly does the female have a sweet, flowery scent stronger than the male.

Lycænids.—The hair-streaks, blues and coppers, which together make up the family Lycænidæ, are all quite small, the largest only slightly over 3 inches in expanse. Most of them spread from 1 to 1½ inches, or in North America from 1 to 1¼ inches, while a few do not exceed half an inch. Considering their small size and delicate build it is remarkable that many of them have a scent sufficiently strong to be detected.

Our common little blue (*Cyaniris ladon*) as described by Mr. Scudder has an exceedingly delicate odor which he compared to that of newly stirred earth in the spring, or of crushed violet stems. He specifically stated that he could not discover any odor in the males of *Rusticus scudderi.*

Six out of eight males of a close relative of our little blue occurring in Ceylon (*Cyaniris singalensis*) were found by Mr. Longstaff to have a scent of varying intensity, described in all cases as sweet, once as luscious, and once as *Freesia*-like.

In the common blue in England (*Lycæna icarus*) both Doctor Dixey and Mr. Longstaff found in the males a decided scent suggestive of chocolate candy. In the English *Chrysophanus astrarche* Mr. Longstaff found in a male the odor of chocolate "not flavored with vanilla."

In tropical America Mr. Longstaff found in a male of the very small *Catachrysops hanno* a very strong *Freesia*-like scent; but most of his specimens appeared to be quite odorless.

Mr. Longstaff writes that 10 males of *Polyniphe dumenelii* gave positive results of a surprising character. In the majority of cases the odor was strong or even very strong; moreover, it was disagreeable. He compared it to pig sties, or perhaps more correctly to pigs. It seemed to him scarcely credible at first that so small a butterfly could smell so strongly. A female was odorless.

In a male of *Theclopsis tephræus* examined in Venezuela a strong peculiar rather disagreeable odor was detected. A male of *Tmolus cambes* yielded an odor of molasses; Mrs. Longstaff compared it to coarse brown sugar. A male of *Tmolus palegon* had an odor of chocolate. In *Thecla atys* in Brazil Fritz Müller found an unusually strong batlike odor in the male, and he also found more or less distinct odors in various other types, the names of which he did not know.

In a male of *Tarucus theophrastus* from the Sudan Mr. Longstaff found a moderately strong, sweet, luscious scent.

All of the remaining records are from Ceylon, where they were gathered by Mr. Longstaff. Two males of *Nacaduba atrata* had a sweet, flowery scent, confirmed by Mrs. Longstaff and in one case compared by her to "very, very faint jasmine." Five males of *Lampides elpis*, all of those examined, had a sweet scent which in one was with some hesitation compared to clover. Nine males of *L. lacteata* all had a distinct odor which was compared to vanilla biscuits or to chocolate candy. These two closely allied species therefore have quite different scents. A minority of the numerous males of *L. celeno* which were examined had a faint, sweet scent. About half of the males of *Polyommatus bœticus* had a slight scent like that of meadowsweet. Three males of *Rapala lazulina* yielded a scent like that of vanilla biscuits.

Skippers.—Among the skippers, or Hesperidæ, which are mostly very small, there are but few observations, though in very many scent scales are extraordinarily developed in various places on the wings and even on the tibiæ of the hindmost legs.

In *Plesioneura eligius* and in a species of *Achlyodes* from Brazil Fritz Müller noticed that the pencil of long hairs on the hindmost tibiæ of the males emitted a very faint odor. In the South African *Gegenes occulta* Doctor Dixey found a very distinct chocolate scent in a male.

FUNCTION OF THE ODORS

What is the purpose of the fragrance of the males of butterflies? Last summer I watched the courting process in *Argynnis cybele.* A female was seated on the upper surface of a horizontal leaf with the wings folded tight together and the fore wings drawn backward to the maximum, a somewhat unusual and strained position for this insect when sitting on a leaf, but one which was maintained unchanged throughout the whole performance. An inch or so behind the female on the same leaf was a male, his body just in line with hers and facing the same way. His wings were close together, but the fore wings were drawn far forward so that their hinder border approached the vertical, as that of hers did the horizontal. At intervals he would suddenly open and close his wings, these intervals, at first about a second, becoming less and less; and constantly, almost incessantly, he slightly shifted his position, in a series of little rapid jerks.

The same drawing forward of the fore wings of the male, the spasmodic opening and closing of the wings, and the constant sudden shifting of position, is also characteristic of the courting of *Cercyonis alope* (fig. 35, pl. 6); but the performance usually takes place upon a tree trunk or some broad surface more or less near the vertical, and the male commonly moves up so that the two sit side by side.

In the common sulphur (*Eurymus philodice*) (fig. 7, pl. 1; figs. 20, 21, pl. 3), the courting of the male always is accompanied by a constant fluttering of the wings, with the fore wings drawn well forward; but in this butterfly the female usually sits with her wings widely spread, the fore wings drawn well back.

In all these cases it is evident that the male endeavors to envelop the female with his perfume, which in the first and last is wholly different from that of any flower upon which the insect feeds. Were the odor of the males really attractive to the females as has been assumed, and as the fragrance of the flowers is, there would surely be no need for such persistence as the males exhibit.

The natural conclusion therefore is that the odors of male butterflies are in reality sex stimulants, like the odors of the males in other creatures. Such odors, though all serving the same purpose, may or may not be agreeable to our senses, and this is probably the reason why in certain butterflies the males seem to us to have a most unpleasant smell.

Undoubtedly the nauseating odors of the subterminal organs of the female fritillaries are protective in their function. The chief enemies of these butterflies with us undoubtedly are mice. I have noticed that discarded individuals dropped into the meadow grass were by the next morning invariably eaten. But these butterflies always spend the night as near the ground as possible, crawling down the grass stems and often many feet along the ground, hiding away in the débris close to the soil, much as in the spring their caterpillars hide themselves away during the daytime. Here they are exposed especially to attacks by mice. The females of our fritillaries seem to be much longer lived than do the males, for by the end of August in New England all the still fairly numerous individuals remaining are females busily engaged in searching for their food plants and depositing their eggs.

Whether the much longer life of the female fritillaries results from superior vitality or from superior protection against mice is an interesting question.

The females of all our fritillaries are larger and more conspicuous than the males, and at the same time less shy with a less swift and less erratic flight. It may be that when on the wing the males are protected by the more conspicuous and more readily caught females with their powerful repellent organs.

Presumably in the other butterflies in which the females have a disagreeable odor absent from or weaker in the males that odor is more or less protective. But it is by no means a complete protection, for certain mice commit great havoc in the wintering swarms of our milkweed butterfly (*Danaus archippus*), while in Africa and Asia certain of its relatives are freely preyed upon by other creatures, especially by certain kinds of mantises.

EXPLANATION OF PLATES

Plate 1

Fig. 1.—The common cabbage butterfly (*Pieris rapæ*); the specimen is from Newtonville, Mass.

Fig. 2.—The green-veined white (*Pieris napi*); the specimen was caught by the author at Interlaken, Switzerland.

Fig. 3.—The clouded sulphur (*Eurymus hyale*), male, from Interlaken, Switzerland.

Fig. 4.—The clouded sulphur (*Eurymus hyale*), female, from Interlaken, Switzerland.

Fig. 5.—*Eurymus eurytheme*, male from Ipswich, Mass., August 25, 1925.

Fig. 6.—The large white (*Pieris brassicæ*), Interlaken, Switzerland.

Fig. 7.—The common sulphur (*Eurymus philodice*), male, Newtonville, Mass.

Fig. 8.—*Eurymus eurytheme*, female, Washington, D. C., September 19, 1925.

Fig. 9.—*Eurymus eurytheme*, white female, Washington, D. C., September 19, 1925.

Plate 2

Fig. 10.—The falcate orange tip (*Anthocharis genutia*), male, from Washington, D. C., April 13, 1925.

Fig. 11.—The falcate orange tip (*Anthocharis genutia*), female, from Washington, D. C., April 19, 1925.

Fig. 12.—*Metura cipris*, male, Brazil.

Fig. 13.—The lesser sulphur (*Eurema euterpe*), male.

Fig. 14.—*Catopsilia eubule*, male.

Fig. 15.—*Rhabdodryas trite*, male, Brazil.

Fig. 16.—*Eurymus phicomone*, female; the specimen was caught by the author at Chamonix, France.

Plate 3

Fig. 17.—The clouded yellow (*Eurymus edusa*), male, from Interlaken, Switzerland.

Fig. 18.—The clouded yellow (*Eurymus edusa*), female, from Interlaken Switzerland.

Fig. 19.—The clouded yellow (*Eurymus edusa*), white female, from Interlaken, Switzerland.

Fig. 20.—The common sulphur (*Eurymus philodice*), white female, Newtonville, Mass.

Fig. 21.—The common sulphur (*Eurymus philodice*), white female, Newtonville, Mass.

Fig. 22.—*Dismorphia nemesis*, male, South America.

Fig. 23.—*Dismorphia melite*, male, South America.

Fig. 24.—*Danaus chrysippus*, male, from Kilossa, Tanganyika Territory; caught by Arthur J. Loveridge, January 15, 1921.

Fig. 25.—The American peacock butterfly (*Junonia cænia*), female, Washington, D. C., September 19, 1925.

PLATE 4

FIG. 26.—*Zerene cerbera*, male, Venezuela.
FIG. 27.—*Belenois zochalia*, Kilossa, Tanganyika Territory, December 4, 1920.
FIG. 28.—*Troides darsius*, male, Colombo, Ceylon.
FIG. 29.—The western checkered white (*Pieris occidentalis*).
FIG. 30.—*Mylothris rubricostata*, Nairobi, Kenya Colony, August 31, 1920.

PLATE 5

FIG. 31.—*Papilio demoleus*, east Africa.
FIG. 32.—The Brimstone (*Gonepteryx rhamni*), female, from Interlaken, Switzerland.
FIG. 33.—*Papilio dardanus*, male, Kilossa, Tanganyika Territory, July 6, 1921.

PLATE 6

FIG. 34.—The black swallow-tail (*Papilio polyxenes*), male, Long Island.
FIG. 35.—*Cercyonis alope*, male, Newtonville, Mass.
FIG. 36.—*Ixias cengalensis*, Ceylon.
FIG. 37.—The European swallow-tail (*Papilio machaon*), France.

PLATE 7

FIG. 38.—*Papilio polymnestor*, Malabar coast, India.
FIG. 39.—*Papilio alcinoüs*, Japan.

PLATE 8

FIG. 40.—*Papilio devilliersi*, Cuba.
FIG. 41.—*Papilio protesilaus*, South America.

PLATE 9

FIG. 42.—*Acræa natalica*, Kilossa, Tanganyika Territory, January 29, 1921.
FIG. 43.—The American peacock butterfly (*Junonia cœnia*), female, migrant form, Washington, D. C., September 27, 1925.
FIG. 44.—*Euplœa core*, India.
FIG. 45.—The common yellow swallow-tail (*Papilio glaucus*), male, raised in Washington from a caterpillar from Cambridge, Mass.

PLATE 10

FIG. 46.—The common yellow swallow-tail (*Papilio glaucus*), female, southern form.
FIG. 47.—The common yellow swallow-tail (*Papilio glaucus*), female, black form.

PLATE 11

FIG. 48.—*Papilio antheus*, Kibwezi, Tanganyika Territory, April 29, 1921.
FIG. 49.—The European wood white (*Leucophasia sinapis*), Interlaken, Switzerland.
FIG. 50.—*Amauris ochlea*, Frere Town, Kenya Colony, August 2, 1920.
FIG. 51.—*Neptis agatha*, Kilossa, Tanganyika Territory, January 22, 1921.
FIG. 52.—The black and white swallow-tail (*Papilio marcellus*), Washington, D. C., April 26, 1925.

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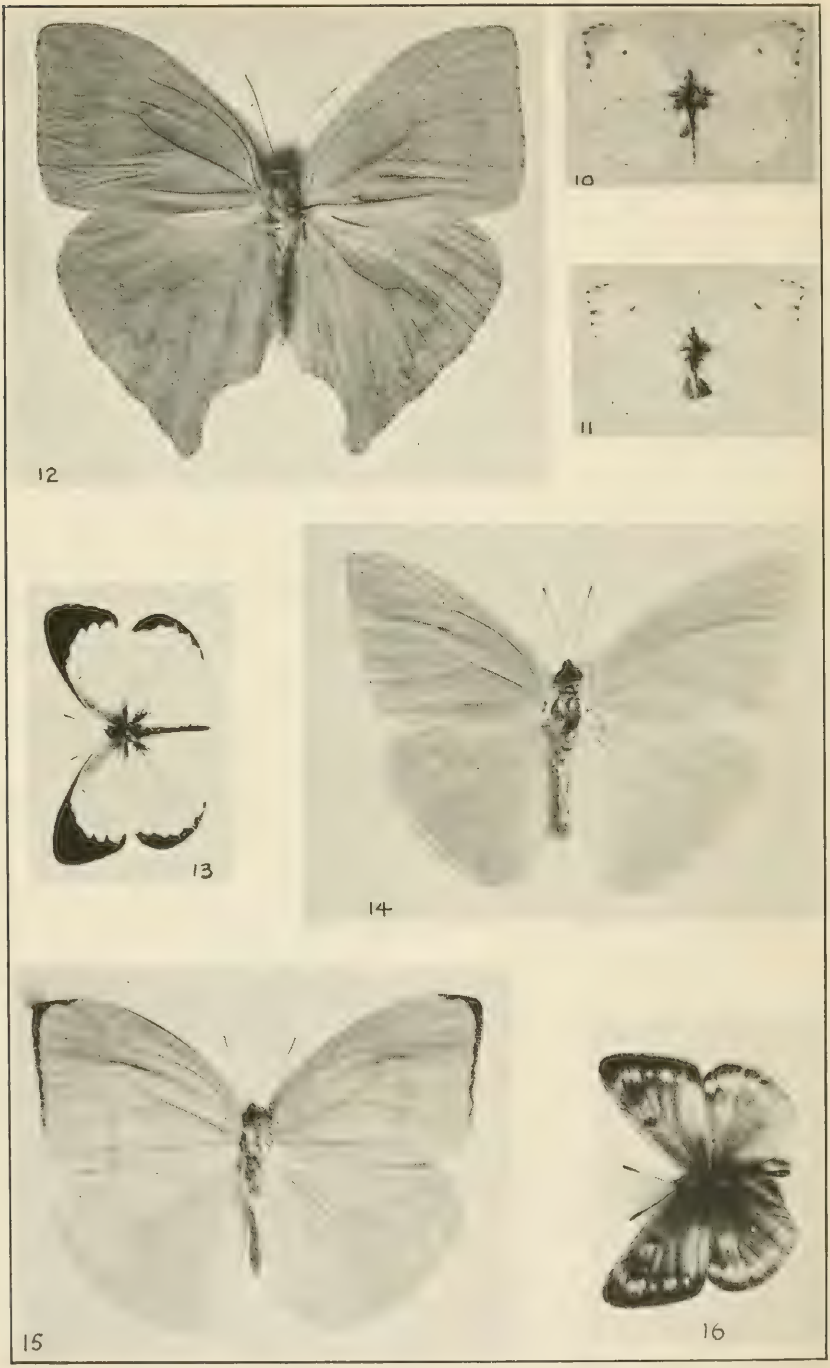
PLATE 12

FIG. 53.—*Danaus genutia*, male, India.
FIG. 54.—*Danaus septentrionalis*, India.
FIG. 55.—*Euplœa sinhala*, Ceylon.

PLATE 13

FIG. 56.—*Papilio doubledayi;* the specimen is from Trong, Lower Siam.
FIG. 57.—*Argynnis atlantis*, male, lower side, Essex, Mass.
FIG. 58.—*Argynnis atlantis*, male, upper side, Essex, Mass.
FIG. 59.—*Argynnis idalia*, male, Essex, Mass.

FOR EXPLANATION OF PLATE SEE PAGE 444



FOR EXPLANATION OF PLATE SEE PAGE 444

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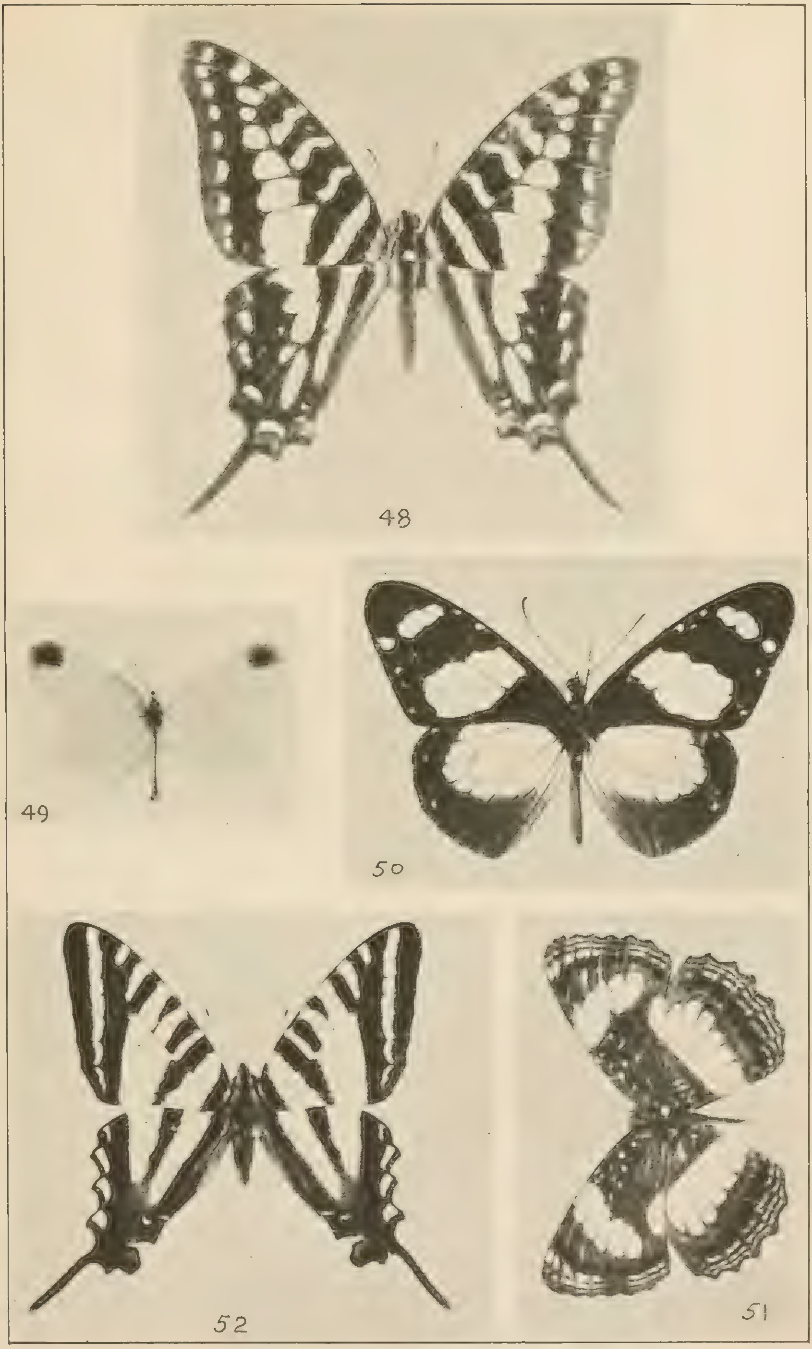
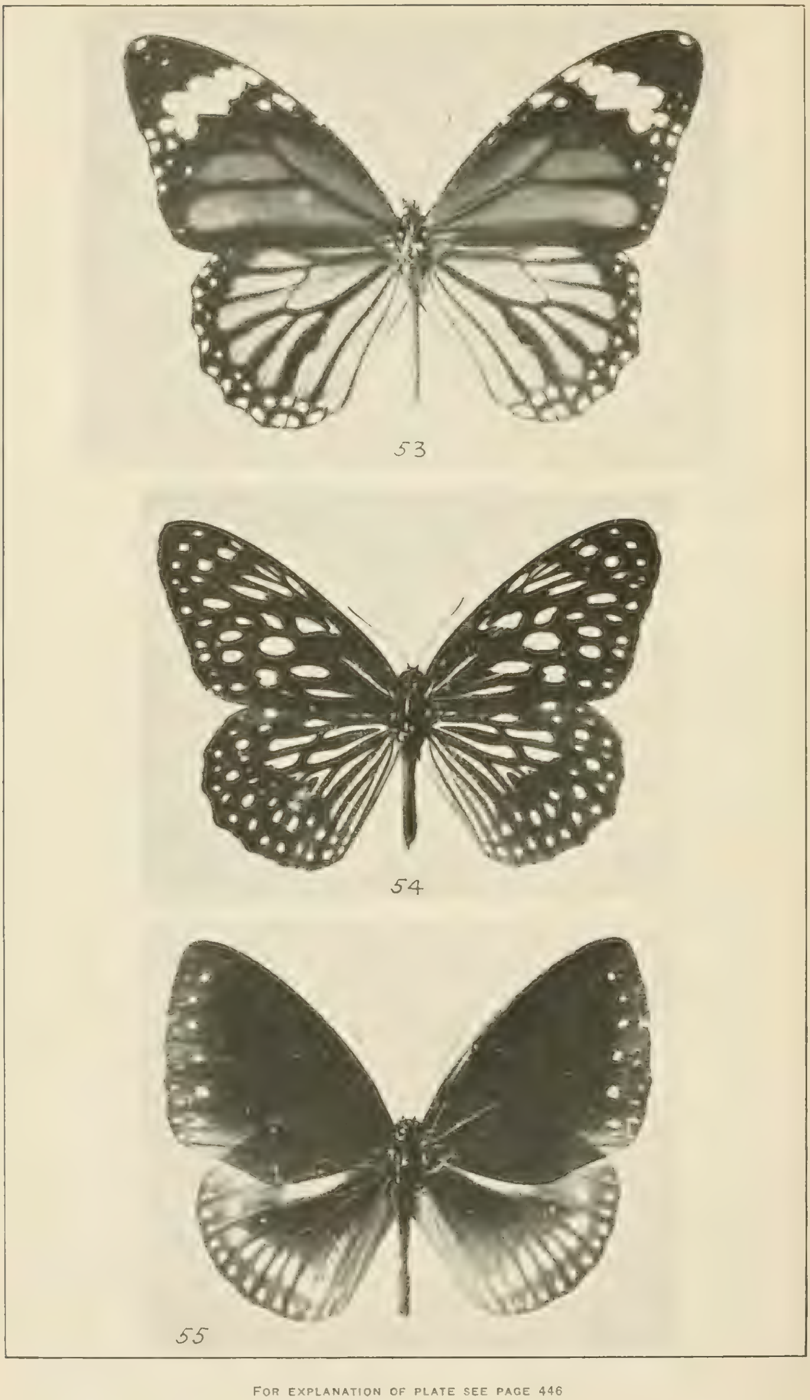


FOR EXPLANATION OF PLATE SEE PAGE 445



For explanation of plate see page 446

FOR EXPLANATION OF PLATE SEE PAGE 446

THE RITUAL BULLFIGHT[1]

By C. W. Bishop

[With one plate]

The custom of holding public contests between two bulls, or between bulls and men, is a very ancient and widespread one, confined to no particular age or ethnic group. Its origin is apparently to be sought in one or another form of nature worship, and, where its primitive significance has not been obliterated or at least blurred through the influence of more developed religious ideas, it almost invariably forms part of a ritual observance intended either to promote the fertility of the crops or to forecast the amount of their yield. In other words, the custom is closely interwoven with the origin and growth of the practice of true agriculture, which implies the use of the plow and the possession of domestic animals, especially the ox, the plow animal par excellence in all agricultural communities down to quite modern times.

That form of the usage in which the contest takes place between men and bulls appears to center in a general way about the Mediterranean area, around which it formerly had a very wide extension, dating perhaps as far back as late Neolithic times. The Cretan representations of contests between bulls and young men and women are well known. The Berbers of North Africa are said to have had a similar custom prior to the Mohammedan invasion. The occurrence upon the prehistoric Egyptian slate palettes of the motif of a water buffalo[2] goring and trampling a man suggests that a similar practice once prevailed on the banks of the lower Nile. That the custom lasted in Greece and Asia Minor well down into the historical period we know from the classical writers, who speak of the rite of the Taurokathapsia, literally "bull baiting,"[3] held in honor of Poseidon at Smyrna and Sinope, as well as in Ionia and Thessaly. In England the custom, originally of ceremonial significance and

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[1] Reprinted by permission from The China Journal of Science and Arts, vol. III, No. 12, December, 1925, pp. 630–637.

[2] For representations of these very interesting palettes, see H. R. Hall, "The ancient history of the Near East," New York, 1913, pl. vi, p. 82. It is clearly the water buffalo and not the bull which is here depicted. On the occurrence of the water buffalo in North Africa in prehistoric times at least as far west as Algeria, see J. Ulrich Duerst, L'Anthropologie, vol. XI, 1900, Notes sur quelques bovidés préhistoriques, p. 137.

[3] From *ταῦρος*, bull, and *καθάπτομαι*, to lay hold of, to irritate. Poseidon seems originally to have been a god of fertilizing springs and of vegetation; hence his epithet of *φυτάλμιος*, producing, nourishing, fostering.

very old, survived as a popular pastime far into the nineteenth century, and although dogs were commonly employed to worry the bull, in certain instances, such as the famous Stamford bull running, we seem to have traces of a far earlier practice, in which the animal was chased about and beaten to death with clubs, which must not be shod with iron.[4] This notion of killing without the shedding of blood is very ancient and widely distributed, and the idea in connection with the custom under discussion doubtless was that if the animal's blood were lost it would fail to invigorate the growing crops.[5] Possibly the rule against the use of iron-shod clubs was a survival of the prejudice against the use of that metal in connection with ritual observances. Another such survival undoubtedly was the fact that it must be a woman who rode or drove the bull to the place of the running. The classical myth of Europa and the bull may not be without significance in this connection, inasmuch as the whole proceedings appear originally to have constituted a fertility rite. As is well known, the custom has survived also under various forms in Portugal, in southern France, and in Spain.[6]

In a somewhat specialized and highly ritualistic form, closely parallel to that of the Stamford and similar bull runnings kept up in the British Isles until a century or so ago, the practice of bull baiting—or, perhaps more accurately, beating—seems to have been carried in prehistoric times right across Asia, in all likelihood as part of the true agriculture complex. This is suggested, for example, by the modern custom reported from regions as widely apart as Turkestan, China, and Annam, of carrying in procession and then breaking up with clubs a clay or paper image of an ox, usually in connection with the spring festival of renewal and growth corresponding to our Easter.[7] Regarding this custom M. Chavannes tells us that although no doubt originally a living animal was used, from the first mention of the custom in China, about the beginning of the Christian era, it has been of earthenware; he adds that the ox really personified the spring and that in beating it the intention was to beat the spring itself in order to hasten its advent.[8] It seems more

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[4] On the Stamford bull running, see Folklore, vol. XV, 1904, pp. 199 et seq.; also Enc. Brit., 11th edit., under "Bear baiting and bull baiting."

[5] "For the life of the flesh is in the blood;" Levit. xvii, 11; cf. also Acts xv, 29.

[6] The origin of the Spanish bullfight has been ascribed both to the Romans and to the Moors; but according to J. Sanchez de Neira (El Toreo: Gran Diccionario Tauromáquico, Madrid, 1879, vol. I, p. 22), a first class authority, it is indigenous, and would seem, therefore, to belong to that ancient preclassical Mediterranean culture already mentioned.

[7] On this see especially Edouard Chavannes, Le T'ai Chan (in Annales du Musée Guimet, Paris, 1910). R. F. Johnston ("Lion and dragon in northern China," London, 1910, pp. 180–182) gives us an interesting account of the spring festival, and Sir James G. Frazer ("The golden bough: a study in magic and religion," third edition, vol. III, p. 10 et seq.) connects the custom of "beating the ox" at the east gate with the idea of fertility and growth.

[8] Chavannes, op. cit., p. 500 and note 2. The Chinese expression is *pien ch'un-niu* (Giles's Dict., Nos. 9190, 2854, 8346).

likely, however, that the primitive idea was that of slaying the tutelary divinity of agriculture, symbolized as a bull, that his life and vigor might pass into the newly planted crops and bring about their abundant yield.

An interesting detail of the custom, suggesting that a human sacrifice may have formed part of the rite in earlier times, appears in connection with its occurrence in the extreme west of China, on the Tibetan border. Here a paper effigy of a youth, supposed to be the leader of the bull, is burnt,[9] while the earthenware body of the animal is pounded to pieces, various auguries being drawn meanwhile from the color and posture of the bull and the costume of its leader.

That the original motive in these practices was the promotion of fertility seems evident. This appears especially clearly in the form which the custom takes, or perhaps took, in Shanghai.[10] Here the ox is constructed of variously colored pieces of paper, selected and pasted over a bamboo frame by a blind man. Auguries are drawn regarding the coming harvest, good or bad as one color or another predominates. Further, the effigy is filled with various sorts of grain which pour forth when it is smashed, typifying the abundant crops hoped for by the celebrants. The ceremony is held in honor of Shên-nung, the ox-headed patron divinity of agriculture.[11] Now Shên-nung would appear originally to have been the bull-god of fertility of the ancient non-Chinese folk of the Yangtze Valley, prayed to by them for rain and abundant crops. It not infrequently happens that beast-gods gradually assume human form while retaining their animal heads; the final stage in this metamorphosis is the appropriation of the human aspect in toto, the pristine shape, if it survives at all, being passed on to an attendant animal. Hence it is not impossible that, as in the Chinese forms of the rite cited above, both the ox and his youthful leader represent the god of agriculture in his earlier animal and later human forms, respectively.

In all the foregoing examples the essential element is that of a struggle between man and beast—originally, it would seem, a beast-god, put to death that his vigor and reproductive power might transfuse themselves into the growing crops. In this form the custom apparently originated in that ancient culture area, embracing most of the temperate zone of the Eurasiatic continent, characterized by the growing of such cereals as wheat, barley, and millet, and where also oxen were first utilized in connection with field work. The

[9] Rev. J. Hutson, "Chinese life on the Tibetan foothills," The New China Review, Vol. II, pp. 470 et seq. See also on the same practice R. F. Johnston, op. cit., pp. 180 et seq.

[10] See The China Review, Shanghai, Vol. I, 1872–73, p. 62, query on "beating the ox" at Shanghai; also ibid., p. 203 et seq., note by John Chalmers on the same; the latter says the ox should properly be made of clay, not paper.

[11] Regarding Shên-nung's ox head, see, e. g., P. Henri Doré, "Recherches sur les superstitions en Chine," Shanghai, 1911, Vol. X, p. 717.

object, as already indicated, is mainly the promotion of the fertility of the fields; but it is also sometimes an effort to forecast the size of the harvest. It is likely, in fact, that the two motives were never clearly differentiated by the celebrants.

There is, however, another form of ritual contest, in which the struggle is between two bulls. This type also occurs over an enormous area, in the main distinct from the former, although overlapping it slightly, and extending from Japan on the east to Madagascar on the west. Throughout this vast area, partly continental and partly oceanic, it appears to be an integral factor, in present or past time, of the irrigated rice culture complex.

In this type also the original idea seems to have been the promotion of fertility. But at present in those localities where the rite survives most fully it is the second motive—that of divination—which is predominant, the likelihood of good or bad harvests being judged according as one or other of the two bulls wins. Again the purpose may become merely that of providing amusement, either for court circles or for the people at large. Finally, the custom may degenerate into a purely commercial affair, where admission is charged, and where one of the principal motives is the opportunity afforded for gambling.

In its full form, however, this type of ritual bullfight combines a number of definite and highly characteristic elements. First comes the selection and preparation and in some cases the training of the bull for the rite, which normally occurs in the spring. Just previous to the fight the animal's pugnacity is aroused by forcing quantities of strong drink down his throat. Then comes the combat proper, at the end of which the victor is led in triumphal procession, to the accompaniment of chants and drums. He is then sacrificed to the guardian divinity of the crops, whose representative he is, by the local headman in his capacity of chief priest of the group, the killing here also being accomplished without the shedding of blood, either by clubbing to death or by driving a spike into the animal's forehead. His flesh is then divided and eaten at a ceremonial communal banquet, at which it is typical for the worshippers to partake liberally of alcoholic beverages, the proceedings winding up in a glorified Donnybrook Fair, where swords, spears, and other lethal weapons take the place of the comparatively innocuous blackthorn. Finally, the slain animal's horns are literally exalted, upon a tall pole set up in some public place, where they are treated as cult objects. The bullfight proper, it will thus be seen, forms only one element in the entire somewhat elaborate cult complex. It happens, however, to be that feature which, with perhaps the exception of the feastings and carousing, tends to persist longer than any of the others.

In no one area, so far as I am aware, do all the elements of the ceremony appear together. Perhaps they never did so anywhere. Nevertheless, where the true ritual bullfight of this type occurs or has occurred, the fact may usually be recognized by the presence, with or without the combat itself, of various others of the features just enumerated.

There can be little doubt that the custom had its inception on the continent rather than anywhere in the Indonesian area where it also occurs. There appears to be a folk recollection of something of the sort in the ancient Irish legends, as for example in the famous fight between the Findbennach, the "white-horned bull of Queen Medb," and the Brown Bull of Cuailgne, in the Cuchulainn cycle.[12] And Strabo informs us that at Memphis, bulls bred for the purpose were made to fight one another, the victor being awarded a prize.[13] Instances such as these—and they might easily be multiplied—suggest an extremely ancient origin and a very wide diffusion for the custom. But both Ireland and Egypt lie outside the typical irrigated rice culture area, and the development of the rite into its more complex form must therefore, it would seem, be sought elsewhere.

With India, however, the case is widely different. That there the growing of rice first arose seems fairly well made out. And by certain of the aboriginal tribes, which have not yet come under the influence of Hinduism, bullocks and buffaloes are ritually killed and eaten. Furthermore, beast fights of various sorts have been held in India from time immemorial. Hence it is on the whole perhaps likely that, while the germ of the idea may have been borrowed along with that of taming and utilizing the zebu and the water buffalo, from the more northern and almost certainly very much older grain and cattle complex, this type of ritual bullfight was brought to its full development by the pre-Aryan populations of that country in connection with the culture of irrigated rice, and that it spread hand in hand with the latter to southeastern Asia, and so ultimately throughout the vast area in which it has been observed as occurring.

But whatever the ultimate source to which the custom is to be traced, it seems at the present day to retain its characteristic features most completely among the non-Chinese hill tribes of South China.[14]

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[12] Regarding this see J. A. MacCulloch, "The religion of the ancient Celts," Edinburgh, 1911, pp. 130 et seq.

[13] Strabo, Geogr., Bk. XVII, ch. 1, sec. 33.

[14] See, e. g., P. Aloys Schotter, "Notes ethnographiques sur les tribus du Kong-tcheou," Anthropos, Vol. IV, 1909, pp. 345 et seq.; George Edgar Betts, "Social life of the Miao tsï," Journal of the North China Branch of the Royal Asiatic Society, Vol. XXXIII, 1899–1900, Fasc. 2; Archibald Ross Calhoun, "Across Chrysê: being the narrative of a journey of exploration through the south China borderlands from Canton to Mandalay," London 1883, Vol. II, pp. 371, 392; John Henry Gray, "China: a History of the laws, manners, and customs of the people," London, 1878, Vol. II, p. 307 and note 1.

Numerous observers have reported the practice of holding spring festivals by these people for the promotion of the fertility of their fields. At these gatherings a bull or water buffalo, previously chosen and fattened for sacrifice, is made to fight another animal of the same species. The contestants are first infuriated with strong drink, and if the one predestined for sacrifice is the victor, the omen is regarded as a favorable one. In a slightly variant form the contesting bulls represent different clans, and it is the victor which is sacrificed. The flesh is eaten at a ceremonial banquet, to the accompaniment of much hard drinking, and the horns are preserved, being sometimes, although not invariably, fastened to poles or trees, where incense is burned before them at intervals.

The coast lands of China from the Yangtse southward have never been fully assimilated by the Chinese proper of the Yellow River basin, and many aboriginal customs are still kept up. Among these is that of bullfighting, particularly in vogue in that Ningpo region where the powerful non-Chinese kingdom of Yüeh had its seat down nearly to the close of the fourth century B. C.[15] The reason at present alleged for the custom is "to take the spirit of combativeness out of the air, so that all may live in harmony"—a highly desirable consummation where clan fights are as rife as they are here. The fact, however, that these fights are held in the spring would appear to link them, in their origin at least, with the fertility rites found elsewhere in connection with the practice. Before leaving this region it will not be without interest to recall that an attempt was made, during the summer of 1919, to introduce this type of bullfight into Shanghai as a popular amusement.

For Japan proper I have not yet found the ritual bullfight of either type recorded, though in view of the extent to which that country has borrowed her ceremonial practices from the continent I should not be at all surprised to learn that the custom of "beating the spring ox" occurs there also. There is, however, indirect evidence that the second form, where two bulls are the contestants, existed there at one time. Domestic cattle appear first to have been imported into Japan, almost certainly from Korea, about the fourth or fifth century of the Christian era, and it is possible that the absence of a genuine agricultural tradition, or the spread shortly afterward of the humanitarian faith of Buddhism, prevented the custom from taking root. That it was actually introduced, however, along with domestic cattle and irrigated rice growing, seems certain from the fact that it still exists, or did until recently, in the little islets of Oshima (Vries Island of the foreign residents) and Hachijo,

[15] W. A. P. Martin, A Cycle of Cathay, pp. 95 et seq. Further and more detailed information regarding the Chekiang bull fights would be most welcome.

out in the Pacific, almost due south of Tokyo Bay.[16] Details are wanting; but the survival in these extremely interesting little islands of many culture elements which we know existed formerly in Japan proper, renders it likely that the local custom of bullfighting had a similar origin. It is only fair to say, however, that there is a rather vague and unsubstantiated legend to the effect that these islands were discovered and colonized from China direct, in the time of the great Ch'in Shih Hwangti, and the historical basis for this may not inconceivably lie in some actual intercourse overseas with the eastern coastlands of China; for modern research is rapidly disclosing the vast amount of voyaging done by the maritime and insular peoples of eastern Asia even far back in prehistoric times.

In Korea the practice survives to this day, and I was told when I saw it there in 1915 that the bulls represent different villages, which achieve honor or disgrace according as their respective champions are victorious or vanquished. Here, as might be anticipated in a country so long and so profoundly influenced by Buddhism, most of the characteristic ritual features have disappeared; but, as I saw myself, the victorious bull is still led in triumphal procession with chants and drum-beating.

For the existence, now or formerly, of the ritual bullfight in northern China I have no evidence. This might perhaps be expected, in view of the fact that the region lies to all intents and purposes outside the irrigated rice area. It is barely possible, however, that a trace of the former occurrence of the custom is to be found in the existence in the Yellow River Valley 2,000 years ago of the popular sport of butting. This consisted in the opponents donning the hides and horns of bullocks and then, mounted upon the shoulders of others, proceeding to knock time out of each other.[17]

In the regions south and southeast of China the custom is quite general. It is found among the Talaings of southern Burma, by whom both bulls and buffaloes are employed for the purpose.[18] The same was formerly true of Tenasserim, where buffaloes were utilized and where, just as among the Koreans and the aboriginal populations of southern China, the animals represented different villages.[19] According to Colonel Gerini, the Malay State of Menang-

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[16] Basil Hall Chamberlain, Vries Island, Past and Present, Transactions of the Asiatic Society of Japan, Vol. XI, 1883, p. 168; B. H. Chamberlain and W. B. Mason, A Handbook for Travelers in Japan, London, 1913, p. 523.

[17] H. A. Giles, "The civilization of China," Cambridge, 1911, pp. 153 et seq.; E. H. Parker, "On race struggles in Korea," Transactions of the Asiatic Society of Japan, Vol. XVIII, 1890, p. 170; the Chinese expression is *Chio-ti hsi*; for the reference, cf. Giles' Dictionary, s. v. Chio (No. 2215).

[18] Max. and Bertha Ferrars, Burma, 3d ed., London, 1901, p. 179.

[19] Shway Yoe (Sir James George Scott), "The Burman: His life and notions," London, 1910, p. 382.

kabau, in Sumatra, owes its name to a contest of this sort somewhere back around the fourteenth century, the words meaning "vanquished carabao" (water buffalo).[20]

Generally speaking, bullfights are common in all the Malay States not under British rule.[21] The same is the case in Java; but here, owing probably to the introduction first of Buddhism and later of Mohammedanism, the custom seems to have lost most of its ritual features and survives as little more than a popular pastime.[22] In the island of Timor the actual fight itself seems not to have been reported as occurring; but other features of the rite appear, buffaloes being sacrificed at festivals attended by much hard drinking, while the slaughtered animals' horns are set up on high poles as cult objects.[23] So perhaps it is fair to assume a connection with the rite as it appears elsewhere in fuller form.

In Madagascar fights between bulls were the favorite amusement of the former sovereigns and their courtiers, who availed themselves of such occasions (as they did, it is only fair to say, of every other) for getting royally drunk.[24] While direct evidence that ritualistic observances attached to these rites seems to be wanting, still we know that bulls were sacrificed and eaten at communal feasts and that they could only be killed by the local headmen officiating as chief priests of their respective groups. The animals' horns, furthermore, were mounted upon lofty masts just as elsewhere. Hence it seems likely that in Madagascar also the bull fight was originally of a ritual character and that it was one of the culture elements brought with them, along with so many others characteristic of the irrigated rice culture area of southern Asia and the neighboring islands, by the Hovas. The latter, however, can hardly have transported cattle across the Indian Ocean, for prior to the introduction of the Arab dhow their largest craft appear to have been nothing more than fairly sizeable seagoing canoes, propelled entirely by the paddle. Moreover, the existing breeds of the cattle owned by the Malagasy, together with the very word for "ox" itself,[25] appear to have been derived from East Africa. That the immigrants, in spite of this, should have preserved so many features of the cult speaks strongly for its vitality.

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[20] G. E. Gerini, "Researches on Ptolemy's geography of eastern Asia (further India and Indo-Malay Archipelago)," London, 1909, p. 641 and note 1.

[21] Nelson Annandale, "The Faroes and Iceland: Studies in island life," Oxford, 1905, p. 185.

[22] A. H. Kiehl, "Notes on the Javanese," Journal of the Anthropological Institute, Vol. —, 1877, p. 357.

[23] H. O. Forbes, "On some of the tribes of the island of Timor," Journal of the Anthropological Institute, Vol. XIII, 1884, p. 419.

[24] C. Staniland Wake, "Notes on the origin of the Malagasy," Journal of the Anthropological Institute, Vol. XI, 1882, p. 25; also James Sibree, "A naturalist in Madagascar," Philadelphia, 1915, pp. 182 et seq.

[25] *Omby*, almost certainly connected with the Swahili *ngombe;* cf. Sibree, op. cit., p. 35.

The facts above enumerated would seem to make it clear that the custom of the ritual bullfight, in one or other of its two forms, spread, mainly in prehistoric times, throughout those portions of the Old World, both continental and oceanic, which are characterized by the cultivation of cereals with the aid of the plow, as opposed to the more primitive culture which employed the hoe alone. As has been pointed out, the custom possesses certain definite and somewhat complex features which distinguish it from superficially similar practices elsewhere. Beyond doubt it is a form of the ancient and widespread custom of slaying periodically an incarnation of the group god for the good of his people, modified to suit the ideas and the needs of an archaic type of farming society. Furthermore, it affords a clear-cut and concrete example of the way in which culture elements were wont to travel, in the dim and unrecorded past, from end to end of the Eurasiatic continent, and even to the isles of the sea. Specifically, it provides us with one proof more, among the very many which have already been accumulated, that the early civilization of China did not rise independently, but that it is indissolubly linked to those of the older peoples at the opposite end of Asia.[20] Viewed in this light, the practice seems not without significance in the working out of the problems of ethnic and cultural diffusion over the enormous area through which it is found to occur.

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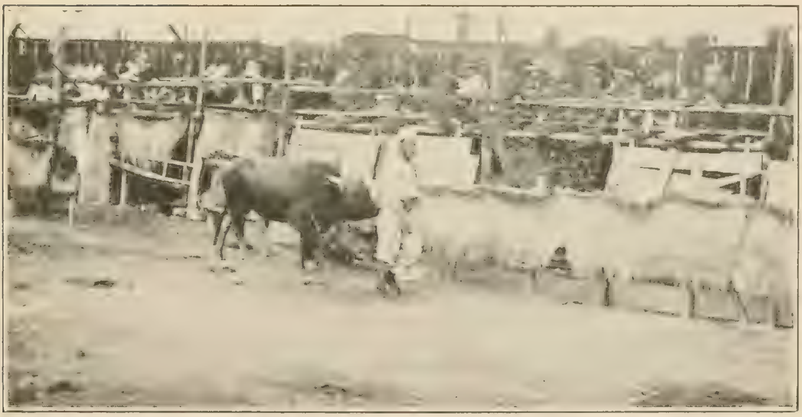
[20] Regarding this, see an extremely valuable paper by Dr. Berthold Laufer, "Some fundamental ideas of Chinese culture," in The Journal of Race Development, Vol. V, 1914–15, pp. 160–174.

1. A BULL FIGHT WITNESSED IN SEOUL, KOREA, IN 1915. NUMEROUS FIGHTS OCCUR IN THE COURSE OF A DAY, THE BULLS REPRESENTING DIFFERENT VILLAGES



2. A VICTORIOUS BULL BEING LED ROUND THE RING TO THE ACCOMPANIMENT OF CHANTS AND DRUM BEATING

Photographs by courtesy of the University Museum, Philadelphia

THE BRONZES OF HSIN-CHÊNG HSIEN[1]

By C. W. Bishop

[With 9 plates]

One of the most significant archeological finds of recent years—perhaps the most significant, for the amount of new light which it throws on a highly important but hitherto little known ancient civilization—is that made at Hsin-chêng Hsien, in Honan, last summer (1923). A correspondent of mine in the United States, whose opinion I value most highly, writes: "It seems to me that you hardly do justice to the finds in comparing them with those discovered in the tomb of Tutankhamen, where little, if anything, was found that was new to Egyptologists." At Hsin-chêng Hsien very much that was new was disclosed, and vastly more would have been found, past all doubting, had the excavation been carried out in a scientific manner.

I was sitting in an art dealer's shop in Chêng Chow one afternoon last September, when word was brought to me that a remarkable collection of ancient bronzes had lately been dug up at a town not far off and was then at the headquarters of Gen. Chin Shih-chang, near by. I at once went over with my associates, Mr. K. Z. Tung and Mr. A. G. Wenley, and although the general himself was absent, we were given cordial permission to inspect the find.

It was late in the day, the light was fading fast, and my time was short. Yet, brief as my inspection was, it brought a quick realization that here was something of the utmost importance from the archeological point of view. So the very next morning, together with my two associates I took a train for Hsin-chêng Hsien, 27 miles south of Chêng Chow, to inspect the site before the digging, which I was told was still going on, should have obliterated everything.

The town of Hsin-chêng Hsien lies 3 miles or so to the westward of the station—about an hour's walk. Soon after starting out we struck into loess deposits, much eroded and terraced for cultivation. About 1 mile west of the railway, after crossing a small stream flowing south, we passed through a gap in an enormous earthwork over-

[1] Reprinted by permission from The Chinese Social and Political Science Review, Vol. VIII, No. II, April, 1924.

hanging the farther bank and evidently built of material taken from the stream bed, as it contained many shells and waterworn pebbles; I noticed also a good many potsherds. Its southern end we could not see owing to a fold in the ground; but to the north we could trace it for a long distance; turning at length to the west, it remained in sight most of the way to Hsin-chêng Hsien. The people thereabout, questioned as to the origin of this really gigantic earthwork, could tell us nothing save that it dated back to the days of Yao and Shun. No doubt a search in the local or provincial records would throw light upon the subject.

Hsin-chêng Hsien itself we found picturesquely seated upon a plateau bordered on the east by a small but deep old torrent bed, now dry, and on the south, at a little distance, by the waters of a pleasant stream large enough to be navigable by boats of good size. The present city wall, of earth faced on the outside with burnt brick, winds along the brink of this plateau. It was just within the southeastern corner of the city, we learned, that the discovery had been made. The ground at this point is higher than elsewhere, and must, before the wall was built, have commanded a splendid view over the river and the picturesque, undulating country to the south and southeast.

Entering the city by the east gate, we followed a sunken road running along the base of the wall, first to the south and then bending toward the west, until the presence of a crowd of sightseers told us that we had reached the scene of the discovery. It was quite clear why the finding had been a chance one. There was no sign on the surface of anything like a burial mound. It was only when I mounted the city wall, by a zigzag path up the sloping inner face of earth, that I was able to see, in the bank bordering the farther side of the sunken road beneath me, indications of the contours of a low mound. It seems probable to me, indeed, that the present city wall cuts across the southern edge of what at one time must have been a tumulus of no small size. This had, however, in the lapse of ages, been so eroded and leveled off and ploughed over, while the hollows roundabout had been so filled in with the downwashing detritus, that all trace and memory of it had been lost long ago.

The original discovery was entirely by chance. A certain Mr. Li, whom I met later and talked with, was sinking a well in a field of his, close by his home, when the workmen came upon a number of bronze vessels, some of which he sold to the local dealers in antiques. Doubt appears to exist as to how much of the whole find was uncovered by Mr. Li before the military authorities at Chêng Chow heard of it, took possession of the premises, seized the vessels already disposed of, and started in to dig for more. But whoever it was that did the digging, the result was one of the most remarkable in one sense, in another one of the most deplorable, in the annals of recent archeology. Most remarkable, in the quality of the objects discovered, in the new light thrown upon the ancient civilization of China, and in the many striking confirmations afforded of the reliability of the Chinese classics; most deplorable, in that no trained investigator was present to show how the objects could be removed from their setting without injury to themselves and to note down the information brought to light in the course of the digging but now, of course, lost forever.

At the time of this, my first visit to the site, on the 8th of September, 1923, several vertical shafts had been sunk to the level at which the bronzes had been found and over these were shears of stout poles from which depended baskets drawn up by ropes. Most, if not all, of the bronzes had already been unearthed before my arrival; in fact, I believe that no subsequent discoveries of this sort have taken place. I say "of this sort" advisedly, for, as will appear, much did turn up later of the greatest importance regarding the significance of this ancient interment.

After an inspection of the dumps where the earth, bones, pottery, and other material brought up in the baskets were being thrown after being examined for fragments of bronze, I had myself lowered into one of the pits which looked the most promising and which was perhaps 12 or 14 feet in depth, although the surface had been too much disturbed to admit of any close measuring. At the bottom, in the north face of the pit, a workman was busy with a pickaxe, quarrying out some bones which I saw at once were human. I took his place, and with my heavy-bladed jackknife, carried for just such purposes, I freed from its earthen matrix a human mandible, at the same time partly uncovering the rest of the skull. In close association I found numbers of cowry shells with the backs ground off; numerous small discoidal mother-of-pearl beads of perhaps a quarter inch in diameter; several very thin laminae of jade, about three-quarters of an inch square, perforated at all four corners and covered with a thick coating of red pigment, which Dr. V. K. Ting tells me is oxide of iron; and a beautifully carved little jade tiger of archaic shape, a fragment of some larger object, probably a pendant.

To judge from the position of the skull—for the rest of the skeleton had been quarried away before my arrival—the corpse had been placed on its back with the head to the north, in the extended position, and turned possibly a little to the right. The mandible, undoubtedly that of a man in mature life, was noteworthy for its very large and massive character. Dr. B. G. Anderson, of the

Peking Union Medical College, has pointed out to me that the molars are similar in type to those of the existing North Chinese race.

Night was now drawing on, and we had to hurry to the station to catch the train back to Chêng Chow, where we were to meet General Chin. But before leaving, I secured the promise of the official in charge to have the skull covered over with planks banked with earth, until I could return. This arrangement appears to have been overruled, however, by those higher in rank, before my next visit. The skull had disappeared, going, no doubt, over the dump, along with so much else of the highest interest from the archeological point of view. Certain other human bones, however, which had been reinterred by the excavators in another place, have been again disinterred, thanks to the efforts of my friends, Doctor Ting and Doctor Li. These, the latter tells me, apparently belong to two individuals, one of them, at least, a woman, and neither of them the one whose skull I partially disinterred, and who, I think there can be no doubt, was the central figure of this interment. Whether the other two individuals belong to this or to other interments must remain doubtful; but it seems possible that they were slaves or concubines, buried along with the central figure.

I noted particularly, while getting out the mandible, that there was no trace of anything suggesting a coffin. There was, however, both above and below the skull, a dark layer about an inch and a half in thickness, quite distinct against the yellowish soil and rather deeply impregnated on both sides with the same red pigment already noted. The natural presumption would be that these dark layers represented some sort of protective covering which had been placed at the time of the interment both below and over the body. Regarding its original nature I scarcely dare to hazard a guess. That it was of wood or any other rigid substance seems unlikely; for that part of it extending over the skull was distinctly curved, as though consisting originally of some flexible material; the possibility of matting, or perhaps of some thick hide, might be indicated.

In addition to what I secured from the pits themselves, I managed to collect on the dumps a number of bones and a certain amount of pottery, all in a fragmentary condition; while still more were brought to me by the workmen and the soldiers guarding the operations. In this connection I should like to express my appreciation of the very friendly attitude of all, both high and low, with whom I came in contact during my study of this find. And incidentally I may say that I secured abundant proof of what I had believed all along to be the case—that the Chinese laborer, given the requisite training, will make excellent material for archeological field work, what with his industry, his cheerfulness, and his quickness to learn.

On my return to Chêng Chow I found that Gen. Chin Shih-chang was still away; so I wrote direct to His Excellency Gen. Wu Pei-fu, telling him about the first-rate importance of the discovery and asking permission to give it further and more intensive study. Feeling confident of a favorable reply, my associates and I hastened back to Peking and began to prepare for a return to the scene of activity. We were not disappointed; for within a very short interval there came a most cordial telegram from General Wu, inviting us to come back and carry on whatever investigations we might wish, and stating that he had issued instructions to his subordinates on the scene to give us whatever help we might need. A very few days later saw us back in Hsin-chêng Hsien, equipped to make a careful and detailed study of the site.

I found that it had been dug almost entirely over while I had been away, the various vertical shafts having been extended to form one large pit (cf. pl. 2), while the work of excavation had been pushed much farther to the north. Nothing, however, in the way of bronze vessels had been found. On the other hand, much had come to light regarding the details of the interment. It was with the greatest eagerness that I set to work, with the help of my two associates, both as keenly interested as myself, to make a study of the site as it then lay exposed. My work consisted in securing photographs, in making a plane-table survey of the site and its immediate surroundings, and in taking copious notes, based partly on my own personal observations and partly on such evidence as I could gather from those who had either witnessed or had actually taken part in the work of excavation.

It would be hard to say with any assurance, from what I saw personally, whether there had ever been a vault or funeral chamber of any sort over the body, for nearly all that portion of the site had been dug away before my first visit. The impression I formed, however, on various grounds was that there had been in all likelihood something of the kind, and that, further, it was of wood, no doubt in imitation of the contemporary dwelling house, and therefore with a pitched roof. There is also, I think, reason to believe that this structure did not collapse under the weight of the mound heaped over it, but that rather the seepage of mud caused by the yearly summer rains gradually choked its interior, completely embedding the contents in a matrix of the same yellow clay of which the mound itself was composed. Had there been a collapse of the structure the bronzes, for instance, would surely have been discovered partly overturned and in more or less disarray, whereas the fact appears to have been that they were found standing upright, as though their embedding in the earth had been a gradual process, unaccompanied by any disturbance of their order.

The likelihood that there had been a wood-lined central vault is strengthened by the actual discovery of a passage from the west side of the grave, which seems to have given into some such chamber; at least it led toward the spot where the body had formerly lain. A portion of this passage—all that was left—I personally saw, photographed, measured, and in part excavated, so that for its existence I can positively vouch. Here the former existence of some sort of plank lining was clearly evident, for there was a very sharply marked plane of cleavage between the earth forming the walls of the passage and that with which it was filled. I was told that the top of the passage was vaulted, and see no reason to doubt the statement, particularly as it came from one of my most intelligent informants.

Soon after I noticed the remains of what may have been a similar passage, already partly dug away, leading from the north in the direction of the spot where the body had lain, and I was informed by more than one eyewitness that two others had been found, on the east and south, respectively. This would make it appear that passages or trenches of some sort had led into the hypothetical funeral chamber, or at least to the spot occupied by the body, from each of the four cardinal points. It is only fair to say, however, that in the remains of this trench from the north I found no signs of a former plank lining, while it seemed to differ also in the nature of its contents from that on the west. The earth filling both was intermingled with potsherds of identical character, but these were far more numerous in that to the north, while the latter also contained great abundance of animal bones and so much charcoal as to give the soil a distinctly blackish tinge.

The very plentiful fragments of pottery were of various shapes and types, most of them new to me. I found no pieces intact in either of the trenches, but on the dump I saw a well-modeled little vase on a high foot, of a fine gray undecorated ware and in perfect condition. Before I could get to it to pick it up, it had been wantonly smashed by the bystanders. I secured the fragments, however, as well as numerous others of the same ware, and I judge from these that a good many vessels must have been found quite intact in the course of the excavation, for the fractures were in a large number of cases quite fresh.

The fragments which I collected appear to fall into two general classes. Of these one is composed of the gray ware just mentioned, of varying degrees of fineness, and either plain or else marked with cord or fabric impressions such as are known in many parts of the world. The other, very much scarcer, is thinner and finer in texture and of a light reddish buff color; it, too, bears cord impressions. What proportion, if any, was wheel-made it will require further study to decide, but some at least of the pieces seem to have been made by the coiling process, while the more irregular shapes were certainly molded by hand. It is perhaps unnecessary to say that there were no traces of any glazed ware, nor have I hitherto, in a somewhat superficial inspection of the fragments in my possession, come across any signs of either painted or slip decoration. The impression I get so far, indeed, is that the pottery occurring in connection with this interment is far from representing the highest skill of the potter of that period, but is composed of archaic types which have been retained for funerary uses through the influence of religious conservatism.

Among the bones which I found are those of the horse, ox, dog, sheep (or goat), pig, and a large bird which seems to be either a bustard or a goose. For these identifications I am indebted to Dr. Walter Granger, of the American Museum of Natural History, and to Dr. Paul H. Stevenson, of the Peking Union Medical College. I personally found in the trench no human bones; but some of those brought to me by the workmen may have come originally from it. These, as well as the mandible which I secured on my first visit, I was glad to be able to submit to Dr. Chi Li for intensive study and comparison with the human material secured by him and Doctor Ting, and I await his completed report with deep interest.

I was particularly anxious to see whether I could find any horse bones; for among the bronzes shown me at Chêng Chow I had noticed three snaffle bits of the ordinary bronze age type and also the metal fittings and decorations of a chariot. So I was especially glad when certain bones which I had found turned out to be those of a rather small horse. I was also shown some horse teeth, and though these I was not allowed to keep, as they were thought to be dragon's teeth, I took some photographs of them which show beyond dispute their equine nature. It seems probable, therefore, that this interment was a regular bronze age chariot burial, with chariot and horses and all, exactly such as has been discovered in so many parts of the western world. One can not help regretting that the remains of the chariot could not have been scientifically excavated; for embedded in the earth as they were, and with even part of the woodwork preserved, through the chemical action of the bronzes with which it was in contact, it should have been possible to secure a practically perfect reproduction of the ancient Chinese chariot, as well, perhaps, as a knowledge of the uses of some of the bronze fittings that now so puzzle us.

As part of my study of this most interesting site and its surroundings, I made a plane-table survey of it, in the course of which I noticed some indications which I thought might point to the existence of another worn-down mound; but Doctor Li tells me that this is not the case.

Of the wonderful group of bronzes found here I speak with diffidence; for I saw them only after their removal to the local military headquarters at Chêng Chow. There, however, through the courtesy of Gen. Wu Pei-fu and of Gen. Chin Shih-chang after his return, I was permitted to examine and photograph them; while on my two visits to Hsin-chêng Hsien I secured all the information I could from those who had been actually present at their discovery and excavation.

Accounts differ, naturally, regarding the precise arrangement of the bronzes in relation to the interment. As nearly as I can learn, however, they were all found to the south of the body, which, it will be remembered, lay with its head to the north; and they occurred at varying depths, beginning about 10 feet below the present surface. This looks as if, at the time when the burial took place, the bronze vessels were placed on ledges of earth or perhaps wooden stands or shelves of varying heights. Such a hypothesis would account at least for their discovery at different depths, about which there seems to be no doubt.

While I make no pretensions to knowing anything about ancient Chinese bronzes, those found at Hsin-chêng Hsien impressed me as being unlike those usually dated as Han, but as resembling rather those commonly attributed to the Chou dynasty, though with important differences. In any case, their style and ornamentation are of the highest order. In some instances traces of former gilding are still visible, and there is reason to believe that the workmen made away with a really very large amount of sheet gold, stripped from the bronze surfaces. There are also instances of turquoise inlay that must have been very effective when intact. The symbolic designs, in high and low relief, are unexcelled. The use of conventionalized animal figures for handles, supports, and decorative elements is most striking and, I think, unparalleled. And the patination, in shades of green and blue and red, is in many cases unusually rich and fine. I know of nothing of the kind comparable with this collection as a whole. The room in which I saw it at Chêng Chow seemed, as it was, a veritable treasure house.

In all, about 100 vessels are known to have been discovered, although it is thought probable that the workmen stole a great many, particularly of the smaller pieces. Of the latter, many were found inside larger vessels, and hence managed to escape the pickaxes of the diggers, which irretrievably ruined so many of the finest specimens. In other cases vessels of similar types, but of varying sizes, were stacked one upon another in regular gradation, "like a pagoda," as one particularly intelligent informant put it. This fact would seem to lend additional plausibility to the view that the earth covering them had accumulated gradually and not as the result of a cave-in or even of the heaping up of a mound by human hands.

But one inscription is known to have been found, and that merely a brief dedicatory one of a few characters, on the lip of a wine vessel, and possessing no definite historical significance.

One of the noticeable things among many in this group of bronze objects is the very great number of bells both great and small. Of the latter there were, I understand, 17, ranging in size from about 1 foot to 18 inches over all, with a projecting handle above, cast in one piece with the rest of the bell. There were also several much larger ones, the biggest approaching 4 feet in height. Of these I saw four on the occasion of my second visit to Chêng Chow. They were really magnificent objects, superior in their proportions, their dignity, and the quality of their decoration to anything of the kind that I ever saw before—really a revelation of the ancient bronze founder's skill and good taste. It is interesting to note, in this connection, that in the year 642 B. C. the ruler of the state of Chêng Chow is recorded to have utilized a gift of metal tendered him by the king of Ch'u to cast three great bells.

Scarcely inferior in prominence, and of even greater interest in many ways, were two pairs of great bronze vases, of fine proportions and beautifully decorated. One rested upon square bases supported on the backs of two couchant animals, apparently conventionalized tigers, while the handles surely represent bulls; on the four corners, lower down and likewise cast in the full round, appear what are unmistakably rams with spiral horns; the characteristic form of a ram's head is most happily rendered. Both of these magnificent vessels were frightfully damaged by the diggers, one even having its couchant tiger base completely knocked off (cf. pl. 4, fig. 1). The other large pair, just mentioned, were very similar, and, though less elaborate in design, form in some ways even more remarkable examples of the founder's art; these also were shockingly injured in digging out.

Another noteworthy piece was a beautifully proportioned cauldron of tripod form, nearly three feet across. It had one side, unfortunately, completely smashed in where a digger had driven his pickaxe into it in order to wrench it out of its earthen matrix. Near it was a two-piece "steamer" of large size, rectangular in shape, with four legs; the lower portion to hold the boiling water; while the upper, detachable and divided into compartments, had its bottom perforated to admit the steam from below. I saw also a large vase, of a slightly oblate spheroidal form, with a rather wide mouth with everted rim; the interesting thing about this was that the exterior was divided by bands into three registers, each ornamented in a totally distinct style—so very distinct, indeed, that if appearing on separate vessels they would probably be attributed to different epochs or schools.

Another vessel was in the shape of a squat, short-legged quadruped with widely distended mouth, perhaps meant for one of the great dogs mentioned in the Classics as being imported into China from the barbarous tribes to the northwest. The cover, on the back, was ingeniously linked to the curled-over tail by means of a chain exactly resembling in shape one of the bronze snaffle bits already mentioned. The short legs of this curious creature had been knocked off by the diggers but had fortunately been preserved, and I was able to prop it up in what must have been pretty much its original position before photographing it.

For sheer beauty and grace, among all the objects included in this find I saw nothing to compare with two cranes, highly naturalistic save for a certain conventional squaring of the wing tips, and so charmingly executed that one could almost fancy them in actual flight. Unfortunately both had been broken by the diggers into a number of pieces, some of which had been lost, or were perhaps included in the innumerable baskets of fragments with which the room was filled—melancholy monuments to the manner in which the excavation of this superlatively wonderful site had been conducted. And to judge by the condition of these two cranes, there may quite possibly have been other small objects, of no less artistic excellence, which have been reduced simply to old metal; for even among the larger and more massive pieces the damage done is simply unbelievable unless seen. In fact I was told that the diggers deliberately broke up numbers of objects in the hope that they might turn out to be of gold.

If the two cranes take the palm for grace and charm, for pure grotesquerie and, one might almost say, horror, it must be awarded to a monster figure, about one foot in height, seated upon its haunches, with forelimbs raised to its vast mouth as if gnawing something; with a hideous toadlike face and huge bulbous eyes; and with the stumps of two spiral upward pointing horns that the diggers had knocked off, as they had also done its hind feet. This object seems to have puzzled all who have seen it. I know of nothing in the slightest way resembling it in the Chinese art of any period. It is something wholly new to me, and it is all the more unfortunate that no record was kept of its position and its relation to the other objects in the tomb while this remained intact. Possibly a careful search of the Classics may throw some light on its significance.

Less important pieces, of all types and descriptions, were to be counted by the score; many were in a fragmentary condition, while others, through the circumstance, already adverted to, of their having been found inside larger vessels, had escaped quite whole.

It is still far too early to begin basing any definite conclusions upon these bronzes; before that time arrives, very much more intensive and comparative study will have to be given them. Even a superficial examination, however, reveals the existence of several hitherto quite unknown types; while in some ways it would seem that the group as a whole suggests contacts not merely with the ancient Chinese culture lands of the middle and lower Yellow River, but also with the art of the old kingdom of Ch'u, which during much of the Chou dynasty dominated the Yangtse Valley. It will be recalled that this State, during the seventh and sixth centuries B. C., invaded Chêng again and again, at times making it tributary; and this long-continued military and political contact can hardly have done otherwise than leave its impress upon the art of this unfortunate buffer State. Beyond this, for the present, I should not like to go.

While opinions appear to differ as to the precise date of this most noteworthy interment, the prevailing view seems to be that it is of the latter part of the Chou dynasty, or, roughly, between 400 B. C. and 250 B. C. The form of the characters appearing on the inscription already mentioned would admit of this; and the curious mixture of primitive and highly civilized elements indicates a considerable antiquity, prior at least to the time when coffins began to be used regularly in State burials. The highly eroded condition of the mound and the total absence of any local tradition or historical record of any burial here point to the same thing.

Of interest is the fact that in the course of the digging there was found a small saw of shell, perhaps 3½ inches in length, and notched at one end as if for hafting. I saw and photographed this curious object at the military headquarters at Chêng Chow. It was stated that it had been found in the course of operations at the Hsin-chêng Hsien site, and I see no reason to doubt this, although I am at present inclined to think that it belongs to a culture stage considerably older than that represented by the interment itself. Possibly this plateau may have been the site of a village in times prior to the advent of bronze.

While fully recognizing the intense interest of the objects found at Hsin-chêng Hsien, and the importance attaching to their further intensive study, it seems to me that the most significant lesson that they teach is the vital necessity of placing Chinese archeological study on a permanent and definitely organized basis, with proper governmental recognition and support, and with provision made for the training up of a staff of scientific archeologists. China has had her antiquarians for centuries; and I should be the last to underrate the value of the work done by them. But antiquarian lore alone is not enough to extract from a site like this even a tithe of the information which might have been secured had the work been controlled from the first by men possessing both technical training and field experience. It is perhaps not too much to say that a properly conducted excavation here would have doubled our knowledge of the material culture and perhaps too of the religious beliefs of a period of the highest importance in the development of Chinese civilization.

The thought suggests itself in this connection (it is not original with me but has been in the air for several years)—can there not be established a school of Chinese archeology, supported by Chinese and foreign institutions alike, both for the training of a force of competent field workers and for the undertaking of a systematic study of the still remaining traces of man's former existence in this country? Few things would do more, either to extend the general sum of human knowledge or, more specifically, to enhance among occidental nations the appreciation of a great civilization, destined to exercise, in the centuries to come, such a profound influence upon the destinies of mankind.

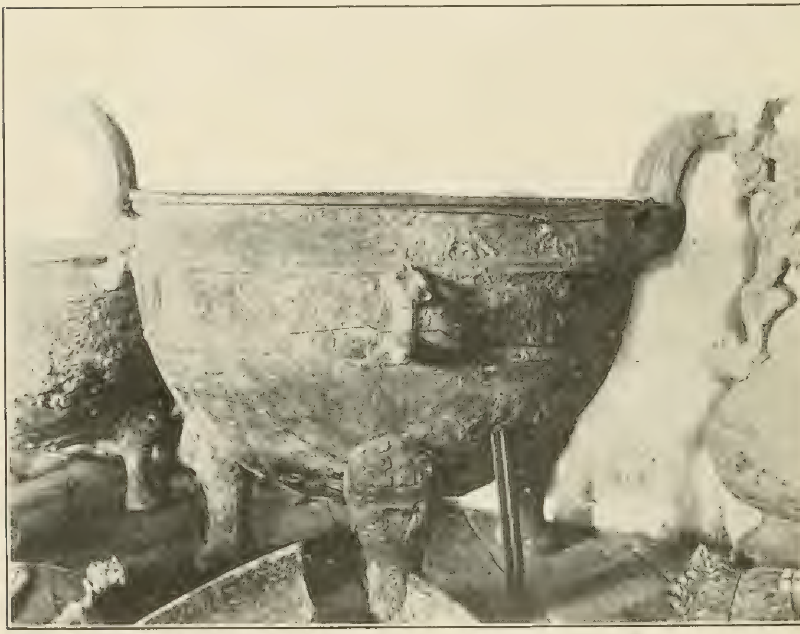
1. HSIN-CHÊNG HSIEN, SOUTHEAST CORNER OF CITY WALL

2. HSIN-CHÊNG HSIEN, ROAD OUTSIDE THE CITY WALL

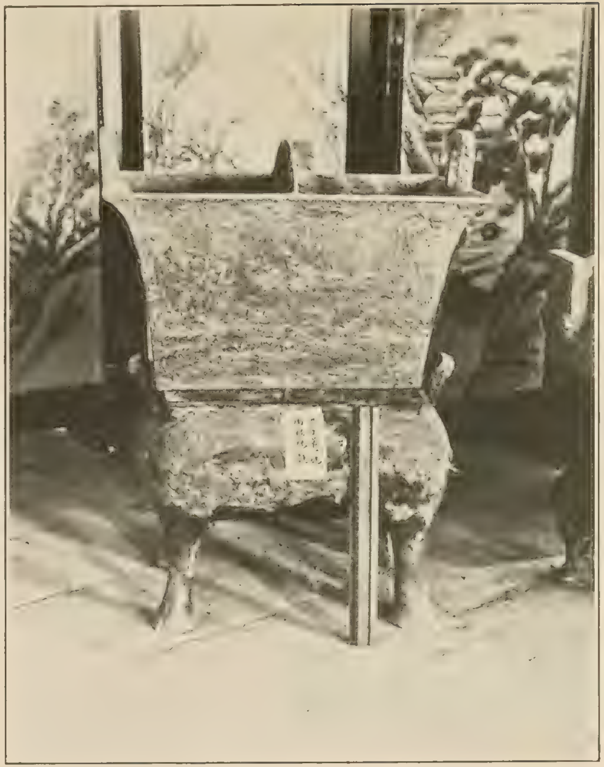
1. HSIN-CHÊNG HSIEN, WORKMEN ABOUT MOUTH OF EXCAVATION SHAFT

2. HSIN-CHÊNG HSIEN. WORKMEN ABOUT MOUTH OF THE PIT, AND MR. WENLEY

BRONZES FOUND AT HSIN-CHÊNG HSIEN, HONAN



BRONZES FOUND AT HSIN-CHÊNG HSIEN, HONAN



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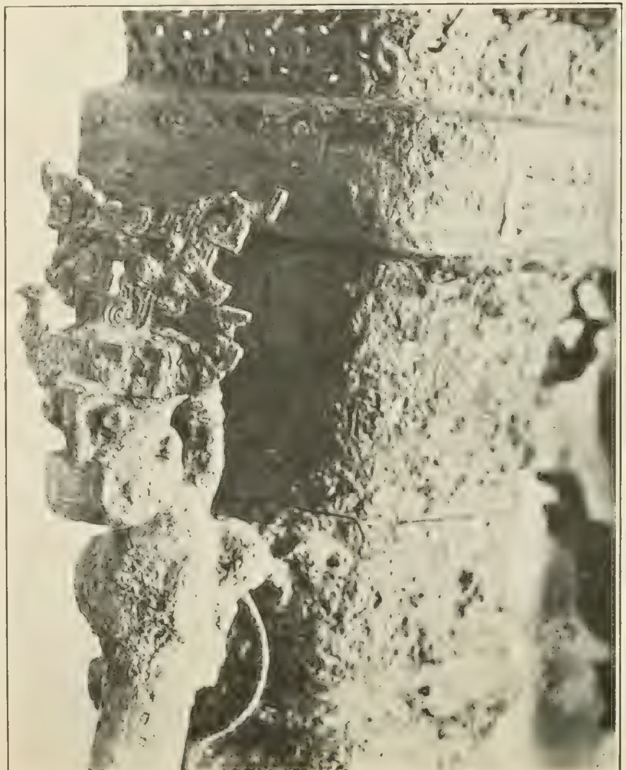

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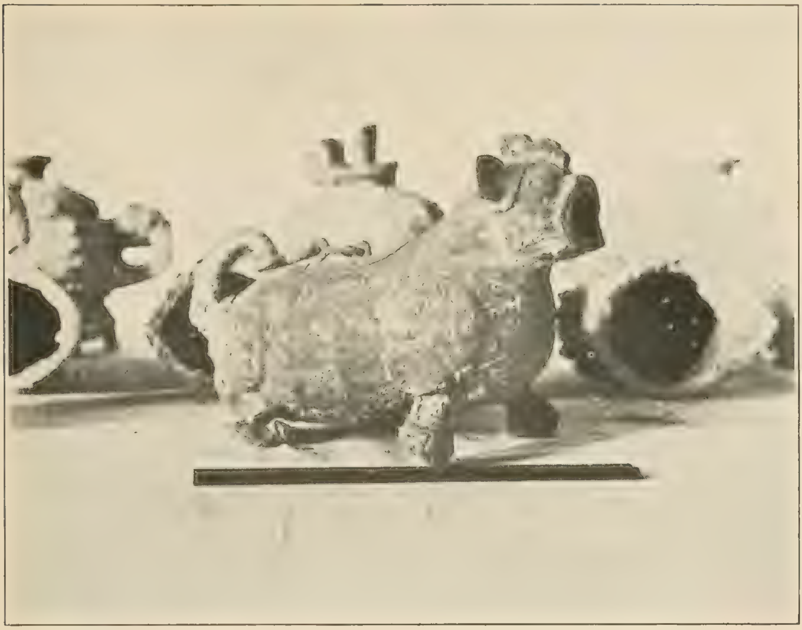

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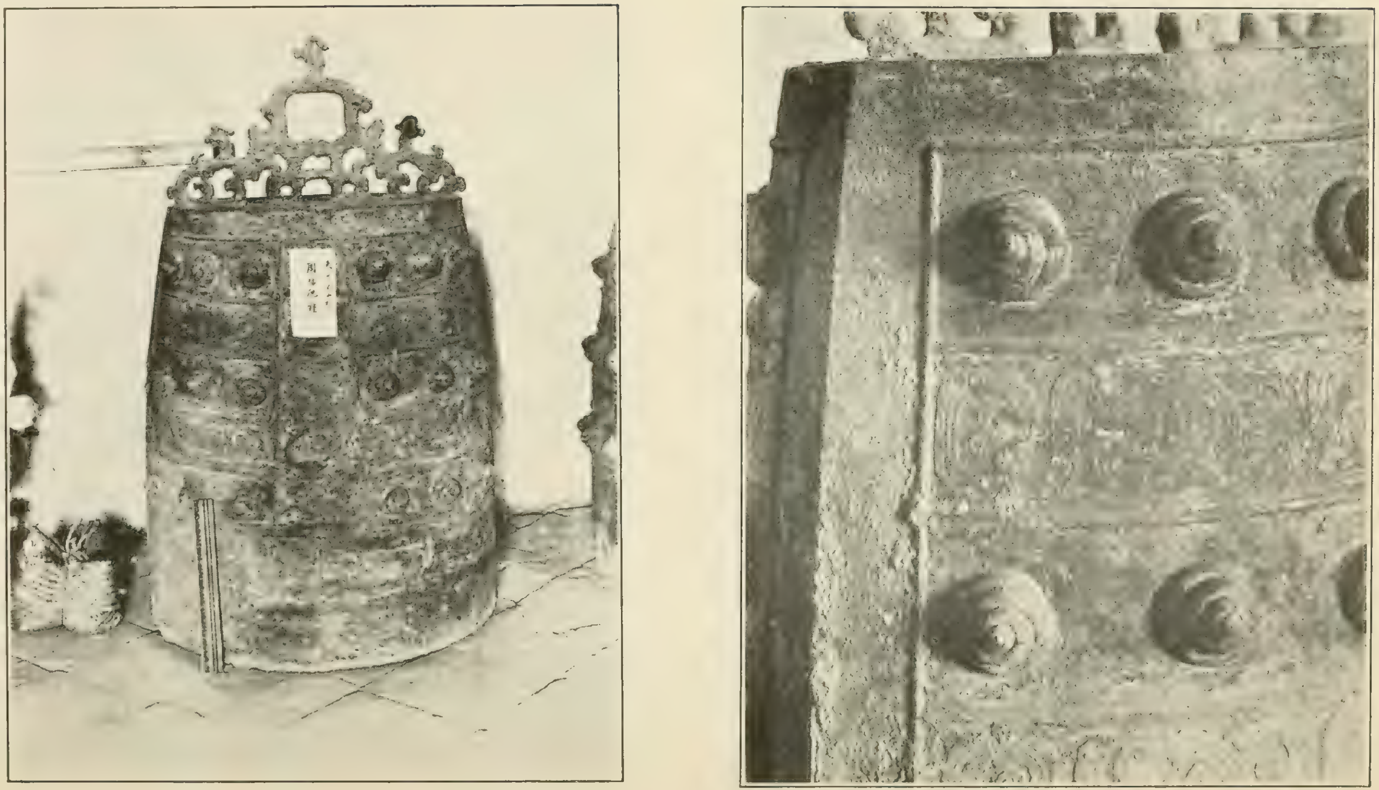

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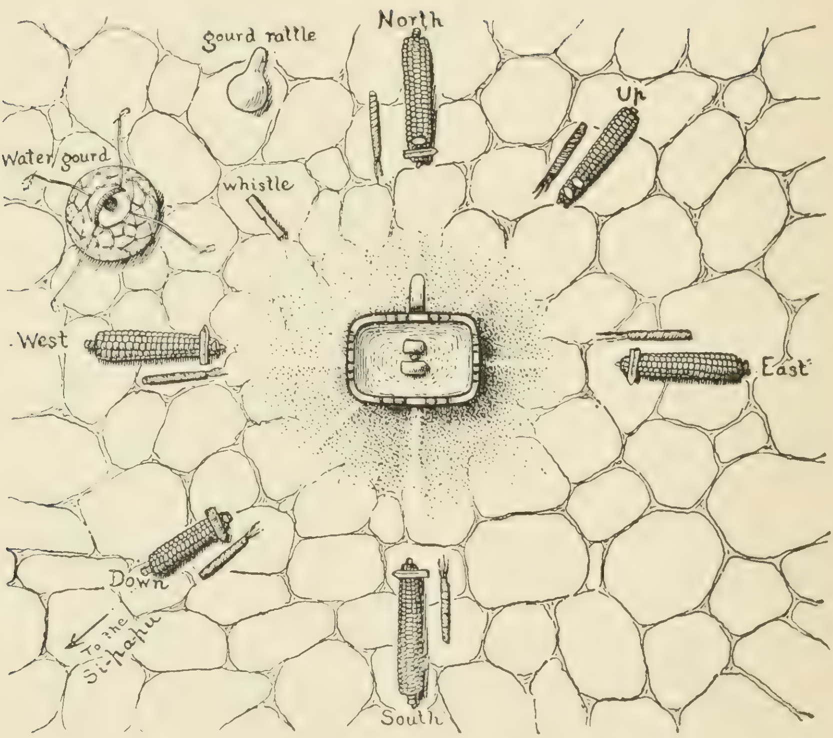

WALPI SIX DIRECTIONS ALTAR

THE KATCINA ALTARS IN HOPI WORSHIP

By J. Walter Fewkes, *Chief, Bureau of American Ethnology*

[With 3 plates]

INTRODUCTION

The present article is the fifth of a series published in the annual reports of the Smithsonian Institution on the composition of Hopi worship. The Hopi, the name meaning peaceful, belong to the Pueblo stock and are agricultural Indians. They are descendants of the Arizona cliff dwellers and have preserved to the present many survivals of their ancient worship. The object of the series of five papers above referred to is to record a few of their rites in sun, fire, and ancestor ceremonies that have survived to the present time. The Pueblos performed their secret ceremonies in subterranean rooms called kivas that were entered from the roof.

It is customary for the priest in the course of the ceremonies to erect an altar, so called, on which is placed their *tiponi*, or sacred badge of office, surrounded by various fetishes, idols, and wooden objects bearing symbols. Here are placed all sacred objects possessed by the fraternity of priests who celebrate the rite. There are four Hopi villages or pueblos that perform the rituals independently, the sacred paraphernalia differing in each. From a study of these altars it is possible for us to learn the aim of their various ceremonies. The present paper compares the four Katcina altars for this purpose.

That element of pueblo worship known as the Katcina forms fully one-half of the Hopi ritual, beginning with the arrival of the Katcinas or masked dancers in January or February, and lasting until their departure in July, inclusive. It is distinguished from other components by the presence of masked participants called Katcinas, supposed to be personators of the ancients, or "others." The yearly departure of these worthies from the villages is celebrated in July by a great religious observance called the Niman or Farewell Katcina ceremony; their arrival by several rites, one of the most striking of which is called Powamu, or "Bean Planting." At the times of their arrival and departure there are erected in the kiva of each of the four villages which celebrate them, the same altars, about which

EXPLANATION OF PLATE 2—Katcina Altar at Oraibi

a, Tunwup, or Sun Katcina; *as*, Aspergill; *b*, Tcuelawu; *c*, Corn mound; *co*, Cotokinungwu; *g*, Gourd; *h*, Planting stick; *l*, Lightning symbols; *m*, Ears of maize; *mb*, Medicine bowl; *p*, Prayer sticks; *ph*, God of war; *pm*, Prayer meal; *ps*, Prayer sticks in basket; *pt*, Gourd (netted) for sacred water; *r*, Rattles; *rc*, Rain clouds; *se*, Sun emblems; *t*, Tiponi.

KATCINA ALTAR AT ORAIBI

certain secret rites are performed. Our knowledge thus far is limited to four of the five Katcina altars,[1] and there still remains the altar of Cuñopavi, regarding which nothing has yet been recorded.[2]

Our knowledge of Katcina altars of the Rio Grande in the other pueblos is very scanty, owing largely to the exclusion of ethnologists from the kivas. Katcina dances in the open plazas are repeatedly figured but the secret rites and accompanying altars, if any, are not known.

In the following pages the author presents a morphological study of the four known Katcina altars of Hopi. The illustrations of the most complex, that of Oraibi, have been taken from the excellent memoir of Voth on the Powamu of that pueblo; the others are from personal studies made in 1890–1895.

The structure of the Oraibi Katcina altar is as follows: The reredos consists of two upright wooden slats united above by a cross-piece which in the illustration (pl. 2) is surmounted by a row of four segments of circles with rain cloud pictures representing the four directions, and colored with appropriate pigments, beginning with yellow or north at the right. The decoration of the cross-piece is obscure, but on the uprights there are figures recalling sprouting vegetation, and circles with differently colored quadrants.

Two idols, probably of wood, stand between the vertical slats of the altar, filling nearly the whole space. That on the left evidently represents the Sky God (Cotokinungwu) for it has a conical apex to the head, a painted chin, and near its left hand stands a wooden slat of zigzag form, a prescribed symbol of lightning.[3] This image has several short parallel marks of different colors on the body, and wears horsehair, stained red, about the loins.

The other figurine wears a coronet with triangular-shaped rain cloud symbols, which remind one of the headdress of the Lakone-

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[1] Journ. Amer. Ethnol. and Archæol., Vol. II, No. 1. Sitcomovi and Hano have no Niman Katcina, nor do they celebrate the Tusayan ritual in its entirety. The word Katcina is used to designate both a dance and a participant in a dance. Between July and January there are no Katcina rites in Tusayan.

[2] I have been interested to discover what proportion of the whole number of Hopi ceremonials have been described, and the results are such as to allay any conceit that we know much about the subject. Without considering the abbreviated ceremonials there are in the ritual 12 which are of nine days duration. There are five variants of this ritual, differing in altars, paraphornalia, and rites, so that we may say there are performed in Tusayan about 60 ceremonials, each nine days long, to be investigated. Of these there are 40 of which we know nothing, save their existence; 15, fragments of which have been described; and 5 which have been fairly well studied. There are about 30 Hopi altars which have never been figured or described, or as far as I know seen by ethnologists. It thus appears that there is plenty of material in this province to occupy the students of primitive ritual for some time to come. An adequate comprehension of the Hopi Katcina ritual requires a consideration of five different modifications of the same altars.

[3] The image of Cotokinungwu in the Oraibi flute altar (q. v.) has zigzag figures down the legs, which would appear to associate this deity with lightning.

mana, a tutelary goddess of the woman's society, the Lalakontu, whose ceremonials in September have been described elsewhere.[4]

The two vertical wooden slats, one on each side of the uprights, bear pictures of the same personage, probably Tunwupkatcina, on whose head is a fan-shaped crest of feathers. On each side the head has a horn, at the extremity of which hangs a symbolic feather.

The human figures have characteristic markings on their foreheads, and their bodies are black, dotted with white spots.

There is no mistaking the symbolism of the remaining idol standing at the right of the altar, as an image of Puukonhoya, the "Little War God," whose characteristic features are the parallel marks on the body, and the weapons of war in his hands.

Several sticks, cut in zigzag shapes with curved appendages and short crossbars at one end, stand between the uprights of the reredos. From their forms, these objects may readily be identified as lightning symbols so common in all Tusayan altars. One of these, which has a complicated tip or head, is placed close to the outstretched arm of Cotokinungwu, with whom it is naturally associated. The straight rod leaning on the same arm is possibly a cornstalk symbol. The rounded stick, tapering at one end, which stands under the extended left hand of the image on the left, is probably a symbol of maize. A somewhat larger pointed object, painted at its base with zones of yellow, green, red and white, and surmounted by a feather, is called "the mound" and suggests the kaetukwi or Corn Mound of the Lalakontu, being similarly situated to an image on the left of this altar. The surface of the latter object, however, instead of being painted, is encrusted [5] with clay covered with different kinds of seeds.

The crook at the extreme left of the altar has attached to it an object which resembles the paddle carried by a participant in the Heheakatcina, or public ceremonial of the Niman at Walpi.

Four pahos, or prayer-sticks, are placed at intervals in hillocks of sand before the images on the altar. The Katcina tiponi,[6] or badge of the chief, stands on the floor before the altar.

Just in advance of the left-hand idol—the image with a coronet—there is a small oblong basket in which are laid a number of sticks with feathers, seeds, and pinches of meal. This is called the "Mother," and recalls similar objects which have been observed on the Lalakontu altar, whose contents have been described elsewhere.[7]

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[4] Amer. Anthrop., vol. 5, No. 2, April, 1892, Pl. I, fig. 1; Pl. III, figs. 1 and 2.

[5] The Hopi, ancient and modern, were adepts in this craft of mosaic encrustations, using for that purpose turquoises, shells, and other substances.

[6] The chief who flogs the children in the initiation, which occurs in Powamu, holds this object in his hand. This flogging at Walpi is performed by a man masked to represent Tunwup. Int. Archiv für Ethnog., Band viii, 1895. 15th Ann. Rep. Bur. Amer. Ethnol., pp. 283–284.

[7] Amer. Anthrop., vol. 5, No. 2, April, 1892.

I need not dwell on the other accessories of the Powamu altar at Oraibi save to note that they are common to other altars, and in no respect characteristic. I refer to the basket tray of sacred meal, the rattles, a medicine bowl, aspergill, and six ears of corn used in special rites.

The strange object at the extreme right, surrounded by a tablet, symbolic of a rain cloud, bears the picture of the head of Ho'katcina. It is supported on a pedestal, and appears to be peculiar to Oraibi.[8]

COMPARISON WITH THE NIMAN ALTAR AT CIPAULOVI

Cipaulovi, the smallest of all the Hopi pueblos, is situated on the Middle Mesa, and its Katcina altar is the poorest in paraphernalia, as shown by a comparison with the altar at Oraibi, the most complicated in Tusayan.

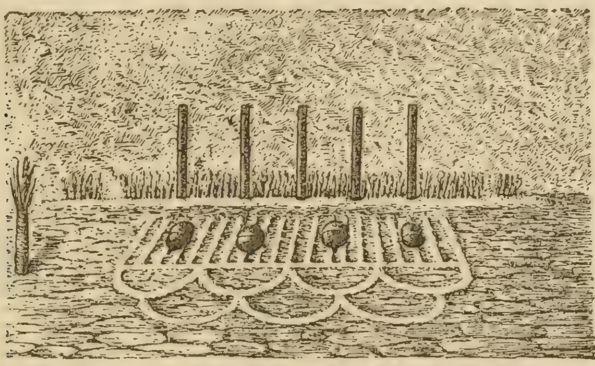
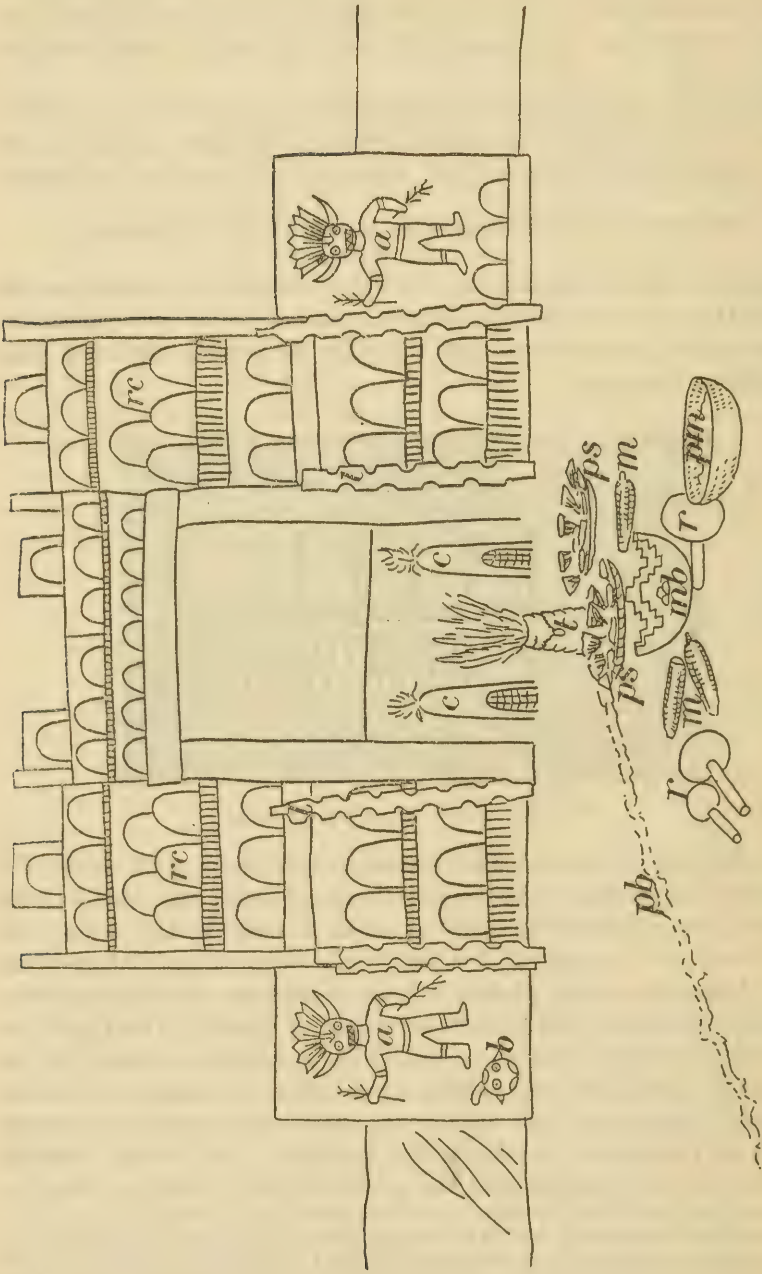


FIG. 1.—Cipaulovi Niman Katcina altar

Omitting the medicine bowl, rattles, sacred meal, and pahos, the Cipaulovi Niman altar consists of a figure of seven rain clouds, with parallel lines representing falling rain, drawn on the floor with sacred meal, and a row of five vertical sticks, symbols of growing corn. Upon the meal picture which represents the falling rain, there are four stone implements arranged in a row. The tiponi, or palladium of the Katcinas is placed on a hillock of sand at the right of the same picture. There are no idols or images of anthropomorphic forms on this altar, and unless the stone implements may be so interpreted, no lightning symbols. The Niman altar at Cipaulovi[9] is very simple, but the essentials of a Katcina altar are

[8] A great many observations remain to be made before any one can claim to know the exact meaning of pueblo rites, but the material awaits investigation, and can be obtained by persistent work in the field. The time, however, is past when any compiler can write an account of the aboriginal religions of America and neglect the Hopi for want of published material.

[9] For Niman altars of Cipaulovi, Miconinovi, and Walpi, see Journ. Amer. Ethnol. and Archæol., Vol. II, No. 1.



EXPLANATION OF PLATE 3—Walpi Niman Katcina altar

a, Tunwup, or Sun Katcina; *b*, Tcuelawu; *c*, Corn mound; *l*, Lightning symbols; *m*, Ears of maize; *mb*, Medicine bowl; *pb*, Path of blessing; *pm*, Prayer meal; *ps*, Prayer sticks in baskets; *r*, Rattles; *rc*, Rain clouds; *t*, Tiponi.

WALPI NIMAN KATCINA ALTAR

included. The two prominent symbols are those representing rain clouds and growing corn, which are elaborated in the more complicated Katcina altars and may be regarded as embodying the two main aims of Katcina celebrations.[10]

COMPARISON WITH THE NIMAN KATCINA ALTAR AT WALPI

The Walpi Katcina is next in simplicity to that of Cipaulovi. It has instead of a meal picture, however, a reredos upon which are depicted rain and rain cloud symbols, and the two supplementary uprights, with pictures of Tunwup referred to in the Oraibi altar. There are zigzag slats, symbols of lightning, and rounded sticks with emblematic corn designs, neither of which, however, is as complicated as at Oraibi.

The Katcina tiponi is prominent, but there are no images on the altar, no basket with seeds and feathered sticks, and no crook with attached handle. While, therefore, the altar of the Walpi Niman Katcina is more complicated than at Cipaulovi, it is not as rich in accessories as that at Oraibi.[11]

COMPARISON WITH THE NIMAN KATCINA ALTAR AT MICONINOVI

The Katcina altar in this, the most populous village at the Middle Mesa, is simpler than at Oraibi, but more complicated than the Walpi representative. It has, in addition to the objects found on the Walpi altar, two idols or images, one on each side. The zigzag sticks are lacking, but stone implements similar to those on the far simpler Cipaulovi altar are present. There are two emblems of maize, as at Walpi, and numerous sticks, representing growing corn, recall the same symbols of the Cipaulovi equivalent.

It will be seen, therefore, that while it is the nearest of all to the Oraibi altar, an additional idol, the "Mother" or basket of seeds, etc., the crook (naluchoya), and the picture of Ho'katcina are unrepresented at Miconinovi.

The two images of the Miconinovi altar are apparently the Little War God and the Germ Maid. There may be a doubt of the accuracy in identification of the latter, but she has the symbols of rain clouds on the head and in the hand. The other image has the parallel marks on the body, symbols of Puukonhoya, but it must be confessed that the same marks are found on the Cotokinungwu idol,

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[10] The character of the public ceremonials of the Katcinas, even when abbreviated, as in the so-called rain dances, justifies the theory that their main objects are the two above mentioned. Even the clowns, a priesthood directly connected with Katcinas and absent in all other ceremonies, are concerned with the growth of seeds.

[11] It may be borne in mind that the same altar is made in Powamu and Niman, and whether called by one or the other of these names it is the same thing—a Katcina altar.

although the latter image has the characteristic cone on the head which is not present in the Miconinovi image. The evidence would thus favor the conclusion that the right hand figurine of the Miconinovi altar represents Puukonhoya rather than Cotokinungwu, and as far as known Oraibi is the sole pueblo which has an idol of Cotokinungwu on the flute altars, of which those of four pueblos are known.[12]

A comparative study of the symbolism, simple and elaborate, of the Katcina altars leads me to the conclusion that the most complicated altar, that at Oraibi, is the result simply of elaboration of the less developed altars, of the introduction of new elements. Analysis reduces this composite symbolism to rain clouds, fertilization, growth,

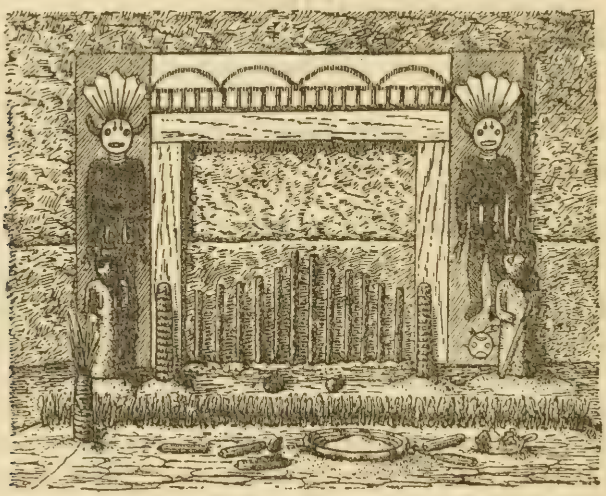

Fig. 2.—Miconinovi Niman Katcina altar

and maturity of corn, the elements which dominate the whole Hopi ritual.

A somewhat more detailed statement of this point is perhaps desirable. In the Hopi ritual three methods of representing supernatural personages are adopted. First, personifications by men, women, and children. Second, representations by images or idols. Third, representations by pictures, conventionalized objects, or symbols. These three methods may coexist; they are interchangeable, and may be phylogenetically connected in the development of rituals. In the public ceremonials the first method is almost invari-

[12] Journ. Amer. Folk-Lore, Vol. VIII, No. XXXI. The conical prolongation of the head is also found in many figurines and images and while the similarity of symbolism would lead to the belief that the two supernaturals are identical, the presence of two similar images on an altar indicates that they are distinct.

ably adopted, but in secret rites all three are employed.[13] The representations on the Katcina altars at Cipaulovi and Walpi are limited to the third method; those at Miconinovi and Oraibi include likewise the second.

There is no need of going into detail regarding the meanings of the symbols of the third method of representation as used on Katcina altars. The simplicity of this method, here applied, is apparent, and the symbols are those of rain clouds, lightning, and corn in various stages of growth.

A discussion of the second method, or representation by images and what they mean when used on Katcina altars, will bring out several points of interest. These images, commonly called idols,[14] occur on the Katcina altars of Oraibi and Miconinovi and represent the same conceptions as the symbols. The idol with the rain-cloud coronet is a representation of a corn-rain supernatural personage who has many names and appears in ceremonials both public and secret of many different priesthoods. In the ceremony called the Lalakontu she is either personated by women in the public dance or represented by images on the altar and is called Lakonemana (Lakone Maid). In the October ceremony, called Mamzrauti, she is likewise represented by the first and second methods,[15] and is called Mamzraumana.[16] The same is true of the Owakulti, still performed at Oraibi, although extinct at Walpi, where she is known as Owakulmana.

During the dramatization in the Antelope kiva of the Snake Ceremonials at Walpi she is personated by a maid called the Tcuamana [17] (Snake Maid) and no effigy of her is employed in this archaic ceremony. The Flute Society represent her in their rites in both the first and second ways, with two girls in the public dance, and images on the altars in the secret observances, where she is called Lenya-

[13] In other secret rites, not considered in this article, the first method is employed as in Powamu. Personifications in public dances are ordinarily masked, and as a rule Katcinas doff their masks when they dance in kivas. In certain instances, however, the mask is worn in kiva ceremonials.

[14] I regard them as complicated symbols, not intrinsically objects of worship.

[15] In the public dance she is represented by a girl, but there is a beautiful instance in this ceremony where the third method is substituted for the first in the public dance. For some reason unknown to me, in the 1891 exhibit at Walpi no girl performed this part, but her place was taken by a participant in the dance who bore in her hands a flat board with a picture of the Germ Maid (see Mamzrauti, Amer. Anthrop., Vol. V, No. 3, 1892, Pl. IV, figs. 9, 10). The picture, not the bearer, represented the Germ Maid. It is a remarkable confirmation of my theory that Mamzraumana is the same personation as Calakomana; that this picture is identical in symbolism with pictures of the latter, and was so called by the priests. Comparing the picture Mamzraumana on the Mamzrau altar and of the same on this tablet we see differences in old and new Hopi art. The picture publicly exhibited conforms to modern conception of her symbolism, as shown in dolls, etc.; that on the altar, which the uninitiated can not see, is the older form, before innovations and modifications.

[16] Amer. Anthrop., Vol. V, No. 3, 1892.

[17] Journ. Amer. Ethnol. and Archæol., Vol. IV.

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mana (Flute Maid).[18] In Palulukonti[19] she is personated by the first method, and is called Calakomana. The most elaborate images of this being, also called Calakomanas, are secular in character, and are used as dolls. All her different names, and some others which might be mentioned, are aliases, sacerdotal society names of the same mythological conception, which may more accurately be called Muiyinwu, the Germ Goddess, who is likewise associated with rain.

The symbolism of images on the left side of the Katcina altars of Miconinovi and of Oraibi is highly conventionalized, but clearly enough developed to show that the images represent the same Rain-Germ Goddess who, in some ceremonials, is personified by a girl; in others by a similar image. This image is called the Rain-Germ (Corn)[20] Maid because in the most elaborate representations of her this bifid nature is strongly indicated by symbolism. Her idol on the Miconinovi Flute altar has four symbols of corn on the body, and bears three rain cloud tablets on the head. In numerous dolls[21] she has a symbol of an ear of corn on the forehead and an elaborate rain-cloud tablet with a rainbow on the head.

The other idol, likewise known in various ceremonials by tutelary sacerdotal aliases, is the male cultus hero, the fructifying principle symbolized by lightning and personified according to the society, by such supernaturals as Cotokinungwu, Puukonhoya, Tcuatiyo, Lentiyo, and the like.

In this totem-pole-like doll we have Hehea, the male, with two Calakos, females, as their symbolism clearly indicates. The Hopi have a legend that the Calako maids brought the first corn to their ancestors, and in that legend it is said that Calakotaka, or the male Calako, a sun god, initiated the youth into the Katcinas by flogging them, as Tunwup still functions in Powamu.

The etymology of the word Calako is unknown to me, and it may have been derived from the same source as the Zuñi word. A corn husk, and by derivation a cigarette paper, is called by the Hopi a calakabu.

The symbolism of the male Calako is identical with that of Tunwup and resembles that of the Zuñi Shalako. The Hopi celebrate

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[18] Journ. Amer. Ethnol. and Archæol., Vol. II; Journ. Amer. Folk-Lore, Vol. VIII, No. XXXI; Vol. IX, No. XXV.

[19] Journ. Amer. Folk-Lore, Vol. VI, No. XXIII.

[20] As maize is the most important food of the Pueblo Indians there is a tendency to make this name more specific, "Corn Maid." This appears to be the name of the doll Calakomana, "Corn Maid."

[21] The range of variation of the dolls of the Calakomana may be seen by consultation of my memoir on Tusayan Dolls (Int. Archiv für Ethnog., Band VII, pp. 45–74, 1894). One of the strangest of these represents two Germ Maids, one above the other, surmounted by a male figurine, Hehea Katcina, which has lightning emblems on the cheeks and phallic symbols on the body.

their sun-prayer-stick making in July, the Zuñi in December, or at different solstices. The Hopi say that they derived their celebration from the Zuñi (see Fifteenth Ann. Rept. Bur. Amer. Ethnol.). When this interesting ceremonial is performed at Sitcomovi the Calako maids do not appear, and the four giants with avian symbolism apparently personate a sun drama, but as a derivative from Zuñi we must await an interpretation of the original for conclusive evidence of its meaning.

The images of the altars as well as symbolic designs depicted upon them show us that fructification, growth and maturing of corn, and rain clouds are predominant in representations on Niman Katcina altars.

I have not offered a suggestion in regard to the identity of the strange being, Tunwup, nor am I quite sure that he can be interpreted, but I strongly suspect that he is none other than the Sun, a worship of whom pervades the whole Katcina ritual.[22]

The element which predominates in the worship at the Powamu ceremony is the fructification of germs; and as beans figure so conspicuously in it as symbols, its popularly called the "Bean Planting," while a ceremony following it is Palülükonti,[23] in which corn is sprouted, is called the "Corn Planting." As in Hopi conceptions the Sun is father of all life, a ceremony called the Powalawu, appropriate to the object or aim of Powamu, precedes the planting of beans in the kivas. The ceremony is strictly a part of Powamu, showing it is a form of direct sun worship. In it a special sun altar is made of a sand mosaic upon which, during ceremonial songs, a tray of meal composed of all kinds of seeds used by the Hopi is copiously sprinkled on the picture of the sun; medicine water is then thrown upon the same to typify the rains which under the sun's action causes these seeds to germinate and grow.

My comparative study of the Hopi Katcina altars has therefore led me to the following conclusions: Their symbolism, whether in pictures, rites, or of images, refer to two elements, or supernaturals, which control rain and growth of corn. The latter are male and female, representing the sky god and the earth goddess, the

[22] He is intimately connected with the "flogging" ceremony, when children are "introduced" to the Katcinas (see Fifteenth Ann. Rep. Bur. Amer. Ethnol., pp. 283–284). The radiating crown of feathers and the two horns on the head, together with the symbol on the forehead, ally him with Calakotaka (male Calako) whose kinship with the Sun-bird is elsewhere referred to. Tunwup appears to be a local name of this worthy in Walpi kivas.

[23] In the so-called "screen drama" of this ceremony, we have pictures of the Sun painted on disks. On the theory that Palülükonti is a fertilization ceremony, it would be explained as referring to corn, and the thrusting of the snake effigies through openings closed by Sun-disk symbols connected with this event.

father and the mother, the lightning and the earth, the two sexes without whose union life is impossible.[24]

The ceremonials performed about the Katcina altars admit of the same interpretation, and it remains for me to indicate their nature and bearing on the above conclusions.

ALTAR OF ORAIBI POWALAWU

A sand picture of the great paternal deity, Tawa, the Sun, has never been reported from any Tusayan altar except Oraibi. Such a picture is made in Powalawu, the opening ceremony of Powamu and described by Mr. Voth.

The altar is made on the floor of the kiva, and is placed on a layer of valley sand on which are made four concentric zones of different colored sands surrounding a middle circle of white sand on which is drawn a stellate figure of the sun. These different concentric zones are yellow, green, red, and white, beginning with the smallest, and ending with a peripheral in white. They are separated by black lines, and a quartz crystal[a] to which a string, with attached feather, is tied, is placed in the middle of the picture of the sun. A quadrant apart on the periphery of the picture, beyond the white zone, there are four arrow-shaped projections, colored yellow, green, red, and white, following a circuit with the center of the whole sand painting on the left hand. These, like the zones, are made of differently colored sands and are rimmed with black. Across the yellow arrow-headed figure extend several parallel red lines of sand; across the green, white; across the red, yellow; and across the white, green.

On the supposition that the inner figure represents the sun, the four peripheral arrow-shaped appendages are supposed to represent heads of the lightning snakes of the four cardinal points, north, west, south, and east, as their colors indicate.[25]

The accessories used in the celebration of the Powalawu are arranged on the floor radially about this sand picture, and fall into two groups, one on lines in continuation of the rays of the central figure, the others on intermediary lines. There are, therefore, four sets of both groups alternating with each other.

The objects which form a single group of the former in this quaternary arrangement are as follows: A yellow reed, a paho-

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[24] In the same way that I have compared the Little War Gods and the Germ Maids of Katcina altars we might also compare the male and female figures of the flute altars which we know from variants. The same will be possible with the cultus hero and his female double of Lalakontu, Mamzrauti, etc. There is a striking morphological identity in many altars of different societies.

[a] A quartz crystal is used to deflect the light of the sun into the medicine bowl in Niman Katcina. Journ. Amer. Ethnol. and Archæol., Vol. II, No. 1.

[25] Similar projections at intervals a quadrant apart are common on symbols of the sun, and I have found them on ancient pottery from Homolobi. The arrow-headed appendages are not, as far as I know, found in any other instance of palæography.

stand, and a ball made of powdered pikumi.[26] Intermediate between these, also with a quarternary arrangement, there is a ball made of clay painted black in which a feather is attached, a blackened reed, and a stone arrow point. The paho-stand with these objects consists of a cubical block in which the following objects are inserted in line: A small crook, a green double paho, several sticks (called civapi, howapki, honyi, masiswapi), a black eagle feather with four nakwakwocis tied to it and a ring with netted cord, and finally a paho of a color corresponding to the cardinal direction in which the paho-stand is placed.

The details of the Powalawu ceremony have been described by Voth, from whose account I will mention a few generalities.

The celebrants gathered at the altar at about noon and sang many songs with accompanying events which were performed by Siima, the chief, now dead.

1. White earth, roots, and honey added to the medicine bowl.

2. Meal made of watermelon, melon, squash, bean, and corn seeds, sprinkled carefully over the sand picture.

3. Charm liquid stirred and sprinkled on sand altar.

4. Priest ascended ladder of the kiva and blew a yellow feather through a reed from the north paho-stand out of the hatch toward the north, after which he blew a whistle pointing it the same way. This was done in sequence to the west, south, and east, taking objects from the altar each time.

5. Priest ascended ladder with a black reed from north cluster, and blew from it, toward the north, a small feather. He then blew a feather in sequence from the four stones, ascending the ladder each time.[27] He licked honey from the stones and spat to the four cardinal points.

6. Couriers carried the clay balls to distant shrines, and four priests bore the four paho-stands, reeds, and yellow balls to other shrines, also at cardinal points.

While the above events were transpiring songs were sung by the assembled priests, and at the close the quartz crystal on the Sun picture was raised from the stand and handled by each priest, who sucked it, and pressed it to his heart.

7. Ceremonial smoke.

8. Prayers.

9. The sand gathered up and carried outside the kiva.

10. Feast.

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[26] Pikumi is a kind of hasty pudding, a favorite dish in ceremonial feasts. It is baked in small pits lined with corn husks, which have previously been heated by building fires within them. The coals are raked out, the mush put in, and a stone slab luted over the pit. Upon this a fire is maintained over night, and on the morning of the final day of a great ceremonial they are opened. The soft part is eaten immediately, but the mush which has caked to the corn husks is reground and made into other forms of food. The above-mentioned balls are made of the latter products.

[27] Evidently this and the following acts are to bring the summer birds.

The aim of the ceremony appears clear. Meal of all kinds of seed sprinkled on the Sun typifies fructification of all Hopi food plants. Water is poured on the meal as symbolic of the rains which the celebrants hope will increase their crops.

The details of the nine days' ceremonials of the Powamu at Oraibi need not be described here, but it may be well to indicate their general character.[28]

Beans were planted in boxes in all the kivas on the day after Powalawu (February 5, 1894) and were forced to germinate in the heated rooms, where they grew for 16 days. From February 13 (the first day of the nine days' ceremony) until the 17th, Siima, the chief, visited all these kivas, and when not so employed passed his time in one of the rooms fasting, or making prayer objects.

I am indebted to Mr. Voth for my knowledge of the secret rites of the Powamu at Oraibi. They supplement that which I have published elsewhere on the Walpi representation, from which, however, it differs very considerably. (See Fifteenth Ann. Rept., Bur. Amer. Ethnol.; also Amer. Anthrop., Vol. VII, No. 1, 1894, and Int. Archiv für Ethnog., Band VIII, 1895.)

The Powamu altar was erected on February 17, and from that day until the ninth (February 21) daily songs of interesting character were sung about it.

Many dolls, bows and arrows[29] for children are likewise made in the kivas, and the chiefs prepared prayer emblems and other ceremonial objects.

The culmination of Powamu, when we should expect the acme of the series of rites, occurred on the afternoon of the ninth day (February 21), when the sprouting beans were pulled up, and distributed with dolls and other presents, and when certain personages of supernatural character brought significant gifts to the priests. It is the last event to which I wish especially to call the reader's attention.

This episode, which seems to me to bring out clearly the aim of the Powamu ceremony, may be called the advent and departure of Hahaiwuqti[30] followed by the Eototo and other supernaturals. The

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[28] The Oraibi Powalawu, witnessed twice, took place Feb. 4, 1894, and Jan. 14, 1896. The chronology of the succeeding events in 1894 was as follows:

Feb. 5–9, bean planting in all kivas.

Feb. 13–21, nine active days of Powamu ceremony, q. v. The Powamu, according to my enumerations, includes not only the nine active days but also several preceding in which the beans are planted, beginning with Powalawu, and making a complete ceremony of 16 days.

[29] These gifts for little girls were made in the Niman Powamu and Palülükonti at Walpi. They were fashioned in the form of Katcinas. (Int. Archiv für Ethnog., Band VII, 1894.)

On the eighth day pahos were made for Hahaiwuqti and Eototo, who visit the kiva on the ninth day. The former personage appears to be known by different names in Oraibi and Walpi, but I believe the same personage is intended by both names.

[30] For a picture of Hahaiwuqti, see Amer. Anthrop., Vol. VII ,No. 1, 1894. For symbolism of Eototo, see Int. Archiv für Ethnog., Band VII, 1894.

main events of this episode were as follows: The man who personified the "Old Woman" (Hahaiwuqti) having masked and otherwise arrayed himself at a shrine[31] outside the pueblo, began to howl vigorously. Siima the chief of Powamu, made offerings at this shrine and drew on the ground, with sacred meal, several figures of rain clouds about 20 yards nearer the village. Hahaiwuqti, as if tolled along by this mystic sign, moved to it and again began to howl. Siima made another set of rain cloud figures, again about 20 yards nearer the village, and the howling Hahaiwuqti advanced to the second meal figures. Halting thus at intervals, and howling as she went, the "Old Woman" at last stood in the public plaza of Oraibi, and in answer to her cries people came to her, sprinkled her with pinches of meal and took objects from the basket she bore.

She then sought the entrance to the kiva in which the priests were engaged in ceremonial smoking and singing. She stood like a statue at the hatch, howling as if to announce her coming to the priests within the room below. They soon responded, and came out of the kiva headed by Siima with a bowl of medicine and an aspergill, followed by a second priest with a reed cigarette and a coal of fire, and others with bags of sacred meal. Hahaiwuqti was asperged, smoked upon and sprinkled with meal, and presented with a paho accompanied with a prayer, after which the priests returned to their room and the "Old Woman" went away to the west. A few minutes later men disguised as Eototo and Ahul approached the kiva hatch near which some unknown Katcina had made in meal on the ground a cross and rain cloud. Eototo rubbed meal on each of the four sides of the kiva hatchway[32] and poured water into the kiva entrance from the sides, as I have described in my accounts of the Walpi and Cipaulovi Niman Katcina. Ahul followed his example, whereupon the priests again emerged from the kiva and treated these two visitors in the same way they had used Hahaiwuqti. They received corn in return, after which the visitors retired, following the "Old Woman."

After their departure, two "mudheads" (Koyimse) and three Katcinas, two men wearing Humis, Jemes, Katcina masks and one

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[31] In the shrine he put a paho, several nakwakwocis, and meal, after which he took a little honey in his mouth and spat to the four cardinal points. He gave a basket with a paho, sprouted beans, and other objects to Hahaiwuqti after he left him at the second meal figures.

This method of tolling the gods is practiced in the march of the Flute priests from the spring to the pueblo. (Journ. Amer. Ethnol. and Archæol., Vol. II; in Lalakontu, and in Mamzrauti, op. cit.)

The Katcinas are tolled along by meal deposited on the trail by the priests. A trail is closed by a line of meal at right angles to the same.

[32] Those in one of the kivas received meal (prayers) and nakwakwocis (personal prayers). Hahaiwuqti gave them the basket she bore and the objects remaining in it, upon which, at the close of the ceremony, all the priests smoked (prayed).

the maskette and apparel of the female Humis, approached the kiva entrance.[33] Then came personifications of Ana, Hehea, and two Tacab Katcinas. Following these were three lame Howaik Katcinas, masked as their predecessors, and clearly designated by appropriate symbolism.

At each new arrival the priests in the kiva responded, emerged from their room, and treated these visitors as they had their leader, Hahaiwuqti.

As the masked personages left the village they passed westward.[34]

When the priests had retired to their kiva for the last time they smoked on the presents left by their strange visitors, and the chief divided the gift Eototo had brought into 10 bundles, and gave one package to each Powamu priest. Then followed minor events, as taking down the altar, which do not now concern us. The departure of Hahaiwuqti and her band closed the main ceremony.[35]

It certainly seems legitimate to conclude that this acme of the Powamu is a dramatic representation embodying the aim of the whole ceremony. It is a visit of Hahaiwuqti in her disguise as known to Katcinas, followed by her children bringing gifts and receiving prayers. What other prayers are more appropriate to Hahaiwuqti than petitions for abundant crops, or what gifts more desirable than those Eototo[36] gave in a symbolic way, viz: water and sprouting vegetation? The rejuvenescence of nature is always to a primitive mind akin to sorcery, and believed to be brought about by the sorcerer's arts, and hence this ceremony takes place in the Powako-muyamuh, or Wizard Moon, which gives it its name by syncopation, Powamu.[37]

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[33] From the belts of Humis the priests took a sprig of spruce. This is only customary after the Humis Katcina dance. (Journ. Amer. Ethnol. and Archæol., Vol. II, No. 1.)

The Humis (humita, corn) wear terraced (rain cloud) tablets on the mask. (Journ. Amer. Ethnol. and Archæol., Vol. II, No. 1.)

[34] For symbolism of their masks and dress see Journ. Amer. Ethnol. and Archæol., Vol. II., No. 1; Int. Archiv für Ethnog., Band VII. Ana wears a ong beard and is therefore called the bearded Katcina. Hehea has zigzag marks on the cheeks. The symbolism of Tacab varies considerably, but is readily recognized.

[35] A Hopi prayer combines two elements of ceremony—prayer proper and sacrifice, the former spoken or not, the latter always expressed by symbols. As they are an agricultural people, their aboriginal wealth is an agricultural product, as corn. Their poverty of corn and the requirement of their ritual necessitated sacrifices of meal, a highly practical substitution. So likewise tobacco smoke is a sacrifice, the burning of rare herbs, or the pine needles in the "New Fire" ceremony.

The act of sacrificing animals or human beings is not a part of their present ritual, but a knowledge of its efficacy exists. They have legends of human sacrifice on rare occasions in the past. The killing of an animal and smearing the body of the man representing Masawuh with its blood, at the time of Lieutenant Brett's visit to Oraibi in 1891, is an instance of animal sacrifice. Several survivals of animal sacrifices in warrior ceremonies might be quoted from legends.

[36] Eototo is believed to be a god of metamorphism, or growth, intimately associated with germination, a sacerdotal equivalent of Masauwuh, as far as these functions are concerned.

[37] I have elsewhere called Powamu a purification ceremony or lustral observance, which it is in certain particulars, but I am now convinced that its main object is to further the fructification of vegetation.

CONCLUSIONS REGARDING THE PLACE OF KATCINAS IN TUSAYAN WORSHIP

We are justified in regarding the Katcinas as spirits of the dead, or divinized ancestors, shades or breath-bodies of those who once lived, as mortuary prayers clearly indicate. The theory of ancestor worship gives us a ready explanation for the fact that ancestral spirits are represented by masked persons, and as a corollary, a suggestion regarding the significance of the different symbolism of those masks.

The Hopi, like many people, look back to mythic times when they believe their ancestors lived in a "paradise," or state or place where food (corn) was plenty and rains abundant, a world of perpetual summer and flowers. Their legends recount how, when corn failed or rain ceased, cultus heroes have sought these imaginary or ideal ancestral homes to learn the "medicine," songs, prayers, fetishes, and charms efficacious to influence or control supernaturals, which blessed these happy lands. Each sacerdotal society tells the story of its own hero bringing from that land a bride, who transmitted to her son the knowledge of the altars, songs, and prayers, which forced the crops to grow and the rains to fall in her native country. To become thoroughly conversant with the rites he is said to marry the maid; otherwise at his death they would be lost, since knowledge of the "medicine" is believed to be transmitted, not through his clan, but that of his wife. So the Snake hero brought the Snake-Maid (corn-rain girl) from the underworld; the Flute hero, her sister, the Flute-Maid; the Little War God, the Lakonemana and other supernaturals.

A Katcina hero in the old times, "on a rabbit hunt came to a region where there was no snow. There he saw other Katcina people dancing amidst beautiful gardens. He received melons from them and carrying them home told a strange story of the people who inhabited a country where there were flowering plants in midwinter. The hero and a comrade were sent back, and they stayed with their people, returning home loaded with fruit in February. They had learned the songs of those with whom they had lived, and taught them in the kiva of their own people." [38]

In the ceremonies with unmasked personifications, or those celebrated yearly between July and January which are not Katcinas, an attempt is made to reproduce rites which legends declare the cultus or ancestral heroes saw in the lands they visited, which lands are reputed to be variously situated, but generally in the underworld, to augment the efficacy of the ceremonies. In the ceremonies between

[38] Journ. Amer. Ethnol. and Archæol., Vol. II, No. 1, p. 152. The Katcina hero in this story would appear not to have brought a wife from this people.

January and August, or those called Katcinas, the same feeling is dominant. Each performance is an endeavor to reproduce a traditional ancestral Katcina celebration. The performers are masked because, according to their stories, the participants in those ancient rites are reputed to have had zoomorphic, or at least only partially anthropomorphic forms. The symbolism of the mask portrays the totems of those legendary participants, and those of corn, rain, water-loving animals, lightning and the like, therefore predominate.

I have shown in preceding papers that both the symbols and figurines on Katcina altars refer to the sun, rain clouds, and the fertilization, growth and maturation of corn. It has likewise been made evident that the ceremonial acts of the priests are employed to affect the supernaturals who control these elements or produce these necessities.

The priests strive to reproduce traditional ceremonials without innovations, and are guided in their presentation by current legends. Masked personations of ancestral spirits are, therefore, introduced that the performance may be more realistic, or closer to the reputed ancestral ceremony. This feeling is at base the reason why the priests, unable to explain why they perform certain rites in certain ways, respond, " we make our altars, sing our songs, and say our prayers in this way because our old people did so, and surely they knew how to make the corn grow and the rains fall."

It appears from what is written above that the cosmic supernaturals which appear on the Hopi Katcina altars are the same as pointed out in the previous article, the Sun, the Sky, Earth, Fire, Ancestors, and that idols are likewise prominent. The Hopi, like all the pueblos, are commonly called sun worshippers, but the relations of the altars of the Katcina cult to Sky God (Sun) worship is very instructive.

In conclusion it should be said that, although the ceremonial practices of the Hopi Katcinas appear very complicated, they are in reality simpler than the literature of them would seem to indicate. In the first place, we must bear in mind that in the Hopi religion the association of religion and ethics is very weak, the duty of the priest being to perform his part of the ceremony as nearly as possible in the traditional way it was inherited from his ancestors. Secondly, the rite and ceremony show that the main object desired is a material not a spiritual one, primarily to fertilize Indian corn, his national food, and incidentally to protect his own life and that of his family. The objects of his worship form together a complex composed of closely allied elements in which the supernatural powers that control the food are preemiment.

OMAHA BOW AND ARROW MAKERS [1]

By Francis La Flesche

[With 4 plates]

The bow, with its arrow, was the most effective weapon known to the North American Indians. This statement applies generally to all the tribes living within the United States, and in particular, to the plains tribes of the Siouan linguistic stock whose habitat for centuries had been along the Missouri River from its mouth to its headwaters, although some of the tribes belonging to this linguistic group dwelt along the Mississippi River even as far south as the mouth of the Arkansas River.

The style of the bow made by these tribes was generally the same. That which was preferred and in common use by the people was a bow that was curved more at the head, or above the grip, than at the foot or below the grip. The expert bow makers say that the bow that is curved equally at the top and bottom works as well as the preferred style, but the makers gave no explanation as to why one style is preferred to the other.

The ta-ko^{n}'mo^{n} de, sinewed bow, was known to these tribes but was seldom used. As a bow it was beautiful, being gracefully curved at the top and the bottom as well as at the grip, but the experienced user of the bow turns away from it because it is a " female bow " and he wants a bow of a stronger sort. The sinewed back bow was not fitted to stand rough usage; in the first place, the bow itself is made slender in order to avoid clumsiness of appearance when the sinew is added and put on the back of the weapon; in the second place the glue used to hold together the fibers of the sinew can not withstand dampness; when the bow is exposed to the rain, the glue and sinew part company and the bow loses both its strength and its beauty.

Several years ago I wanted to secure an Omaha bow, but there was none to be found in the tribe; for the weapon was no longer in use. A young man who knew of my fruitless search said to me: " I could make a bow for you, but it would only be an imitation, not a real bow. Any man who can whittle and scrape with a knife can make something like a bow, but it takes a man skilled in the making

[1] Reprinted from Annaes do XX Congresso Internacional de Americanistas, Rio de Janeiro, 1922. Published 1924.

of bows to make a bow as it should be made. There are only two Omaha men living who can be called bow makers." The young man gave me the names of these old men; one was a stranger to me, but the other one I knew very well.

The Omaha bow maker, like the medicine man, has to be ceremonially approached, therefore I had to send a special messenger to make known to him my wishes. The old man for whom I sent did not come to see me for about two days, and when he did come he brought a bow partially finished. He apologized for not coming at once but explained that he thought I might be in a hurry to have the work finished so he had started it before coming. He said: "I feel honored in being your choice of a bow maker. I used to make your father's bows. He always liked them long and heavy. There are only two bow makers now living and I am one of them."

The old man was putting the finishing touches to the bow when the other bow maker just happened to come in. My man handed the finished bow to the visitor who took it with a smile and caressed it by running his hands over its smooth surface. "What a beautiful piece of wood it is." Then, after examining it critically, he said,

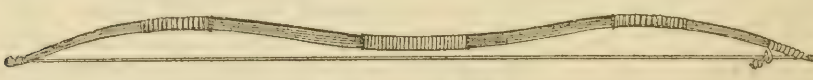

FIG. 1.—Omaha bow

"If it ever breaks it will be right here," pointing to a weak spot midway between the grip and the top. "The rule is," continued the visitor, "that where there has been a knot, that spot must be left 'thick'. I notice another mistake, one that is commonly made; the neglect to blunt the edges of the nocks, for sharp edges endanger the cord." He meant that the sharp edges of the nock wears the cord by friction, causing it to break. My bow maker accordingly made a few slight cuts with his sharp knife along the edges of the nocks to blunt them, and the bow was finished. Then my bow maker asked for a bit of grease. This I supplied and he greased the "breast" of the bow at the upper and lower parts. The upper part he held over the fire and when it became hot, he bent it with his foot and held it until it cooled. "That was nicely done," the visitor said, "but I would not put so much curve at the lower end of the bow."

From these two old men I learned that there were three choices of wood for the bow, namely, the ash, the white elm, and the ironwood. These three kinds of wood take on polish and do not "turn over" as they expressed it, which means that they do not warp badly when exposed to wet weather. The wood that the bow maker likes best to work upon is the young ash that was killed by a prairie fire, because the wood is then thoroughly seasoned and set, so that dampness and rain do not affect it. The elm and ironwood are cut green and hung over the lodge fire to season, which is a slow process. There is one danger which the bow maker carefully guards against, and that is a splitting by shrinkage. Experience had taught the men who loved to make bows that there is one winter month during which it is safe to cut green wood for making bows, and if I remember rightly it is the "month of the return of the geese," that is, February.

The Osage and the Kansa had the best and the most costly bows. This remark does not refer to the making but to the quality of the wood. This wood was called by the Osage and Kansa, Mi^{n}'-dse-sta, smooth bow, and by the Omaha, Zho^{n}-zi, yellowwood, the most serviceable of any of the bowwoods. The yellowwood was called by the French, bois d'arc, and was procured along the Arkansas River, for the tree did not grow in the regions north of Kansas.

The bowstring or cord is made from the sinew taken from the muscles lying on either side of the spine of the buffalo. The bow maker's art does not include the making of the bowstring. There are men who are skilled in the making of bowstrings who are employed to make them. The man whom I employed is still living at this writing, close to the age of 90 years. This bowstring maker took five strands from a sinew that I had procured and soaked them in glue water over night. In the morning he squeezed the water out of the sinew, then spliced together the ends of the strands, using fresh glue, thus making one long strand. This he put in the sun to partially dry, just enough to give the glue strength to hold together the spliced parts of the sinew. The strand having dried to the desired consistency, the bowstring maker formed a little loop exactly in the middle for the upper nocks of the bow. He put this little loop over the small end of a slender pole which he had planted firmly in the ground for this purpose. He then grasped in each hand an end of a strand and swung the two strands simultaneously. With each swing he twisted the strands with his fingers. As the strands were thus twisted and swung, they twined around each other and by the movement of twisting and swinging the twist traveled toward the man until the string thus formed came to the man's fingers, when he tied a knot in the finished cord.

As the man strung the cord to the bow he said: "That bow was made by E-shno^{n}'-hun-ga; I know the way he makes his bows. He is one of the best bow makers." When the cord was put on the bow, the man gave it a few pulls and the bow responded with a resonant ring at each pull. The old man remarked, with a sigh: "This takes me back to my buffalo-hunting days."

The wood for making the arrow shaft was chosen with as great care as the wood used in making the bow. By long experience the arrow makers had found two kinds of wood to be serviceable. These two were the ash and a species of dogwood. The latter had the same name among the Omaha, Ponca, Osage, and the Kaw, related tribes, Mo^{n}'-c̃a-hi, meaning arrowwood. The sapling of this species of wood was preferred because when in that stage of growth the wood is straight and has but few knots.

The sapling of the ash is not used, for it has a large pith and the wood is soft. However, the trunk of the mature ash is cut into the proper length and split up for arrow shafts. Both the dogwood and the ash are polishable and flexible. The wood is hard, but will bend under strong pressure and not break.

If by accident a hunter loses his arrows, and neither ash nor dogwood is obtainable, he will use the sapling of the wild cherry tree for his arrows; but this wood breaks easily and is used only in an emergency.

When the arrow shafts are cut into the desired lengths and roughly shaped, they are tied in a bunch and hung over the fireplace to season. This process takes about 10 days to two weeks. Then the tedious task of the final shaping begins. First the arrow maker carely examines each shaft; when he finds a crooked place, he greases the spot and holds it over the fire to heat; he then quickly straightens the crooked place and holds it securely until it cools. A deer's horn through which a hole has been drilled is used for this straightening process.

The next process is the final shaping of the shaft. A good arrow maker aims to make the shaft as nearly cylindrical as possible. To accomplish this, he holds the shaft in his left hand between the sandstone polishers, each piece grooved lengthwise, and gives the stick a twirling motion by rolling one end of it back and forth on his thigh with the palm of his right hand. He shifts the polishers along the shaft in order to keep it uniform in size. When one end is polished, he works in the same manner on the other end, until the full length of the shaft is round, smooth, and uniform.

Then follows the making of the nock for the bowstring. In polishing the top of the shaft the arrow maker works it down so that the nock has a rounded appearance to give the archer a good grip. The notch of the nock may be shaped either like a **V** or a **U**.

The next process is the grooving of the shaft. The arrow maker measures the top part of the shaft with one of the feathers to be put on it and begins his groove from the lower end of the feather. There must always be three undulating or zigzag grooves. There has been considerable discussion as to the meaning of these grooves. Some writers have said that the zigzag lines mean lightning, others that these grooves were made for the blood of a wounded animal to flow through. An explanation was given to me when I was a boy by an old Omaha groove maker, which is so simple and practical that it has always impressed me as being the true explanation of the making of grooves on the arrow shafts.

One day I went home from school and found that my father had been taken sick in the midst of his preparations for the annual summer tribal buffalo hunt. He had finished polishing and straightening the shafts and shaping the nocks, but he was too weak to groove the arrow shafts. As this was a necessary part in making the arrow he had sent for U'-shi-wa-the (Quail) who was a very skillful workman in grooving arrow shafts. The quality of the fee my father had given for the work to be done put the old man in very good spirits; he talked as he worked, pointing out the defects in some of the shafts and mentioning the names of the men who in the past were skilled in grooving arrow shafts, but who had departed for the spirit land. Without pausing in his talk he picked a shaft, put on it the grooving tool; with a swift movement he deftly cut the first groove, then he cut the second one, then the third one and the threadlike shavings fell to the floor. Looking up at my father I said: "Da-di, what is he making those grooves for?" My father smiled, and addressing the old man said: "Father, tell the boy, for he may be making arrows some day." The old man picked up a shaft and said: "My grandson, your father spent much time in selecting these saplings for his arrows; he sorted out those he thought to be perfect, but there is no perfect wood; there is always some fault in it. Now look at this one I have in my hand, there was a sharp bend which he had hard work in straightening, but when I put on it the groove, thus, and thus, and thus, the shaft will not roll back to its natural imperfection, but will remain straight; that's why these grooves are made."

The next process is the feathering of the shaft, and it may not be out of place here to continue the story of Quail, the old Omaha arrow groover. So pleased was he with his fee that he offered to finish the arrows for my father. He also allowed me to take a very humble part in the work. I was requested to bring to him a bag containing glue, sinew, and feathers; also a pan of warm water. I started a little fire to heat the glue and to soften it. The old man took the pan of warm water and put into it the sinew which he had shredded into many threads; he also put into the pan the glue which was attached to one end of a stick nearly as long as an arrow shaft.

As the old man examined the feathers, which were owl feathers, he remarked "a bird of night." The feathers were from the wings, the stems were split, the pithy part scraped with a knife, leaving the aftershaft clean like parchment. He next tested the threads of sinew, taking up one strand from which he squeezed the water then wiping his hands, took up a split feather, put the top end against the shaft, aftershaft of the feather downward, so as to overlap a little the bulb-shaped nock; taking a strand of sinew, he wound one end once around the shaft and the feather near the nock. He then took the other end of the sinew between his teeth and holding the strand taut, he heated the glue a little over the fire and rubbed it on the sinew; he then put the second feather on the shaft which he gave one turn and the sinew held the feather; he treated the third feather in the same manner; then he thinned the end of the strand of sinew by scraping it with a knife and putting the thinned end of the strand around the shaft; he smoothed it down with his finger. Then he dipped the sinew in a little pile of white powder, made of burnt gypsum, for the purpose of cleaning, whitening, and drying it.

Quail held up the arrow shaft with the drooping feathers and said to me: "My grandson, this sinew will do two things at the same time, it will hold the ends of the feathers on the shaft and support the nock of the arrow so that the bowstring will not split it." He then glued the under part of the aftershaft of one of the feathers and neatly stuck it on the arrow shaft, the other two feathers he treated in the same way, and all three feathers lay neatly on the arrow shaft, equi-distant apart.

The old man, addressing my father, said: "My son, I see that you have two kinds of the little ornamental feathers for the lower part of the feathers, one white and the other red, which shall I put on?" "The red," my father replied, and the old man remarked, "Ah! the color of the red dawn." Quail took a shred of the soaked sinew, squeezed the water out of it, wound one end once around the arrow shaft and the quill part of the feathers, near the web, then taking between his teeth the other end of the sinew, he glued it, then put a little red downy feather in the space between the large feathers and gave the arrow shaft a slight turn; in the second space he put a little red feather, gave the arrow shaft another slight turn, and treated the third space in the same manner, then quickly covered the quill part of the arrow feathers with the glued sinew which he smoothed down with his finger; after that he dipped the sinew in the pile of powdered gypsum. Then, turning to me, he said: "My grandson, always overlap the ends of the quills with glued sinew when you make arrows, and don't forget to dip the sinew in the white powder. Be neat, always, in your work."

The old man held the arrow at arm's length to examine his work, while his face brightened with pleasure. Then, speaking to my father, he said: "My son, the glue works quickly, would you mind telling me what you made it of?" My father replied: "The glue was made from the shell of a soft-shelled turtle."

The slits for the shanks of the arrowheads, which were made of iron, had already been made in the shafts, and the gluing of shanks, inserting them in the slits, and fastening them with glued sinew, took the old man but a short time to finish.

Quail then, speaking to my father, said: "My son, I am about to trim the feathers, will you have the leaves (webs) narrow or wide?"

"Make them narrow," my father replied. "Ah!" the old man remarked, "I see you know the principle, the narrow leaves hold the arrow steady, the broad leaves will cause the arrow to make an undulating movement as it takes its flight."

The old man sharpened his knife very carefully, laid an arrow, nock toward him, along the edge of a board so that the web of the feather lapped over the edge; he then trimmed the web, giving it a straight line. All the other webs he treated in the same manner.

Again addressing my father, the old man said: "What about the marking, my son?" "Black on the shaft," my father replied, "the length of a finger joint, along the lower part of the feather, and the upper part red, to the nock." "Night and day," the old man remarked, "the symbol of precision." From a small package the arrow-maker poured into the shell of a fresh water mussel the black coloring material, and from another package he poured into another shell the red pigment. Into these shells he poured glue water and stirred the mixture with a stick. Then using the tip of his index finger for a painting brush he first put on the black paint, and then the red. When the paint, which had a glossy appearance, had dried, the old man gathered the arrows together in a bunch and handed them to my father, who caressed them by passing his hands over them; then, with a pleased expression he lifted the arrows up and said to me: "Look at these, my son, and let me tell you that a neatly finished arrow is the pride of a good archer!" A smile rippled over the wrinkled face of the arrow-maker, as he nodded his head with pleasure at the compliment.

The bow and the arrow figure prominently in the religious rites of some of the plains tribes of the American Indians. In Osage mythology, the bow was the gift of the moon to the people, and the arrow a gift from the sun, taken from one of its rays. In three of the tribal rituals of the Osage, two arrows, one painted black to represent the night, and the other red, to represent day, are set in flight (figuratively), by a bow also painted black and red, toward the setting sun. These two arrows, thus set in flight at an initiation of a candidate into the mysteries of certain tribal rites, not only symbolize the endless recurrence of night and day, but the flight of these mystic arrows is also equivalent to the Initiator saying to the candidate: "Your life, represented by your descendants, shall be as the night and day, endlessly recurring. Among the Omaha tribe seven arrows were used as symbols in an annual ceremony. Each gens of the seven principal gentes of the tribe is represented by one of these mystic arrows, which are used to foretell what will happen, good or evil, to each gens during the year following the ceremony. These divining arrows also stand for the continuity of each gens through its natural increase. The members of the gens to whom is entrusted the keeping of these sacred articles are privileged to name their sons, "Mo^n'-pi-zhi," Bad Arrow; this name has been seldom used. The word "pi-zhi" or bad, is not used here in its ordinary sense, but refers to the mysterious characters of the divining arrow.

LAST OF THE OMAHA BOW MAKERS

THE ASH BOW SHOWN IN THIS PICTURE WAS MADE BY E. SHNOŃ-HONGA, THE LAST OMAHA BOW MAKER. THIS SPECIMEN IS IN THE CALIFORNIA STATE UNIVERSITY

XO'-KA SETTING TO FLIGHT THE MAGIC ARROWS

ARROW RELEASE OF OMAHA INDIANS

THE NATIONAL PARK OF SWITZERLAND[1]

By G. Edith Bland

[With 5 plates]

Many people who have completed one of the usual tours of Switzerland depart with the impression of a small country which seems to be but one large national park containing some of the most wonderful beauties of nature. However, away toward the eastern frontier, rather off the beaten track of the tourist, lies a small inclosed region which is Switzerland's real or official national park.

OBJECT AND LEGAL PROVISIONS

The object in establishing the Swiss National Park was to set aside a district where nature could develop freely, untrammelled by man. It was not intended that the park should become a center for excursions, and for this reason few conveniences for the tourist are to be found within its confines. It is essentially a scientific institution where nature in her wild state may be preserved and studied.

It is proposed to increase the already rich flora and fauna of this region in every possible way and to make it a national treasure ground of nature. Much has already been done in this respect, and in order to protect the treasures collected strict regulations are enforced. No shooting, trapping, or fishing is allowed, no flowers or plants may be picked, no specimens of any kind may be taken away, all visitors must keep to the official paths and roads, and all are requested to remember that the Swiss National Park is the national sanctuary where every flower, plant, and animal enjoys absolute safety.

AREA AND SITUATION

The national park at present covers an area of about 140 square kilometers (approximately 57.8 square miles). It is situated in the canton of Graubünden, in the lower valley of the Engadine, on the

[1] The information in this article was obtained from the following sources: Annual Reports of the Swiss Federal Commission of the National Park, 1924 and 1925; "Der Schweizerische Nationalpark," by Dr. S. Brunies; "Kleiner Führer durch den Schweiz. Nationalpark," by Dr. S. Brunies; "Graubünden," by Verkehrsverein; and from personal investigation.—Author.

right of the River Inn, stretching between Scanfs and Schuls. It lies in the wildest and most rugged part of the Eastern Alps, the Engadine Dolomites, the highest peak of which is Piz Pisoc

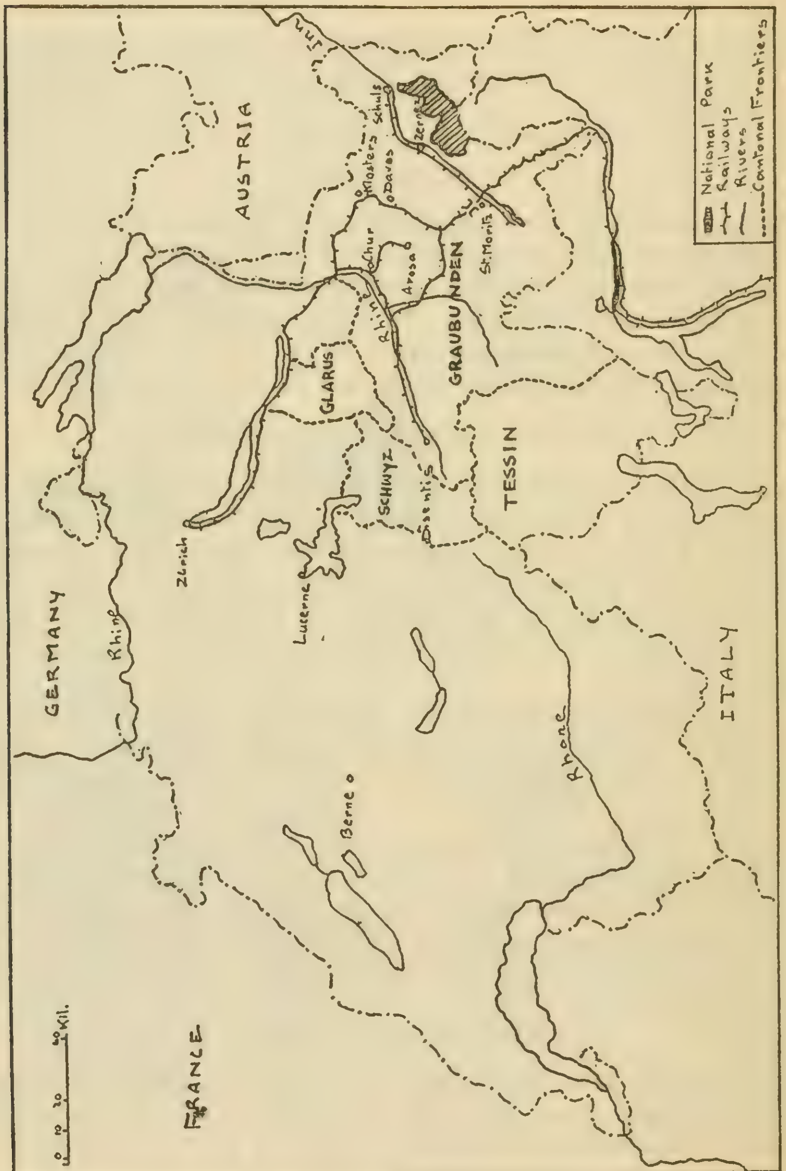

FIG. 1

(3,178 meters). It is a region of imposing snow-capped peaks, rushing torrents, deep valleys, and thick forests, the natural home of the bear and chamois.

This enchanting wilderness can be reached by rail from Chur or St. Moritz to Scanfs, Zernez, or Schuls-Tarasp, from all of which points roads lead to the park. The park itself is crossed by a number of roads and paths leading in various directions and all kept in good condition. Only by special permit from the park keepers can visitors leave the beaten roads and paths, and the district round Piz Terza is strictly closed to the public.

ACCOMMODATION FOR VISITORS

There is one restaurant and house of refuge in the park in Val Cluoza. Here as many as 35 to 40 people can pass the night and obtain refreshments, but it is not to be looked upon as a hotel and can only be used in cases of real need. During 1925, 846 visitors stopped at the Cluoza shelter.

BOUNDARIES AND GUARDIANS

Where no natural frontiers exist the boundaries of the park are clearly marked. At first there was only one guardian, who has been at his post since 1910. As the size of the park increased, others were appointed, and the park is now guarded by a body of keepers and in the districts of Fuorn and Scarl by the Federal frontier guards. A number of huts and shelters for the use of the guardians exist in various parts of the park, and the personnel is insured by the State against accidents, old age, and death. The guardians and the frontier guards all keep diaries and render reports at regular intervals. In this way a great deal of scientific information is collected which assists the authorities in research work and improvements. Due to the vigilance of the guardians, poaching is each year becoming less and cases of visitors willfully breaking the park laws less frequent.

CLIMATE

The park is noted for its exceptional dryness and its extreme continental climate. The region has been called the Swiss Tibet. In 1924 it enjoyed 1,040 hours of sunshine, the average cloudiness not exceeding 40 per cent of the sky, and entirely cloudy days were rare. The temperature varies about 20° C. between midwinter and midsummer. The reason for its dry and sunny climate is that it is a highland shut off by higher mountains, the northwestern Alps almost exhausting the rain-bringing winds from the west before they reach it.

There are three meteorological stations in the national park (at Scarl, Buffalora, and Cluoza) which are all fitted with self-registering apparatus such as thermographs, maximum and minimum thermometers, and totalizers.

HISTORY

The Swiss National Park was actually founded in 1914, but years before, the idea that such an institution was desirable had been agitated by many lovers of nature. At the end of the last century Switzerland, like many other countries, began to give expression to its love for its natural beauties and its traditions. During the first decade of the present century this feeling grew, and it became evident that the natural treasures of the country must be protected in some way. Agricultural exploitation, the invasion of tourists, the mania for collecting specimens, the growing passion for hunting, were recognized by the Helvetic Society of Natural Sciences as being a great menace to the flora and fauna of the country. In 1906 this society formed a special commission for the protection of nature, which aimed at preventing destruction wherever it might threaten and preserving those natural monuments which represented scientific interest. This commission became most active, it formed cantonal subcommissions, acquired all kinds of natural monuments and got the cantons to enforce legislation for the protection of the flora. However, success was only partial, and it was seen that in spite of much enthusiasm and propaganda it would be necessary to create large inclosures where natural beauties would be absolutely protected. To Doctor Coaz, General Inspector of Forests, must be given the credit for first having suggested the district where the national park is now located. In 1905 he published an article describing his visit to Val Scarl, some three years before, in which he depicts the wild beauty of Val Cluoza, the former home of bears. The Cluoza and Scarl Valleys were the last places in Switzerland in which bears had been seen, and Doctor Coaz believed that through their disappearance the country had lost a certain trait and tradition. He thought that the region should be made into a refuge for bears and local proprietors indemnified for whatever damage they might do.

The Society of Physics and Natural History of Geneva succeeded in interesting the Federal authorities in the idea of natural inclosures. In a note addressed to the Federal Council in 1907 it protested against the construction of a railroad up the Matterhorn and added that Switzerland should follow the example of the United States of America and shut off inclosures of geographical and geological interest for the free play of nature undisturbed by man. The Federal authorities showed themselves disposed to favor the idea, and in a general conference which followed between the various societies the appropriateness of the Fuorn region was again pointed out. During the summer of 1908 two members of the Helvetic Society of Natural Sciences set out to explore the district. They returned most enthusiastic over the beauties of Val Mingèr, the richness of the fauna of these districts, the old forests, and the diversity of the flora. They came to the conclusion that an inclosure taking in the districts of Scarl and Quatervals, joined by the high plateau of Fuorn, would constitute an ideal national park. Doctor S. Brunies wrote an article showing the interest of the Cluoza Valley from a geological, meteorological, botanical, and zoological point of view, describing the isolation of this part of the country and its wild grandeur. He pointed out that the commune of Zernez viewed the park idea favorably. It was then that the Commission for the Protection of Nature definitely chose this territory. After some negotiations Val Cluoza was at last obtained as an inclosure for 25 years to date from December 1, 1909, the commune forfeiting the right of exploiting this valley in any way in return for an annual indemnity. Thus the National Park was founded. In 1910 the Tantermozza Valley was added; in 1911 the lateral valleys of Trupchum, Mela and Muschauns, the left side of the Scarl Valley, and the valleys of Mingèr and Tavru. In each case contracts were made with the respective communes by which a certain annual indemnity was to be paid and reserving the right of transfer to the Confederation.

The Commission for the Protection of Nature found itself thus faced with heavy financial responsibilities, and therefore an auxiliary society was formed toward the end of 1908, the membership of which cost 20 francs per annum and was open to all. It took the name of the Swiss League for the Protection of Nature and inaugurated an extensive educational campaign. The membership rose year by year, and the League was able to meet the expenses of the park. But, meanwhile, the commune of Zernez offered to give up the districts of Praspöl, Schera, Fuorn, and Stavelchod in return for an annual indemnity. The League not having sufficient funds in 1911, put the matter before the Federal Council and asked for a yearly subsidy of 30,000 francs. The Federal Council sent two of its members to inspect the country reserved. They returned with a favorable impression, but suggested that if the park were only to last for 25 years it would not have much value as an institution, and that the League should attempt to get the communes to extend their contracts for 99 years. In spite of numerous efforts all the communes but Zernez refused. In 1912 the Federal Council appointed two commissions to study the question. They visited the park and made a number of recommendations regarding its administration and finances.

In December, 1913, a contract was signed between the Confederation, the Helvetic Society of Natural Sciences, and the League for the Protection of Nature, by which the Confederation would pay a subsidy of 30,000 francs per annum, the park would be administrated by a Federal commission made up of members of the three contracting parties, the use of the park for scientific ends was to be organized by the Helvetic Society, the Swiss League was to furnish the finances as laid down by its statutes, and the control of the park was to be under the care of the Federal Council.

At last the efforts of the nature enthusiasts were crowned with success. The project was brought before the National Council (Parliament), a brilliant report in support was read which closed with the wish that the park should add another feature to the beloved face of the home country. It is true that in the discussion that followed one or two dissenting voices were heard, particularly from a member of Parliament for Glarus, who feared that the district inclosed would become the haunt of beasts and birds of prey which would be a danger to the surrounding country. He even pretended to suspect the Austrians of taking advantage of the situation and sending over all the bears, wolves and other terrible animals which infest their country. An enterprising legislator thought that the park could be made to serve as a means of national defense by using the wild animals against anyone who dared to violate the neutrality of the eastern frontier, and thus a national saving on the score of military defence could be made. The project was eventually adopted by 107 votes to 13. The law was passed on April 3, 1914, and came into force on August 1, 1914, and thus the park became a permanent national institution.

Since this date most of the territory making up the national park has been conceded to the Confederation on interminable leases or sold outright to it. But parts of the Val Scarl and Val Plavna still remain under a 25 years' lease, and in spite of negotiations it has been impossible to come to terms with the various communes or to extend the park to the banks of the Inn.

FLORA

Due to its position and varying altitude, the park region possesses a rich flora, ranging from valley to snow line and including both eastern and western Alpine species. Many of the rarest plants of Switzerland are found only in this district. The greater part of the park lies within the sub-Alpine pine forest line. The dark heavy cloak of the tall black forests of the Engadine covers the shoulders of the mountains up to a height of 2,300 meters (Val Scarl). Parts have still a rather primeval aspect. Here are found in abundance the fir (*Abies alba*), the yew (*Taxus baccata*), and savin (*Juniperus sabina*). The slopes of the high valleys between Scanfs and Schuls are thick with spruce (*Picea excelsa*), which ascends to an altitude of about 2,000 meters and then is replaced by the cembra pine (*Pinus *cembra*) and larch (*Larix decidua*). The middle and upper Fuorn region is covered principally with mountain pines (*Pinus montana*), which form the largest intact forest of the upright arborescent species in the whole of Switzerland. The decumbent species, the Scotch pine (*Pinus silvestris*), which grows up to an altitude of 2,400 meters, constitutes almost impenetrable thickets in Cluoza, Praspöl, and particularly on the slopes of the Pisoc group (Val Mingér). Next to the common forest pine (*Pinus silvestris*), the characteristic tree of the dry central Alpine region is the Engadine pine (*Pinus silvestris* L. var. *engadinensis* Heer). The larch (*Larix decidua*), the typical tree of the upper Engadine, grows all over the park region, and here and there forms thick clumps. The grandfather of this family, said to be at least 400 years old, was unfortunately crushed by a falling rock in 1924. The upper forest line, which in this region extends higher than in other parts of the Alps, consists chiefly of larch and of cembra pine, the noblest tree of the Alps. Only isolated specimens of this pine are found on the lower slopes, but it flourishes in the high altitudes, producing particularly fine cones; it is found most profusely in Val Scarl. These giants of the forest, growing on the upper slopes of the rugged peaks, are often hard pressed in the fight against the elements. The "Battle Zone," strewn with fallen trees struck down by lightning, avalanches, and frosts, is an impressive sight.

The unparalleled richness of the Alpine flowers, which are at the height of their beauty during the last half of June, lends a fairy-like charm to this wild region. Above the brightly colored army of spear violets (*Viola calcarata*), the vivid blue of the gentian (*Gentiana*), the fiery red of the catchfly (*Silene acaulis*), the striking purple saxifrage (*Saxifraga oppositifolia*), the white and gold Pyrenean and Alpine buttercups (*Ranunculus*), the golden hawkweed (*Hieracium*), the graceful panicles of grasses and rushes, appears the wonderful star of the edelweiss (*Leontopodium alpinum*), elsewhere so rare. Early in April, as soon as the snow clears away, the sunny spots on the lower slopes are covered with *Aster alpinus*, *Anemone vernalis*, and *Crocus vernus*.

Delicate flowers such as *Linaria alpina*, *Cerastium*, *Valeriana supina*, and the bright golden-yellow Alpine poppy (*Papaver rhaeticum*) grow in the crevasses and gorges. Even the high slopes do not lack a decoration of flowers. Besides the famous Alpine roses (*Rhododendron ferrugineum*) and other flowering shrubs are found *Androsace helvetica*, primroses (*Primula*), and stonecrop (*Sedum acre*). Owing, however, to the dryness of the region and to the changing temperature, Alpine roses, lilies, and anemones are not found in such thick carpets as in other parts of the Alps.

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From time to time new plants and flowers are discovered in the National Park, the most recent being *Draba ladina*, previously unknown to botanists. It is a yellow-flowered plant of the mustard family.

FAUNA

Years ago this part of the Alps was the home of the wolf, lynx, bear, and lammergeier, but the ever advancing tide of civilization has now forced them to flee to wilder regions. The last lynx was shot in the neighborhood of the National Park in 1872 and the last bear in 1904. In August, 1919, a bear with two young ones was seen near the National Park, but no later appearance of these animals has been recorded. The lammergeier became extinct in the Alps during the last century. The park is now the haunt of less fearful animals. On the grassy slopes feed herds of graceful stags, deer, and chamois; eagles circle majestically over the forests, dividing their prey with hordes of foxes, marmots, and weasels.

The park commission has made great progress with the repopulation of the region with some of its native fauna. Particular interest is taken in the colony of ibex which was started in 1920 and now counts 12 members. They have quite returned to their wild state and live chiefly around Piz Terza. The ibex figured in the history of Graubünden for centuries and appears on ancient coats of arms of that canton.

The following table shows the gradual increase of animals and birds in the park since 1918 when the first census was taken:

Year	Stags	Roe deer	Chamois	Foxes	Black grouse	Small grouse	Ptarmigans	Eagles
1918	12	60	1,100	----------	10	40	120	----------
1919	20	80	1,100	----------	6	60	130	----------
1920	20	90	1,130	----------	15	65	135	----------
1921	25	90	1,160	15	3	60	180	15
1922	60	170	1,000	65	40	200	310	15
1923	80	140	1,150	70	38	180	350	10
1924	70	150	1,150	85	50	170	310	25
1925	95	190	1,230	90	60	190	310	40

The census for 1925 in the various districts was as follows:

	Ibex	Stags	Roe deer	Chamois	Marmots	Foxes	Black grouse	Small grouse	Red partridges	Ptarmigans	Hazel grouse	Eagles
Trupchum-Tantermozza	------	35	65	460	120	35	30	35	4	130	------	12
Cluoza-Praspöl	12	45	55	400	114	15	23	80	18	65	15	10
Fuorn	------	15	45	160	70	25	7	25	------	50	------	5
Scarl	------	1	30	210	35	15	3	50	------	70	6	13
Total in 1925	12	96	195	1,230	339	90	63	190	22	315	21	40
Total in 1924	12	70	151	1,144	358	69	49	169	29	317	20	20

The figures given above are taken from the guardians' annual reports.

GEOLOGICAL CHARACTERISTICS

The National Park region presents an entirely different rock formation from that of the other Swiss and French Alps; it is more nearly related to the Austrian Alps, and it has therefore been named Austro-Alpine or eastern Alpine. The eastern Alpine range forms a mighty wall from south to north. It is this that makes the section between Scarl and Tarasp so beautiful; with the soft, gently undulating slate mountains in the north and to the south the sharp ridges of the eastern Alpine Dolomites.

Val Cluoza, the first acquisition of the National Park Commission, rises with forbidding blackness against the lighter Dolomites. It towers in baffling uniformity above the isolated valleys; its débris chokes the murmur of the streams; its cheerless desolation and oppressive silence is scarcely relieved by the glittering snow peaks of its background; and its very mouth is blocked with wild gorges, making a picture which can scarcely be found elsewhere in the Alps.

These mountains are comparatively young, belonging to the middle tertiary period. Dolomite is the ruling formation. Grotesque points, broken ridges, and unending slopes of débris make up the greater part of the lofty peaks. These belong to the Trias formation and are called principal dolomites. Another dolomite series is distinguished by beds of lime, colored slate, sandstone, and gypsum, called the Raibler stratum. An older Trias dolomite, the belemnite, is also found in this region, and under it lies another dolomite lime series, shell limestone. Shell limestone, belemnite, and Raibler stratum form the peaks of the Astras and Starlez group as well as the range which stretches from Piz Daint, Munt da Buffalora to Munt la Schera. On the principal dolomites lies still a younger Trias stratum, the Rhaetian.

The region is particularly rich in petrescent stones and fossils. Between Piz Murter and Piz Terza are found hundreds of graceful pieces of coral (Lithodendren) and small round brachipods (*Terebratula greparia*).

Sediment of the younger Jura formation is found in the south. It is dark limestone and slate of the Lias formation and is also rich in fossils (belemnite and ammonite). In Val Trupchum lies a vein of still younger minerals, red, green, and white hornstone.

Colored sandstone and Verrucano (green and red quartz and slate) are chiefly found on the south side of Ova del Fuorn, in Val Mustair and in Scarl, while gneiss appears in the upper Val Mustair and granite in the upper Val Scarl and in the Sessvena group.

SWISS NATIONAL PARK, VAL CLUOZZA WITH PIZ QUATER-VALS (10,396 FEET).

Photograph by J. Feuerstein, Schuls

SWISS NATIONAL PARK, PIZ PLAVNA DADAINT FROM SUR IL FOSS

Photograph by J. Feuerstein, Schuls

1. HERD OF CHAMOIS

Photograph by Engadine Press Co., Samaden

2. MARMOTS

Photograph by Atelier Flury, O. Lochan, Pontresima

CASTLE OF TARASP IN THE LOWER ENGADINE

Photograph by J. Feuerstein, Schuls

SWISS NATIONAL PARK, VAL CLUOZZA AND PIZ QUATER-VALS

Photograph by Albert Steiner, St. Moritz

SAMUEL SLATER AND THE OLDEST COTTON MACHINERY IN AMERICA

By Frederick L. Lewton
Curator of Textiles, U. S. National Museum

[With 3 plates.]

According to the census of 1920, there were in 1919, 33,718,933 cotton spindles at work in the United States; yet it was only 136 years ago that all the cotton yarn made in this country was spun by hand. The building of the first cotton spinning machinery in America and the starting of the first cotton mill in 1790, marked the foundation of one of America's greatest industries. Many persons will be surpised to learn that part of the machinery of that first cotton mill is still in existence preserved in the collections of the United States National Museum. This cotton machinery, the progenitor of the millions of spindles whose daily revolutions convert the greater part of our cotton crop into yarn for thread and cloth making, was for many years lost and forgotten and was only recently brought out of its hiding place and placed on public view.

The account of the building of America's first cotton machinery reads like a romance, and although parts of the story have been told before, the books containing them are now out of print and are not available to the general reader.

The machines now in the National Museum, a carding engine and a spinning frame of 48 spindles, are two of the five machines built by Samuel Slater and started in operation by him on December 20, 1790, with power obtained from the old fulling mill water wheel in Ezekiel Carpenter's clothier shop on the east bank of the Blackstone River at the southeast abutment of Pawtucket Bridge. Slater's three cards and two spinning frames were operated for nearly two years in the old clothier shop, during which time several thousand pounds of yarn accumulated for which there seemed to be no demand, so small a quantity in those days sufficed to supply the market. Although every exertion had been made to weave it up and sell it, the market was glutted and the machinery was stopped for some months.

Upon starting the machinery in 1790, Mr. Slater set four persons at work in his " mill ": Arnold and Charles Torpen, Smith Wilkinson, and Jabez Jenks. The following week four more were em-employed—Ennise Torpen, John and Varnes Jenks, and Otis Borrows. The third week Ann Torpen commenced working in the cotton factory, and the fourth week the same nine were employed. Thus during the first month of cotton manufacture in America by means of machinery, the entire business was carried on by Samuel Slater and nine assistants, nearly all of whom were young children.

SLATER'S FIRST MILL

Early in the year 1793, Slater and his partners, Obadiah Brown and William Almy, built a new mill especially designed for the cotton business. The three cards and two spinning frames, containing together a total of 72 spindles, were removed thereto and set in motion on July 12, 1793. This was the first cotton mill on the American Continent in which all the processes of the improved Arkwright cotton-spinning and preparatory machinery were carried on under one roof. More spindles were added as the sales of yarn increased. This factory, which has been known for many years as the "Old Slater Mill," still stands in Pawtucket and is to be preserved as a textile museum. Several times the building has been enlarged in height, width, and length, but the original timbers and frame form part of the existing building. The spinning, bleaching, dyeing, and finishing of cotton yarns and cloth were likely all carried on in this building, but the weaving was done in private houses on hand looms, the cloth being returned to the factory to be dyed or finished.

SLATER'S SECOND MILL

In company with his father-in-law, Oziel Wilkinson, William Wilkinson, and Timothy Greene, son and son-in-law of Oziel Wilkinson, Mr. Slater formed the firm of Samuel Slater & Co. in 1798, in which he held a half interest. The erection of a mill was soon after begun on the east side of the river almost opposite the first factory, but the machinery was not started until some time in 1801. This was the first spinning mill in Massachusetts that operated successfully the Arkwright type of machinery; consequently to Slater belongs the credit of starting the first mills in both Rhode Island and Massachusetts.

Slater was superintendent of both mills, and received in each case $1.50 per day for his services, making his wages $3. He attended strictly to his business, and it is said that for 20 years he labored 16 hours daily. In 1810 Slater sold out his interest in this factory, which was commonly known as the White Mill, to the other partners, who conducted the business in the name of Wilkinson, Greene & Co. The mill was burned in 1824 but was rebuilt by Timothy Greene & Sons.

SLATER'S THIRD MILL

John Slater, a brother of Samuel, arrived from England in 1803, bringing with him a knowledge of the spinning mule invented by Crompton. In 1805 a new enterprise was planned, Almy, Brown, and the two Slaters each taking a fourth interest, and during 1806 the erection of a mill was begun in the northern part of Rhode Island on the South Branch of the Blackstone River. The mill was finished and began operations in 1807, John Slater being superintendent. This was the beginning of the village of Slatersville. John Slater eventually bought out all the other partners, and the mills and village were passed on to his grandson, John W. Slater.

SLATER'S FOURTH MILL

In 1811, in company with a young man named Bela Tiffany, who had been in his employ a number of years, Samuel Slater started a cotton factory at Oxford, Mass., a part of which village is now known as Webster, about 35 miles northwest from Providence, R. I. An excellent water power was furnished by the French River and several ponds. At first the business was conducted under the name of Slater & Tiffany, but it soon came wholly into the possession of Samuel Slater, and ultimately was carried on in the name of Samuel Slater & Sons. The property in 1817 consisted of one cotton factory of 2,000 spindles, a woolen mill, a grist and saw mill, 16 dwelling houses, and 700 acres of land.

In 1822 with Willard Sayles and Lyman Tiffany of Boston, Oliver Dean of Franklin, and Pitcher & Gay of Pawtucket, Slater formed a company, and purchased an estate consisting of a small cotton mill, several tenements, and a fine water-privilege at Amoskeag Falls, on the Merrimack River. This was the foundation of the well-known Amoskeag Manufacturing Co., and the real beginning of the great manufacturing city of Manchester, N. H.

The War of 1812, by shutting out foreign goods, gave a great impetus to domestic manufacture, and as Samuel Slater had all his various enterprises well under way, he was enabled to reap great advantage. Cotton cloth sold at 40 cents a yard, and the demand was unlimited. Besides the interests which he possessed in the mills already mentioned, he invested capital in woolen and iron manufacture, and other lines of business.

According to a memorial presented to the United States Congress, there were reported to be at the close of the year 1815, 99 cotton mills in Rhode Island, with 75,678 spindles; in Massachusetts, 57 mills with 45,650 spindles; and in Connecticut, 14 mills with 12,886 spindles; making a total of 170 mills operating 134,214 spindles. The average capacity of cotton mills at that time was only 500 spindles.

The "Old Slater Mill" at Pawtucket, was up to this time the largest in the country, and contained 5,170 spindles. President Monroe visited Providence in 1817, and was escorted by a committee to see the old mill in Pawtucket. Here he was received by Mr. Slater and shown the first spinning frames which had been running 27 years. The Slater machinery was also viewed by President Jackson, who visited Pawtucket during his first term of office. Slater was at that time laid up with rheumatism, the result of exposure in starting the water-wheel of his first machinery during the severe New England winters. After watching the machinery, President Jackson called at Slater's home to show his respect to the man whom he called "The father of American manufactures." The following conversation is said to have occurred between the two: "I understand," said the President, "you taught us how to spin so as to rival Great Britain in her manufactures; you set all these thousands of spindles to work, which I have been delighted in viewing, and you have made so many happy by a lucrative employment." "Yes, sir," said Slater, "I suppose that I gave out the psalm, and they have been singing the tune ever since."

In 1827, Slater and his sons started a mill in Providence, R. I., containing 7,000 or 8,000 spindles, and operated it with a steam engine. This was the first mill of its kind in the State and one of the first in the country, and it was very commonly known as the "steam mill" until recently.

During the great business depression of 1829, Samuel Slater sold to William Almy his one-third interest in the "Old Mill," owned by Obadiah Brown, Almy, and Slater, and gave his attention to the "Steam Mill," which was known as the Providence Steam Cotton Manufacturing Co. This mill proved to be very successful, and after 1830 experienced judges said that it produced the finest goods in the country.

During his later years, Samuel Slater spent the greater part of his time at Webster, Mass., where his fourth mill was started, and where he died on April 21, 1835, in his 67th year. Through his influence three villages that had grown up from his enterprise, together with some territory from the towns of Dudley and Oxford, were in 1832 incorporated as the town of Webster, and named after Daniel Webster. Webster still interests the Slater family, as H. N. Slater, a grandson of Samuel, is president of the corporation now operating over 82,000 cotton spindles in the place.

Just how long the carding and spinning machinery built in 1790 and left in the "Old Mill" were kept running seems not to have been recorded, but George White, a friend of Slater's, wrote just after the death of his friend in 1835, that the machines were still in the old mill and were shown to visitors as curiosities. They were probably soon after relegated to the upper part of the old mill, where they lay unused and forgotten for nearly 20 years.

In 1856, Dr. Samuel Boyd Tobey, the executor for the heirs of Moses Brown and of Obadiah Brown and William Almy, his son and son-in-law, deposited a cotton-carding machine and a spinning frame of 48 spindles with the Rhode Island Society for the Encouragement of Domestic Industry, then occupying a building in Providence known as Railroad Hall. The report of the society for the year 1856 records the fact.

At the request of the Rhode Island Society, Doctor Tobey prepared for its records a certificate of authenticity for the Slater spinning frame and cotton card which he had deposited earlier with the society. The following is an exact copy of the wording of the certificate:

History of the Old Card and Water Frame Presented to the Rhode Island Society for the Encouragement of Domestic Industry.

Samuel Slater arrived in New York in January, 1790. On the 18th of the same month he went to Pawtucket and commenced building the first machinery for the "Old Spinning Mill," and started the same in a clothier's shop by the power of the Fulling Mill wheel, December 20, 1790, viz.:

Three carding machines.
Drawing and roving machines.
One water frame, 24 spindles.
One water frame, 48 spindles.

Where they run for about 20 months and overstocked the "Domestic Goods" market, several thousand pounds of yarn having accumulated in that time, notwithstanding the most active exertions on the part of the proprietors to dispose of the product, both in yarns and in cloth woven by hand.

The spinning frame of 24 spindles was the first experimental machine, and consequently imperfect, and taken from the Mill to give place to machines of more perfect construction.

In 1793 William Almy, Obadiah M. Brown and Samuel Slater, under the firm of Almy, Brown and Slater, built a small factory, the center portion of the "Old Spinning Mill," into which the above-mentioned machinery was removed and put in operation on the 12th day of July of the same year.

One of the carding machines and the 48-spindle water frame mentioned above were presented as above by the heirs of Moses Brown, William Almy and Obadiah M. Brown, and now stand in state in the rooms of the society.

Moses Brown was the foster father of the whole enterprise. Almy, Brown and Slater were the owners and recipients of the benefits arising therefrom.

Samuel Boyd Tobey,
Trustee and attorney of heirs aforesaid.

Providence, 9th Month, 11th, 1856.

Note: The above facts are chiefly derived from a memo. by Samuel Slater to the R. I. Hist. Society.

W. J. H.

At the time of the Philadelphia International Exhibition in 1876, better known as the Centennial, the old Slater cotton machinery was exhibited in Machinery Hall by the Providence Machine Co., a corporation which had been started in 1834 by Samuel Slater, in partnership with Thomas J. Hill, to build cotton machinery.

The Rhode Island Society for the Encouragement of Domestic Industry moved its headquarters several times during the next 25 years and evidently found the care of the old machines to be something of a burden, for in 1880 the Slater machinery was presented to the Brown University Museum. A few years later Prof. Jeremiah W. P. Jenks, of the university, "believing that these valuable instruments marking the beginning of cotton manufacure in America should not be immured in a dungeon," as he described the damp basement room where the machines were stored, suggested the deposition by the society of these relics in the National Museum at Washington. After about a year of negotiation with the society, Professor Jenks succeeded in having a vote passed at the annual meeting in January, 1883, that "The progenitor of all the cotton machinery in the country" be presented to the National Museum at Washington.

In due time the machinery was packed and sent to the Museum by the water route via Norfolk, the Rhode Island Society sending at the same time a complete set of implements used in the preparation and spinning of flax. It was hoped that the old machines had at last found a resting place, but they were fated to do some more traveling as later paragraphs will show.

The Slater machines were loaned by the Smithsonian Institution to the State of Rhode Island for exhibition as part of that State's display at the World's Industrial and Cotton Centennial Exposition in New Orleans during the winter of 1884–85. The machines were returned to the National Museum in March, 1885, but were only allowed a few years' rest for in 1890 their travels began again, this time back to their point of origin. In the meantime, on date of July 23, 1888, the National Museum received from J. Erastus Lester, of the Rhode Island Society, the original certificate of authenticity of the Slater machines signed by Samuel Boyd Tobey, which was needed to make the exhibit complete and which had been lost for many years.

In 1890 Senator Nelson Aldrich of Rhode Island, requested the loan of the Slater machines for the Cotton Centenary, a celebration by the City of Pawtucket of the one hundredth anniversary of the beginning of cotton spinning by power machinery on the Western Hemisphere, and on August 5, 1890, the National Museum shipped them to Albert R. Sherman, superintendent of exhibits. The directors of the industrial exhibition were anxious to have the Slater spinning frame actually spin cotton yarn as it had begun to do 100 years before, so the ancient machine was taken to be put in running order to "Brown's Machine Shop" at the corner of Main and Pine Streets, where Sylvanus Brown, the grandfather of the proprietor, had under the direction of Samuel Slater made the original patterns for the old machine.

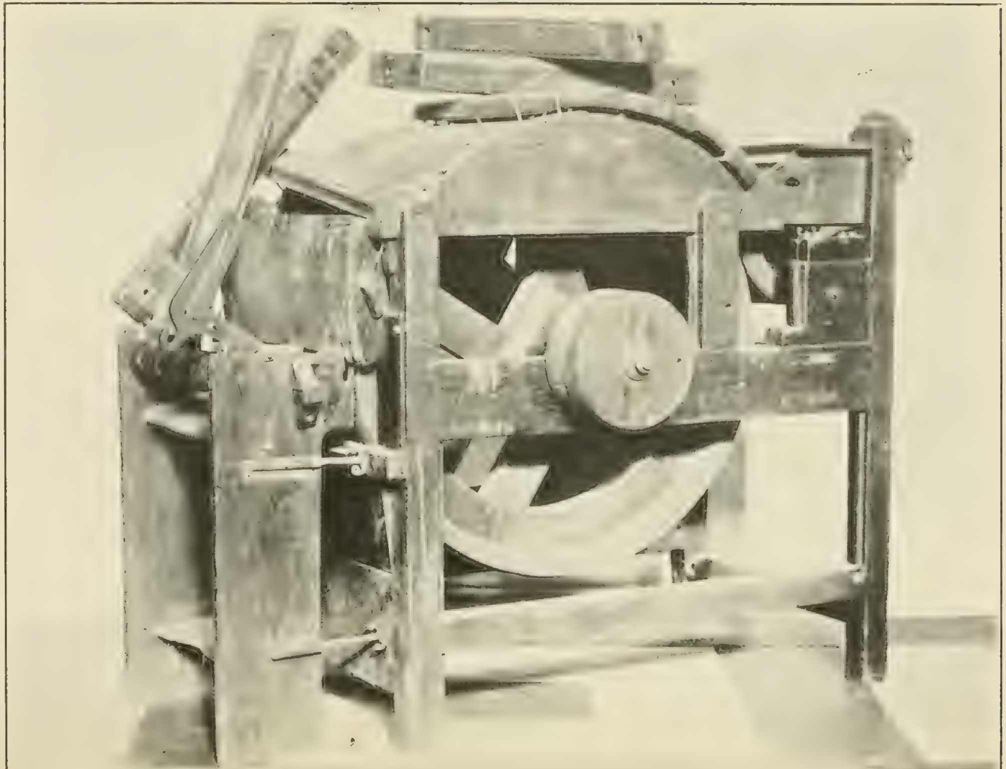
Within Centenary Hall was erected a pavilion called the Slater Pavilion, within which were displayed a large number of articles formerly belonging to Slater and his family. In one room, over the entrance to which was a sign reading "Almy, Slater & Brown," there was arranged a tableau, showing at opposite sides of a table, impersonations of "Uncle Sam" and Samuel Slater, the latter seated in a chair with different kinds of yarn before him. Uncle Sam was congratulating Slater on his success, and there were shown in this room the finest cotton goods made, produced in mills which had been started by Samuel Slater. Two objects, however, were the source of constant attention; these were the old card and the spinning frame built by Slater and loaned by the National Museum, the card by the side of a modern card, and the spinning frame by the side of the most recent machine built to do the same kind of work. The old spinning frame was put into operation and produced as good yarn as could be made by the most modern machines. As evidence of the intense interest taken by visitors to the Cotton Centenary in this achievement, the local papers recorded the sale of the first skein of 5 ounces of yarn spun by the revived old spinning frame at the price of $5. It is greatly to be regretted that interest of another kind by souvenir hunters robbed the machine of many of its parts so that by the time the Slater frame was returned to its home in the National Museum it had been robbed of nearly half its spindles and bobbins.

Owing to various circumstances, the extensive textile collections in the United States National Museum were put in storage in 1890, the old spinning frame being stored away in the crate as it was returned from the Pawtucket Cotton Centenary.

Soon after the reestablishment of the Division of Textiles of the National Museum in 1912, the writer discovered the precious relic and restored it to its deserved place in the Textile Hall. Doctor Tobey's original certificate of authenticity had been filed away when the Slater machines were sent to Pawtucket, and this precious document was not found until 35 years later.

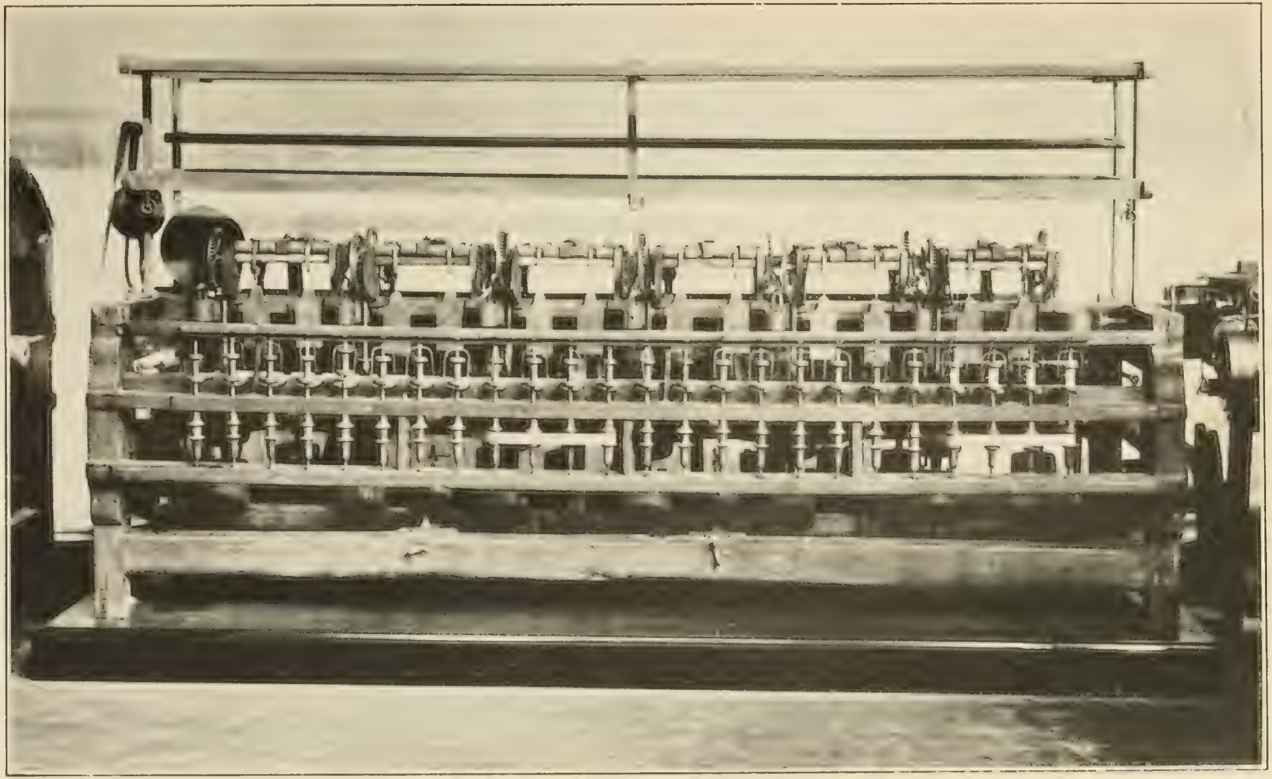
SAMUEL SLATER

Builder of the first cotton-spinning frame in America, constructed on the Arkwright system of spinning. Pawtucket, R. I., 1790



COTTON-CARDING MACHINE

Built by Samuel Slater in 1790



COTTON-SPINNING FRAME

Built by Samuel Slater at Pawtucket, R. I., 1790

PREVENTIVE MEDICINE [1]

By Mark F. Boyd, M. D.

Preventive medicine may be defined as that branch of applied biology which seeks to reduce or eradicate disease by removing or altering the responsible etiological factors. Included within its scope are two subjects which are often confused with it; these are hygiene and sanitation, respectively. Hygiene is the proper care of the body to permit the normal functioning of the various organs and tissues, while sanitation is the proper cleanliness of the environment.

Since preventive medicine requires a complete knowledge of the etiology of disease for its application, it is apparent that deficiencies of etiologic knowledge must necessarily limit the scope of successful work. There are, however, five groups of disease whose etiology is sufficiently well known to warrant their classification as preventable. The groups are:

1. Diseases produced as the result of the invasion of the body by microorganisms;
2. Diseases the result of a faulty or deficient diet;
3. Diseases the result of unhygienic or insanitary conditions of employment;
4. Diseases arising as the result of the puerperal state; and
5. Diseases transmitted from parent to offspring.

Despite the fact that the number of diseases included in the above groups is limited, this handicap is very much reduced by the fact that the diseases included in the above groups are for the most part of considerable importance as causes of morbidity and mortality, so that effective control measures directed against them will accomplish a great deal in reducing the hazards of life. Their importance may be judged from the following mortality statistics from the registration area of the United States:

Table I

	1912	1913
Per cent of total population of United States in registration area	63.2	65.1
Total deaths, all causes	838,251	890,848
Deaths, disease of Group 1	287,645	304,580
Deaths, disease of Group 2	4,409	15,005
Deaths, disease of Group 3	156	171
Deaths, disease of Group 4	9,035	10,010
Death, disease of Group 5	Not a direct cause of death.	

[1] This article forms Chapter I, Introduction, of the book entitled "Preventive Medicine," by Mark F. Boyd, M. D., published by W. B. Saunders Company, Philadelphia and London, and is here reprinted with their permission.

While the diseases of Group 5 are not of importance as causes of mortality, they nevertheless exert a certain definite influence which we will consider later.

Directly as well as indirectly these diseases are the cause of immense economic losses. These affect both the individual and the social fabric. The following economic losses may be enumerated:

(*a*) Temporary or permanent disablement of the patient as an immediate result of the disease, resulting to the individual in temporary or permanent loss of earning power, and to society in the loss of productive labor;

(*b*) Sequelæ or complications which permanently impair the individual's usefulness or hasten death from other causes;

(*c*) Expenses of illness, which if due to preventable illness, must be regarded as an economic loss;

(*d*) The expense incident to the establishment and maintenance of public hospitals, asylums, and charitable agencies to relieve want arising from disabling sickness;

(*e*) Making vast regions of the earth's surface uninhabitable for the civilized races; while

(*f*) Preventable diseases of the domesticated food poisoning animals may cause such inroads into their numbers that animal foods become scarce and consequently high in price. This is due both to a destruction of the animal as well as to a decreased productiveness of those surviving.

With most of the diseases included in the foregoing groups our available knowledge is sufficiently adequate to justify us in classifying them as preventable. Their continued presence with us is chiefly due to the lack of ways and means for placing effective control measures in operation. It may never be practicable to place in operation in civil life the drastic, but nevertheless effective measures which have made the military application of preventive medicine so brilliant, though the experience with military discipline emphasizes the administrative difficulties which are encountered in the civil application of these measures, where tact rather than force must win the point. Conceiving a population wherein an adequately organized defensive and offensive body was available to apply proper measures, we might expect that their continued application would have certain effects. Among these we may prophesy the following:

(*a*) An increase in the period of expectation of life, that is the probable duration of the life of the hypothetical average individual. This change will be accompanied by the following phenomena: (1) There will first be a gradual diminution in the total death rate, due to the gradual disappearance of the preventable diseases as causes of mortality. (2) A change in the age distribution of the deaths will next be apparent. The majority of the conditions we are considering are most active as causes of death among the ages below 30. Their elimination will, of course, permit a larger proportion of individuals to survive to ages beyond 30, and as the change takes place the number of deaths above 30 will slowly increase, proportionate to the decrease in the deaths below 30. (3) The conditions which are operative as causes of death at the age periods beyond 30 other than those of our particular groups will gradually be found to be responsible for an increasingly greater number of deaths. This state of affairs is not necessarily alarming, but rather is encouraging, as indicating that a larger proportion of individuals are permitted to survive to middle life and older periods. This is in our opinion, the most rational explanation of the increases which have been observed in the mortality from carcinoma and cardio-renal disease. The completion of this cycle of transformation will probably leave us with a crude death rate from all causes very nearly the same as before the days of even the most feeble preventive work. The important difference will be in the age distribution of the deaths. Instead of the many dying young, the majority will survive to middle life or old age. The individual will have a better chance of living what may be said to be a life of "normal" duration.

New York City furnishes us with a concrete example of the influence that improved hygiene and sanitation exerts in prolonging human life. In 1882 Dr. J. S. Billings prepared a life table for New York City based upon the mortality experience for the years 1879, 1880, and 1881. At that time a male child five years of age could expect to live 39.7 years longer, and a female child 42.8 years longer. In 1913 a similar table was prepared based upon the experience of the years 1909, 1910, and 1911. Males at the age of five have an expectation of 50.1 further years of life, and females an expectation of 53.8 years. Thus in this period of 30 years the expectation of life for males at the age of five years has increased by 10.4 years and that of females by 11 years. The life tables referred to are reproduced in Table II. This increase in the expectation of life is observed at all ages up to 35, while at all ages above 43 is a constantly increasing diminution in the duration of life. This change in the expectation of life in New York is justly referable to improved hygiene and sanitation, as New York City was one of the first cities in the country to organize an efficient health department, which has since been maintained on a high plane of efficiency.

(*b*) Unhealthful regions of the earth will be made habitable, consequently human overcrowding will be relieved, and more of the earth's treasures will be available for mankind.

TABLE II.—*Approximate life tables for the city of New York based on the mortality returns for the triennia 1879 to 1881 and 1909 to 1911*

Years of mortality (ages)	Expectation of life, 1879 to 1881			Expectation of life, 1909 to 1911			Gain (+) or loss (−) in years of expectancy		
	Males	Females	Persons	Males	Females	Persons	Males	Females	Persons
−5	39.7	42.8	41.3	50.1	53.8	51.9	+10.4	+11.	+10.6
5	44.9	47.7	46.3	49.4	52.9	51.1	+4.5	+5.2	+4.8
10	42.4	45.3	43.8	45.2	48.7	46.9	+2.8	+3.4	+3.1
15	38.2	41.2	39.7	40.8	44.2	42.5	+2.6	+3.	+2.8
20	34.4	37.3	35.8	36.6	40	38.3	+2.2	+2.7	+2.5
25	31.2	34	32.6	32.7	36	34.3	+1.5	+2	+1.7
30	28.2	31	29.6	28.9	32.1	30.5	+ .7	+1.1	+ .9
35	25.3	28.1	26.7	25.4	28.4	26.9	+ .1	+ .3	+ .2
40	22.5	25.2	23.9	22.1	24.7	23.4	− .4	− .5	− .5
45	19.8	22.4	21.1	18.9	21.1	20	− .9	−1.1	−1.1
50	17.2	19.4	18.3	15.9	17.7	16.8	−1.3	−1.7	−1.5
55	14.5	16.4	15.4	13.2	14.6	13.9	−1.3	−1.8	−1.5
60	12.2	13.8	13	10.8	11.8	11.3	−1.4	−2	−1.7
65	9.9	11.2	10.5	8.8	9.4	9.1	−1.1	−1.8	−1.4
70	8.5	9.3	8.9	6.9	7.5	7.2	−1.6	−1.8	−1.7
75	7.1	7.5	7.3	5.3	5.7	5.5	−1.8	−1.8	−1.8
80	6.2	6.5	6.4	4.1	4.5	4.3	−2.1	−2.0	−2.1
85+	5.4	5.5	5.5	2	2.4	2.2	−3.4	−3.1	−3.3
Balance							+24.8 −15.3 +9.5	+28.7 −17.6 +11.1	+26.6 −16.6 +10

(*c*) The economic productiveness of the individual as well as of the race will be increased. As a consequence individual and national wealth will increase and poverty and want diminish.

(*d*) The supply of animal foods will increase and only be limited by the available roughage.

(*e*) Lastly, we may prophesy an improvement in the general physical condition of the race.

The effective operation of the necessary machinery to apply the etiological knowledge we shall briefly sketch may be said to be the problem. It is one of great difficulty and complexity and its complete solution is far distant. Partial means to control the diseases of Group 1 are, as we shall presently see, of considerable antiquity, and arose from a recognition that persons infected with communicable diseases were a danger to the public. Thus there developed the field of public health. Originally it arose from a purely selfish attitude on the part of society as a whole to protect itself from certain infected individuals, whose objectionable characteristics arose from no fault of their own. To-day we find a changing attitude, a realization that if society requires protection by enforcing certain restrictive measures on individuals innocent of crime, justice demands that these persons receive consideration. In addition, the field of public health has recently come to have a broader scope, due to the realization that many of our problems, if not all, have a sociological foundation, and that a divorce is not always possible. Relief will only be secured when these associated problems are solved.

In a general way our problem of disease prevention has two aspects, namely curative and prophylactic.

The curative aspect is primarily the problem of the practicing physician and when effectively solved will be manifested by a lowered case mortality. The physician will be assisted in its solution by the development of methods and the provision of facilities for the making of prompt diagnoses and the development and application of specific therapeutic measures. This aspect is clearly a problem of the practicing physician in his relation to the individual requiring his services.

On the other hand the prophylactic aspect can only give satisfactory results when an entire social unit, such as any community, takes cognizance of its problem and attacks it with all the resources at its collective command. For this purpose our social and political units have delegated power and authority to certain officials for the protection of the public health. The problem confronting the officials relates particularly to a reduction in the number of cases of preventable diseases in the population under their care. They are not professionally interested in disease from the individualistic standpoint of the physician. The degree of success achieved by these officials will be directly in proportion to the degree in which they educate their public in the principles they are trying to apply. Without the cooperation of the medical profession and the laity, health authorities will accomplish very little effective work.

In general the field of public health work may be said to have the following scope:

(*a*) Improved personal hygiene of all individuals, including better standards of personal cleanliness, better dietaries, reasonable working hours, recreation, and adequate clothing.

(*b*) Improved standards of domestic and public sanitation, including relief from overcrowding, proper illumination, heating and ventilation, water supply, excreta disposal, etc.

(*c*) Improved sanitation of places of employment.

(*d*) The immunization of susceptible persons and the control of infected persons.

(*e*) The improvement of the breeding stock of the human race by the elimination of the physically and mentally unfit from reproduction.

(*f*) The provision of facilities for aiding physicians in the diagnosis and care of their patients, i. e., laboratories, hospitals, and clinics.

LANDMARKS IN THE DEVELOPMENT OF PREVENTIVE MEDICINE

The only practices of the ancients which we at this day may consider to be preventive measures based upon a firm, rational foundation as we understand the subject, are found described in the Mosaic law. All other practices of the ancients designed to prevent diseases are clearly allied with religion and superstition, and hence were of little importance and no value. Therefore the Mosaic instructions when interpreted in the light of present-day knowledge have an immense importance. These practices, however, do not seem to have been copied by contemporaneous Gentile races.

Aside from the foregoing the earliest public-health practice which has survived to the present day is maritime quarantine, which was developed by the mediæval Italian cities of Venice and Genoa when at the height of their commercial splendor as a protection against the introduction of plague from oriental ports. At this time the ideas of disease transmission were very vague, but a suspicion of the transmissibility of some seems to have existed. A little later, in 1546, Geronimo Fracastorius published in Venice a work entitled "De contagionibus et contagiosis morbis et curatione" in which was first definitely advanced the doctrine of contagion. He divided infections into three classes: (1) Those infecting by immediate contact, (2) those infecting through intermediate agents, such as fomites, and (3) those infecting at a distance or through the air. In 1659, Kircher, and, in 1675, van Leeuwenhoek first observed and described living organisms too small to be seen by the naked eye. Kircher in 1671 suggested that various infections were the result of the activity of these minute organisms. Kircher's views were received with skepticism by his contemporaries, and later, in 1672, Plenciz of Vienna again advanced the same views. These theories, however, did not gain headway until the following century, when they were demonstrated scientifically.

The first attempt at artificial active immunization among European nations must be credited to Lady Mary Wortley Montague, who, from 1717 to 1721, introduced into England from Constantinople the process of variolation as a protection against smallpox. This was an event whose importance has been overshadowed by the employment of an attenuated virus for the same purpose by Jenner. His discovery was first published in 1798.

In 1843, Oliver Wendell Holmes, an American physician and author of note, first called attention to the contagiousness of puerperal fever. The activity of water as a route for the transfer for infective agents was first recognized, in 1854, by Doctor Snow in connection with the famous Broad Street well cholera outbreak. Three years later Doctor Taylor recognized the similar activity of milk in an outbreak of typhoid at Penrith. The first scientific demonstration of the transmissible character of an infectious disease was performed by Villemin with tuberculosis, in 1865, while the first demonstration of the etiological relation of microparasites to disease was accomplished by Pasteur in the case of anthrax in 1876, thus substantiating the earlier beliefs of Kircher and Plenciz. Patrick Manson recognized the first known insect-transmitted disease, when he found that mosquitoes transmit *Filaria bancrofti.*

From the time of Jenner no progress in artificial immunization was made until Pasteur demonstrated the protective power of his anthrax vaccine on sheep in 1881, and in 1885 extended the same principle to the treatment of rabies.

In 1893, Smith and Kilbourne, two Americans, discovered the cause and means of transmission of the first known insect-transmitted protozoal disease, namely Texas fever of cattle.

The importance of carriers in the perpetuation of typhoid fever was first recognized by Robert Koch, who called attention to them in 1902. Carriers of the diphtheria bacillus had been observed before this, but their importance was not recognized.

The results which can accompany the application of the principles of preventive medicine received their first great popular demonstration by Gorgas, when he eradicated yellow fever and malaria from Havana and the Canal Zone. This accomplishment may be considered to mark the beginning of active public interest in the possibilities of preventive medicine, a situation which may be said to characterize the present day.

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WILLIAM BATESON [1]

By T. H. Morgan, *Columbia University*

William Bateson was born in 1861. He was the son of Rev. W. H. Bateson, D. D., master of St. Johns College, Cambridge. After Rugby School, he went to Cambridge, where he took first class honors in both parts of the natural science tripos, receiving his degree in 1882. He was elected to a fellowship in St. Johns.

"Bateson's span of life carried him through one of the most remarkable transition periods in the history of biology. In his earlier Cambridge days he experienced the full effects of the phylogenetic school of descriptive embryology of which Francis Balfour was the recognized leader in the English speaking world. Bateson's three contributions to the embryology of Balanoglossus show how he reacted to these influences." [2] The materials for these studies were collected in this country in 1883.

"He had seen an announcement in the Johns Hopkins University circular that Balanoglossus had been found at the marine station, then situated at Hampton, Va., and wrote to Brooks asking permission to come to the station to work on this rare and extraordinary worm. 'Brooks sent me a cordial invitation to come over and try. Such leave was no little thing to give, for Balanoglossus must have been known to be one of the prizes of the station, but in professional generosity Brooks was royal and lavish.'

"The friendly relation between Brooks and his students that had so much to do with his influence over them was soon established with Bateson. At the time Brooks was absorbed in writing his treatise on heredity. Bateson wrote later (1910): 'For myself, I know it was through Brooks that I first came to realize the problems which for years have been my chief interest and concern. * * * Variation and heredity with us had stood as axioms. For Brooks they were problems. As he talked of them the insistence of these problems became imminent and impressive.'

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[1] This biography is in large part compiled from an article in Science (Vol. LXIII, May 28, 1926); from another in Nature (Vol. 117, Feb. 27, 1926); from the Eagle, St. Johns College (Vol. XLIV, 1926); and from a forthcoming obituary in the proceedings of the Linnean Society.

Proceedings of the Linnean Society.

"That material collected at Hampton and in the following year at Beaufort, N. C., led to papers on the early stages of development and on the morphology of the adult worm. In a later paper on 'The Ancestry of the Chordata' Bateson discussed, in guarded terms, the position of Balanoglossus in relation to the vertebrates, reaching the conclusion that the structural resemblances indicated relationship and that the unsegmented nature of the notochord and central nerve cord indicated that the ancestor was not segmented, and that the repetition seen in the body cavities and gill slits must have had an independent origin. This question of repetition haunted Bateson for the rest of his life. His later conclusion is interesting.

"'The meaning of cases of complex repetition will not be found in the search for an ancestral form which, itself presenting the same character, may be twisted into a representation of its supposed descendant. Such forms there may be, but in finding them the real problem is not even resolved a single stage; for from whence was their repetition derived? The answer to the question can only come in a fuller understanding of the laws of growth and of variation which are as yet merely terms.'

"At the present time—43 years later—this statement may still stand word for word.

"In 1894 appeared 'The Materials for a Study of Variation' which has recently been called Bateson's most important work. Here he brought together a great number of widely scattered cases bearing on discontinuity in variation. It is the particular use that Bateson made of this evidence that is the most interesting feature of the book. He argued that since evidence for discontinuity is to be found everywhere in animals and plants, evolution through natural selection—which he interpreted to mean by the selection of continuous variation—will not account for the origin of species. This relationship of variation to species formation was a problem that interested Bateson intensely. He recurs to it over and over again in his later writings.

"This book on discontinuity in variation appeared six years before de Vries's mutation theory, in which discontinuity in inheritance is the central theme, but Bateson seems never to have become convinced that the discontinuity shown by de Vries's mutants in Oenothera furnishes the sort of evidence for discontinuity which he himself appealed to as supplying the materials for evolution.

"In the preface to 'The Materials' Bateson says, referring to his earlier discussion of the phylogeny of the vertebrates, 'over it all hung the suspicion that the then current morphological arguments and interpretations might not be sound.' In these discussions we are continually stopped by such phrases as 'if such and such a variation then took place and was favorable.' Again, 'the whole argument is based on such assumptions as these—assumptions which, were they found in Paley or Butler, we could not too scornfully ridicule.' Bateson set himself, therefore, the task of collecting and codifying the facts of variation as 'the first duty of the naturalist.' He brought together a great body of evidence from the literature and from this he reached the conclusion that the forms of living things taken at a given moment show a discontinuous series and not a continuous series. He also argued that the forms of living things may be separated into specific groups or species, 'the members of each such group being nearly alike, while they are less like the members of any other group.' Assuming that the doctrine of descent is true in the main because of the difficulty of forming any alternative hypothesis as good, he then examined the theory of natural selection in the light of these conclusions. On the theory of natural selection 'specific diversity of form is consequent upon diversity of environment and diversity of environment is thus the ultimate measure of diversity of specific form.' But 'diverse environments often shade into each other insensibly and form a continuous series, whereas the specific forms of life which are subject to them on the whole form a discontinuous series.' The magnification of this difficulty furnishes the basis of Batson's critical attitude towards Darwin's theory.

"He points out that while the study of the adaptation of living things was undertaken as a test of the theory of natural selection its study ceases to help us at the exact point at which help is most needed. 'We are seeking for the cause of the differences between species and species and it is precisely on the utility of specific differences that the students of adaptation are silent. For, as Darwin and many others have often pointed out, the characters which visibly differentiate species are not as a rule capital facts in the constitution of vital organs, but more often they are just those features which seem to us useless and trivial * * *.' 'In the early days of the theory of natural selection it was hoped that with searching the direct utility of such small differences would be found, but time has been running now and the hope is unfulfilled.' 'Hence though the study of adaptation will always remain a fascinating branch of natural history it is not and can not be a means of directly solving the origin of species.'

"Bateson's general conclusion is summed up in the statement 'that the discontinuity of which species is an expression has its origin not in the environment nor in any phenomenon of adaptation but in the intrinsic nature of organisms themselves manifested in the original discontinuity of variation.' 'The discontinuity of species results from the discontinuity of variation.'"[3]

[3] Science, Vol. LXIII, pp. 531–533, 1926.

"The root of the difficulty that troubled Bateson is found, I think, in the title of Darwin's book of 1889, 'The Origin of Species by Means of Natural Selection.' Bateson's chief contention, if I understand him, is that the theory of natural selection does not explain the distinctive features of species, namely in that their distinctiveness often rests on trivial characters that are not variable but constant. How, he asks repeatedly, could species be created by natural selection if those parts that distinguish related species from each other are concerned with parts not essential to the life of the individual? This undoubtedly raises a serious question for Darwin's theory, but I venture to think that it is not so serious as it appears unless one accepts Bateson's interpretation of the nature and existence of 'species.' In the first place, it is to be remembered that although Darwin entitled his work the 'Origin of Species,' his whole argument went to show that the attempt to sharply separate species from varieties was futile because in most cases there is no such sharp separation. If this is conceded, then natural selection may offer an approximate solution of the situation as it exists. But Bateson believes that there are distinctions, essential ones, that give species a particular hierarchy in the realm of organic life. If so much be granted, the difficulty he points to may seem to be real. But there is another interpretation not fully appreciated at the time when Bateson wrote (although more than hinted at in Darwin's writing) which has been established by modern work in genetics. This consideration goes far towards meeting the difficulty raised by Bateson, even conceding, for the sake of the argument, his point that some species at least are sharply separated by constant characters that seem unimportant for their existence. I refer to the discovery that the effects of the gene are as a rule widespread, affecting many parts of the body at the same time. If, now, some of these effects involve the physiologicial actions essential to the individual's existence, other effects of the same gene may be structural but no less constant even though trivial. Natural selection, having 'fixed' the former, will incidentally include the latter. The argument is no longer an appeal to ignorance but to established fact. Its implications only are theoretical.

"There is another problem intimately bound up in Bateson's arguments with respect to the species question. The origin of infertility between species and the sterility of the hybrids produced by 'species crosses.' Both questions were much discussed by Darwin with a fullness of information and open mindedness never since surpassed. Personally, I believe that he practically met the requirements of the situation. More recent work substantiates, I think, the essentials of his argument. In fact, the difficulty raised by Bateson deals the mutation theory of evolution a harder blow than Darwin's view, if only because the mutation theory demands a more objective and rigorous answer than one that might have sufficed in Darwin's time. The points raised by Bateson are the following: If mutants are incipient species, why has no infertility been observed between any mutant and its parent type, the individuals of the new type being fertile inter se? If infertility does not arise in the single step, what reason can be given for supposing that more steps will lead to infertility? That this point is well taken, no one familiar with the mutation process is likely to deny. The tables might, perhaps, be turned by stating that when such a mutation does occur it will give rise to a new species in the sense defined. But such a counter-argument would be foolhardy, both because it concedes too much to the restricted definition of species and also because it appeals to something not yet observed. It is true that Plough has recently observed a case in which a mutant type appeared that is more fertile with others of its kind than with the parent type, but a single case of this sort, not yet fully reported, is a dangerous precedent to appeal to. The point that Bateson has made was, I believe, well made. He scorned to take an easy road to success if in taking it, a difficulty is ignored, and we will do well, I think, to follow his example, which, after all, involves only waiting to see whether a solution may not be found. One possible source of hopefulness may at least be pointed out. Practically all the cases of mutant changes that have been observed and studied relate to external characters that can not be supposed to have anything to do with physiological functions causing infertility. It is the latter that must be involved when species are infertile inter se. There is no good reason to expect that any of the recorded mutant types should have been infertile with the parent type. Moreover, if a mutant individual should appear that was infertile with the parent type it is unlikely that it would be, or even could be, tested at the time with one of its kind, etc. Bateson intended no doubt that the point he raised should not be simply one of carping criticism—he was singularly free from raising a question in that spirit—but rather that it might lead to observations in a direction that would bear directly on the point at issue rather than to take something for granted that had not been proven.

"The second difficulty that Bateson has raised is perhaps not so serious. The sterility of the hybrid (which is generally regarded as a more decisive feature of specific distinction) has not been observed for any new types that have a known mutational origin when mated to the parent type. It is generally known that the sterility of the hybrid is a very variable condition. It has been shown in a number of cases to result from failure of the conjugation of the chromosomes at maturation, which leads, automatically, to great subsequent mortality of the germ cells. If it be granted that, in the course of evolution, changes in the constitution of the chromosomes occur, or else in the rearrangement of their elements, as we now have demonstrable evidence may occur, there is no difficulty in understanding why the hybrid is sometimes infertile. On the other hand, the origin of such a type from its supposed parent type does present the same difficulties as those met with in the case of infertility. It may be pointed out that this same difficulty arises whatever point of view of evolution is held; it is no greater for the mutation theory than for that of natural selection or of Lamarckianism."[4]

"When in 1900 Mendel's paper (1865) was brought to light and confirmed by the results of de Vries, Correns, and Tschermak, Bateson at once realized its importance. He was at the time himself engaged in a study of the inheritance of discontinuous variation and had become familiar with evidence that falls into line with Mendel's interpretation. He republished (1902) the English translation of Mendel's paper that had been prepared by the Journal of the Royal Horticultural Society (1900), and emphasized its far-reaching application. In collaboration with Miss Saunders, Bateson sent in his first report of the work to the evolution committee of the Royal Society (December 17, 1901), which was published in 1902. In this report experiments of Miss Saunders with plants (Lychnis, Datura, and Matthiola) and Bateson's with poultry furnished an admirable verification of 'Mendel's Law' and served as a sufficient reply in themselves to an inadequate and prejudiced critique of Mendel's results that had appeared in Biometrica. As I have said, in the first edition of the 'Principles' in 1902, Bateson took up the cudgels in defense of Mendel's work. His vigorous onslaught (based on direct familiarity with the facts in the case) on Weldon's misleading review of Mendel's work made it impossible that the importance of the new discovery should be overlooked or disregarded. 'The study of variation and heredity must be built on statistical data, as Mendel knew long ago; but as he also perceived, the ground must be prepared by specific experiment. The phenomena of heredity and variation are specific and give loose and deceptive answers to any but specific questions. That is where our exact science will begin.' 'In our sparse and apathetic community error mostly grows unheeded, choking truth. That fate must not befall Mendel now.'

"Between the years 1902 and 1909 further reports to the evolution committee were made by Bateson and his collaborators. A large amount of exact information concerning heredity over a wide range of animals and plants appears in these reports. They have also a special interest to students of genetics. Each stage in the progress

[4] Proceedings of the Linnean Society.

of the work that Bateson and his collaborators were carrying out at Cambridge is here set down. The reports give an insight both into the methods undertaken to study the problems and into the origin of some of the ideas at which Bateson later arrived. It is difficult to pick out any one subject as more important than another, but the work on stocks by Miss Saunders, the work of Hurst and of Bateson and Punnett on the inheritance of the shape of the comb and color of the plumage in poultry, the work on sweet peas by Bateson and Punnett contributed many important facts to the study of genetics. The explanation of the reversion that occurs when certain white races of peas are crossed, taken in connection with Cuénot's analysis of the relation of recessive whites to color determiners in mice, and the discovery of coupling and repulsion of certain characters in sweet peas (1906) (now more familiarly known as linkage) are two of the outstanding results that have had important developments in the extension of Mendelism. But in such an abundance of material it is difficult to select the more significant parts. One feature of these reports is characteristic. Nothing is glossed over for the sake of uniformity. Exceptions are reported and emphasized. Their examination whenever possible is the starting point for further study that is often illuminating. In a summary of genetic work up to 1906 (Progr. Rei. Botan.) Bateson made the following significant comment '* * * It is practically impossible to make any general statement as to which characters are dominant and which are recessive * * * It may be suggested that in the dominant type some element is present which is absent in the recessive type. The difficulty in applying such a generalization lies in the fact that not very rarely characters dominate which appear to us to be negative.' As examples, the dominance of hornless cattle and of the abortive condition of the female organ in the lateral florets of barley are given. 'Consequently we are almost precluded from regarding dominance as merely due to the presence of a factor which is absent in the recessive form. Not impossibly we may have to regard such negative characters as due to the presence of some inhibiting influence, but in our present stage of knowledge there is no certain warrant for such an interpretation.' This reserved attitude Bateson always held, returning to a discussion of it in a paper that appeared (Jour. Genetics, 1926) shortly after his death."[5]

"Of the public addresses that Bateson gave, the inaugural lecture delivered at Cambridge in 1908 on his appointment to the new professorship in biology is in some respects the most interesting. In this address he puts the essential facts of the new work in heredity before a general university audience with a vigor that still makes it interesting reading. In it occurs a statement that I like to quote both on

[5] Science, vol. LXIII, p. 533, 1926.

account of its intrinsic interest and also because it typifies Bateson's general attitude toward genetics: 'Treasure your exceptions! When there are none the work gets so dull that no one cares to carry it further. Keep them always uncovered and in sight. Exceptions are like the rough brick work of a growing building, which tells that there is more to come and shows where the next construction is to be.'

"The Herbert Spencer lecture (1912) on 'Biological Facts and the Structure of Society' is in the main a warning to the eugenists that our present knowledge of Mendelian principles tells us not to make hasty generalizations as to human society, for 'let us remember that a polymorphic and mongrel population like ours descends from many tributary streams. We are made of fragments of divers races, all in their degree contributing their special aptitudes, their special deficiencies, their particular virtues and vices, and their multifarious notions of right and wrong. Many of us have, for instance, the monogamous instincts as strong as pigeons, and many of both sexes have it no more than fowls. Why should some be ambitious to make all think or act alike? It is much better that we should be of many sorts, saints, nondescripts, and sinners.' Again he gives the warning, 'Before science can claim to have any positive guidance to offer, numbers of untouched problems must be solved.' 'For these and other reasons I am entirely opposed to the views of those who would subsidize the families of parents passed as unexceptional. Galton, I know, contemplated some such possibility; but if we picture to ourselves the kind of persons who would infallibly be chosen as examples of "civic worth"—the term lately used to denote their virtues—the prospect is not very attractive. We need not for the present fear any scarcity of that class, and I think we may be content to postpone schemes for their multiplication.'

"Bateson gives an emphatic warning, unpalatable to propogandists in general and to eugenists in particular, who take for granted that the 'standard of perfection' is known to them. Every attempt to interfere with the course of human breeding except in the segregation of the 'hopelessly unfit' carries with it the implication that the end to be desired is obvious, while in reality in such a complex, biological, sociological, and economic group as human society the opportunity for serious blundering is too obvious to put the future 'structure of society' in such hands. I can not resist the temptation for one further quotation from this address, because it makes clear a relation that is often overlooked by the novices of the theory of natural selection, although Darwin himself fell into no such error concerning the 'survival of the fittest.' Bateson writes, 'I lay stress on this aspect of the social problem because I have seen several times of late the claim put forward that the teaching of biological science sanctions a system of freest competition for the means of subsistence between individuals under which the fittest will survive and the less fit tend to extinction. That may conceivably be a true inference applicable to forms which, like thrushes, live independent lives, but so soon as social organization begins the competition is between societies and not between individuals. Just as the body needs its humbler organs, so a community needs its lower grades, and just as the body decays if even the humblest organs starve, so it is necessary for society adequately to insure the maintenance of all its constituent members so long as they are contributing to its support.'

"It is difficult to characterize the Australian addresses in a few words. There is so much that is excellently put with an abounding humor. The Melbourne address is a clearly reasoned statement of the standpoint of modern genetics as interpreted by Bateson with the necessary reservations. He gives a somewhat clearer statement of his attitude toward natural selection, pointing out that from what we know of the distribution of variability in nature, the scope claimed by natural selection in determining the fixity of species must be greatly reduced. 'The doctrine of the survival of the fittest is undeniable so long as it is applied to the organism as a whole * * * but to see fitness everywhere is mere eighteenth century optimism. * * * Shorn of these pretensions the doctrine of the survival of favored races is a truism, helping scarcely at all to account for the diversity of species.' Here we find the admission that natural selection may account for the 'organism as a whole' and for 'favored races,' but 'scarcely at all' for the 'diversity of species' which when all is said is not so different from much that Darwin himself was contending for. Bateson says at the conclusion of his address that it is with reluctance and rather from a sense of duty that he has devoted so much of his report to the evolutionary aspects of genetic research, the outcome of which is negative, 'destroying much that till lately passes for gospel.'

"The Sydney address extends some of the conclusions reached in the preceding address to 'our own species, Man.' It covers somewhat the same ground as the Spencer lecture. Like the latter, it is rather pessimistic in tone, but is full of suggestions of good sense and pointed criticism. Its final recommendation, which is a little too general for daily use, to suggest to reformers that they should direct their efforts toward 'facilitating and rectifying class distinctions' rather than to abolishing them, because, Bateson believes, the teaching of biology is 'perfectly clear,' namely that man is essentially at present polymorphic and that men are born unequal. In a word, that the main differences are genetic and not environmental.

"Several years later Bateson made another address before the American Association at Toronto that aroused in Canada and the States widespread criticism and comment. In point of fact it contained little that had not previously been given, but this time it was reported in the newspapers in a garbled account. It would be unnecessary to dwell on this episode were it not that it received notice also from some of the old school naturalists who rushed to the defense of the evolution theory that Bateson seemed (to them) to have attacked. Curiously enough, men who had themselves rejected Darwin's theory as insufficient were the severest critics of Bateson, on the ground, I imagine, that they supposed that he had given away the case for evolution. It is needless to point out that he stated the case for evolution with extraordinary lucidity, and was quite above juggling with the 'facts' and the 'causes' of evolution."[6]

"The Cambridge period came to an end in 1910 on the acceptance of the directorship of the newly founded John Innes Horticultural Institution at Merton. It was a great opportunity, and Bateson made magnificent use of it. When he went there was nothing; in a few years there grew up a splendidly equipped station, and of far greater moment, an enthusiastic and devoted band of workers. Here, too, his position gave him better facilities for promoting that cooperation between the practical breeder and the man of science upon which he had so often insisted. He made the breeder feel that his problems were also the problems of science, and out of his sympathy begat trust. Of his own inquiries at this period, and of those directly inspired by him, the keynote was segregation, its nature and the time of its occurrence. To this impulse we owe the striking series of investigations on variegation, bud sports, and root cuttings, and on the phenomenon of anisogeny, accounts of which appeared from time to time in the Journal of Genetics; and it is in the fitness of things that his matured judgment on these phenomena should have appeared in the Journal only a few days before his death."[7]

"It is with some hesitation that I take up Bateson's point of view toward the chromosomes as the material bearers of the hereditary units, because his attitude was for a long time diametrically opposite to my own. Bateson committed himself rather fully in his Melbourne address (1914) when he said in reference to the sorting out of the 'elements or factors' by a process of cell division: 'What these elements, or factors as we call them, are we do not know. That they are in some way transmitted by the material of the ovum and of the spermatozoon is obvious, but it seems to me unlikely that they are in any simple or literal sense material particles. I suspect,

[6] Proceedings of the Linnean Society.

[7] Nature, vol. 117, p. 313, 1926.

rather, that their properties depend on some phenomenon of arrangement.'

"Despite the valiant attempts Bateson made to give as much credit as he honestly could to the chromosome theory, it is clear from his posthumous paper (Journal of Genetics, Vol. XVL, January, 1926), that the evidence on which the theory is based was not congenial to his way of thinking. He states that 'the work of the Columbia school has shown beyond possibility of doubt that in animals the reduction division must be the moment at which segregation in respect to Mendelian factors is usually affected.' Nevertheless he adds 'at least in plants of many kinds comparable segregations occur at somatic divisions also.' I should want to qualify the latter statement, for some of the cases cited by Bateson in plants are capable of a different interpretation, while for others the interpretation is very problematical and not certainly due to segregation. It is unnecessary to affirm that segregation, like the typical Mendelian process, may never be found to occur in somatic tissues of animals as well as plants, but the evidence at present does not, I think, require this interpretation, while there is clear evidence that the typical process of segregation both in animals and plants occurs at the time of reduction of the chromosomes. Bateson also states that 'if we press for a more exact account of the nature of the association subsisting between factors and chromosomes, no answer is forthcoming.' I must dissent also from this somewhat positive statement, for we have at least supplied an abundance of data that we think answers the question. Whether the answer is right or wrong the future alone will decide.

"Bateson reviews in his last paper, under the heading of anisogeny, some of the interesting problems that have grown out of the work of the institute at Merton. His discussion of chimaeras, especially those arising from root buds of Pelargonium, is full of suggestion. The paper ends with a further shot at the 'extension and implication' of the chromosome theory. In plants, he again affirms, phenomena are met with to which the simple chromosome theory is inapplicable and 'the conviction has grown that the problem of heredity and variation is intimately connected with that of somatic differentiation.' In these respects the chromosome theory 'has fallen short of the essential discovery.' Here, once more, I find my point of view miles apart from that of Bateson. If by the 'essential discovery' he had meant the connection between the postulated genes and the differentiation of the cells of the embryo, then no one would deny that we are still much in the dark, but the whole context of his statement can not be twisted into such a meaning. There is no need to dwell on these points on which we disagree so radically, for there is so much on which we could agree that it is an easy and delightful task to join with his other friends and admirers in praise of his character and his influence."[8]

An anonymous writer in the Eagle, a magazine supported by members of the St. Johns College, gives the following account of his personality. "He was essentially a man of intuitions and convictions. The intuition of some scientific men runs sympathetically with the working of the natural universe, and they contribute to knowledge leading ideas which experiments hasten to verify. Others only arrive by plodding, strenuous analysis of phenomena until the unity within them is laid bare, free of the diversities which obscured it. Bateson was of the former gifted type, and his enthusiasms were for clear-cut new ideas. In his scientific work, as in all things that really counted with him, he was filled with a very intense earnestness. Working rapidly but thoroughly through the evidence on complex problems, he could arrive at firm conviction of where the truth lay. Such a conviction would fill his vision, and all his intense vitality be concentrated at the center of what he saw. He was impatient of expositions which involve elaborate quantitative treatment and then still leave residual suspense accounts.

"Bateson was a born leader. He loved to lead a cause and win, and was at his best in attracting young men to the good scientific causes he had at heart. Never for half-measures or compromises, it sometimes happened that when he was up against men of older generations, whose views were inflexible, he could make no progress, but only camp over against them in stubborn opposition. This is a situation that does not make for personal happiness in a scientific community, and Bateson certainly sacrificed something for his faiths."[9]

"Bateson was a born leader. He loved to lead a cause and win, and hand familiarity with plants and animals. He had also an extensive knowledge of the literature of his subject at command and an ability to express himself fearlessly in classical and clear English. His personal interests extended far beyond the immediate fields of his researches. His deep interest in painting and other forms of art must have surprised his scientific friends when they discovered it for the first time, and his artistic friends would no doubt have been equally surprised to have discovered his far-reaching influence on the biological science of his time."[10]

"Such in brief outline was Bateson's record of scientific achievement. Fearless in criticism and generous in appreciation, he stood above all for that spirit of freedom in inquiry through which alone the world may progress to better things."[11]

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[8] Proceedings of the Linnean Society.

[9] The Eagle, Vol. XLIV, pp. 330–331, 1926.

[10] Science, Vol. LXIII, p. 535, 1926.

[11] Nature, vol. 117, p. 313, 1926.

H. KAMERLINGH ONNES, 1853–1926[1]

By F. A. Freeth

Prof. Heike Kamerlingh Onnes, whose death on February 21 will be widely regretted, was born on September 21, 1853, in Groningen. As a youth he attended a school in that town, of which J. M. Van Bemmelen, who later became professor at Leyden, and whose name will always be remembered in connection with colloid chemistry, was principal.

In 1870 Onnes became a student at the University of Groningen, and from 1871 until 1873 he worked under Bunsen and Kirchhoff at Heidelberg. He remained in Groningen until 1878. His doctoral dissertation was entitled " New Considerations on the Axial Changes of the Earth," and was marked by the combination of theory and accurate experiment which is characteristic of all his later works. In 1881 he became influenced by the theories of Van der Waals and wrote an important paper in which he deduced the law of corresponding states from considerations of statistical mechanics.

In the following year Onnes became professor at Leyden. In his inaugural address he insisted that the laws of physics could be determined by accurate experiment alone. His motto "From measurement to knowledge" was then stated for the first time, and his remarks upon the necessity of the then recently designed pumps of Cailletet and Pictet for the attainment of low temperatures were almost prophetic. It was about this time that Onnes planned his cryogenic program, which has since made his name famous throughout the world. In 1894 he published his first paper on the design and equipment of the Leyden laboratories, and in his inaugural address in 1894 he laid down the importance of accurate measurements at very low temperatures.

The formation of the cryogenic laboratory at Leyden was only made possible by the extraordinary energy and tenacity, combined with organizing talents of a very high degree, which Onnes brought to bear on this subject. As a preliminary it was necessary for him to train mechanics and glass blowers, and as a result of many years of patient work he obtained an organization which is still unique. In 1904 Onnes was able to control large supplies of liquid air. By

[1] Reprinted by permission from Nature, vol. 117, No. 2940, Mar. 6, 1926.

1906 he had developed the technique of the liquefaction of hydrogen on a large scale. In 1908 he attained the triumph of his career by liquefying helium. This feat, taking into consideration the limited supplies of helium and the difficulty in obtaining it in those days, was little short of superhuman.

The amount of careful organization and planning necessary before the experiments were started can only be appreciated by those who have seen the laboratory in action. It is worthy of record that the whole staff was so tired out by their exertions that they could not see the helium even after it was liquefied. The presence of the liquid was pointed out to them by Prof. F. A. H. Schreinemakers, who was in the laboratory at the time.

The boiling point of helium enabled Onnes to reach a temperature only 4.22° above absolute zero. By reducing the pressure he was finally enabled to arrive at a temperature of 0.9° absolute. The writer had the privilege of seeing Onnes attempt to solidify helium. A battery of 15 large Langmuir pumps were put into connection with a supply of liquid helium whereby the pressure was reduced to about 0.2 mm.; in spite of this, however, the helium did not solidify.

The ability to control really low temperatures enabled Onnes to make the astonishing discovery of supraconductivity. It had always been assumed that the resistance of a metal would run out to nil at the absolute zero. Onnes discovered that quite a number of substances showed a sharp discontinuity in their resistance curves at a temperature of about 4° or 5° absolute. Typical examples are lead and cadmium. He passed a current of 1,000 am./sq. mm. through a conductor under these conditions without being able to detect the slightest change of E. M. F.

Onnes's work is well summarized in the volume presented to him on the occasion of the fortieth anniversary of his holding the chair at the University of Leyden. Most of his work was published in the Proceedings of the Physical Laboratory of Leyden, and it is due to the comparative inaccessibility of this publication that Onnes's work is not so widely known as it should be.

It is impossible, within the limits of a brief notice, to give more than an idea of the scope and range of his activities. The division of the above-mentioned work into thermodynamic, magnetic, optical, magneto-optical, radioactive and electric subsections, in each of which he published numerous papers, is an indication of the magnitude of his work.

In later life Onnes received the fullest recognition of his great talents. His own country awarded him a Commandership in the Order of the Lion of the Netherlands. Similar decorations were conferred upon him by the Governments of Poland and Norway. In 1913 he received a Nobel prize for physics. He was an honorary member of practically every learned society in the world. Onnes was awarded the Rumford medal of the Royal Society in 1912 and was elected a foreign member of the society in 1916.

Turning to his personal side, it is impossible to speak of him without emotion. Onnes was one of the most genial, kind-hearted, and accessible men who ever lived. He made unremitting efforts toward the feeding of children in the destitute areas of Europe in the years immediately following the war. To young men, he was an inspiration. The writer will always remember, with gratitude, his extraordinary kindness and hospitality. He practically kept "open house."

Onnes' scientific memory is imperishable, and his personality will never be forgotten by any one who had the privilege of knowing him.

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