FOR·THE·INCREASE·AND·DIFFVSION·OF·KNOWLEDGE·AMONG·MEN·

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·SMITHSONIAN·INSTITVTION·WASHINGTON·1846·

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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

1915

WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

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, 1915.

SMITHSONIAN INSTITUTION,
Washington, December 15, 1915.

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, 1915. I have the honor to be,

Very respectfully, your obedient servant,

CHARLES D. WALCOTT, *Secretary.*

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ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1915.

SUBJECTS.

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1915, with statistics of exchanges, etc.

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, 1915.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1915.

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 1915.

THE SMITHSONIAN INSTITUTION.

June 30, 1915.

Presiding officer ex officio.—WOODROW WILSON, President of the United States.
Chancellor.—EDWARD DOUGLASS WHITE, Chief Justice of the United States.
Members of the Institution:

WOODROW WILSON, President of the United States.
THOMAS R. MARSHALL, Vice President of the United States.
EDWARD DOUGLASS WHITE, Chief Justice of the United States.
ROBERT LANSING, Secretary of State.
WILLIAM GIBBS MCADOO, Secretary of the Treasury.
LINDLEY MILLER GARRISON, Secretary of War.
THOMAS WATT GREGORY, Attorney General.
ALBERT SIDNEY BURLESON, Postmaster General.
JOSEPHUS DANIELS, Secretary of the Navy.
FRANKLIN KNIGHT LANE, Secretary of the Interior.
DAVID FRANKLIN HOUSTON, Secretary of Agriculture.
WILLIAM COX REDFIELD, Secretary of Commerce.
WILLIAM BAUCHOP WILSON, Secretary of Labor.

Regents of the Institution:

EDWARD DOUGLASS WHITE, Chief Justice of the United States, Chancellor.
THOMAS R. MARSHALL, Vice President of the United States.
HENRY CABOT LODGE, Member of the Senate.
WILLIAM J. STONE, Member of the Senate.
HENRY FRENCH HOLLIS, Member of the Senate.
SCOTT FERRIS, Member of the House of Representatives.
MAURICE CONNOLLY, Member of the House of Representatives.
ERNEST W. ROBERTS, Member of the House of Representatives.
ANDREW D. WHITE, citizen of New York.
ALEXANDER GRAHAM BELL, citizen of Washington, D. C.
GEORGE GRAY, citizen of Delaware.
CHARLES F. CHOATE, Jr., citizen of Massachusetts.
JOHN B. HENDERSON, Jr., citizen of Washington, D. C.
CHARLES W. FAIRBANKS, citizen of Indiana.

Executive committee.—GEORGE GRAY, ALEXANDER GRAHAM BELL, MAURICE CONNOLLY.
Secretary of the Institution.—CHARLES D. WALCOTT.
Assistant secretary.—RICHARD RATHBUN.
Chief clerk.—HARRY W. DORSEY.
Accountant and disbursing agent.—W. I. ADAMS.
Editor.—A HOWARD CLARK.
Assistant librarian.—PAUL BROCKETT.
Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM.

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

Assistant secretary in charge.—RICHARD RATHBUN.

Administrative assistant.—W. DE C. RAVENEL.

Head curators.—WILLIAM H. HOLMES, LEONHARD STEJNEGER, G. P. MERRILL.

Curators.—PAUL BARTSCH, R. S. BASSLER, A. HOWARD CLARK, F. W. CLARKE, F. V. COVILLE, W. H. DALL, CHESTER G. GILBERT, WALTER HOUGH, L. O. HOWARD, ALEŠ HRDLIČKA, FREDERICK L. LEWTON, GEORGE C. MAYNARD, GERRIT S. MILLER, JR., ROBERT RIDGWAY.

Associate curators.—J. C. CRAWFORD, W. R. MAXON, DAVID WHITE.

Curator, National Gallery of Art.—W. H. HOLMES.

Chief of correspondence and documents.—RANDOLPH I. GEARE.

Disbursing agent.—W. I. ADAMS.

Chief of exhibits (Biology).—JAMES E. BENEDICT.

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

Editor.—MARCUS BENJAMIN.

Assistant librarian.—N. P. SCUDDER.

Photographer.—T. W. SMILLIE.

Registrar.—S. C. BROWN.

Property clerk.—W. A. KNOWLES.

Engineer.—C. R. DENMARK.

BUREAU OF AMERICAN ETHNOLOGY.

Ethnologist-in-charge.—F. W. HODGE.

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

Special ethnologist.—LEO J. FRACHTENBERG.

Honorary philologist.—FRANZ BOAS.

Editor.—JOSEPH G. GURLEY.

Librarian.—ELLA LEARY.

Illustrator.—DE LANCEY GILL.

INTERNATIONAL EXCHANGES.

Chief clerk.—C. W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK.

Superintendent.—FRANK BAKER.

Assistant superintendent.—A. B. BAKER.

ASTROPHYSICAL OBSERVATORY.

Director.—C. G. ABBOT.

Aid.—F. E. FOWLE, JR.

Bolometric 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, 1915.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith the annual report on the operations of the Smithsonian Institution and its branches during the fiscal year ending June 30, 1915, including work placed by Congress under the direction of the Board of Regents in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, and the United States Bureau of the International Catalogue of Scientific Literature.

The general report reviews the affairs of the Institution proper and briefly summarizes the operations of its several branches, while the appendices contain detailed reports by the assistant secretary and others directly in charge of various activities. The reports on operations of the National Museum and the Bureau of American Ethnology will also be published as independent volumes.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

The Smithsonian Institution was created an establishment by act of Congress approved August 10, 1846. Its statutory members are the President of the United States, the Vice President, the Chief Justice, and the heads of the executive departments.

THE BOARD OF REGENTS.

The Board of Regents consists of the Vice President and the Chief Justice of the United States as ex officio members, three Members of the Senate, three Members of the House of Representatives, and six citizens, "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."

In regard to the personnel of the board there were no changes during the fiscal year. The roll of Regents on June 30 was as follows: Edward D. White, Chief Justice of the United States, Chan-

cellor; Thomas R. Marshall, Vice President of the United States; Henry Cabot Lodge, Member of the Senate; Henry French Hollis, Member of the Senate; William J. Stone, Member of the Senate; Scott Ferris, Member of the House of Representatives; Ernest W. Roberts, Member of the House of Representatives; Maurice Connolly, former Member of the House of Representatives; Andrew D. White, citizen of New York; Alexander Graham Bell, citizen of Washington, D. C.; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; John B. Henderson, jr., citizen of Washington, D. C.; and Charles W. Fairbanks, citizen of Indiana.

The board held its annual meeting on December 10, 1914. The Hon. George Gray was on that date elected chairman of the executive committee to fill the vacancy caused by the death of Senator Bacon on February 14, 1914. The proceedings of the above meeting, as also the annual financial report of the executive committee, have been printed, as usual, for the use of the Regents, while such important matters acted upon as are of public interest are reviewed under appropriate heads in the present report of the Secretary. A detailed statement of disbursements from Government appropriations, under the direction of the Institution for the maintenance of the National Museum, the National Zoological Park, and other branches, will be submitted to Congress by the Secretary in the usual manner in compliance with the law.

FINANCES.

The permanent fund of the Institution and the sources from which it was derived are as follows:

Deposited in the Treasury of the United States.

Bequest of James Smithson, 1846		$515,169.00
Residuary legacy of James Smithson, 1867		26,210.63
Deposit of savings of income, 1867		108,620.37
Bequest of James Hamilton, 1875	$1,000	
Accumulated interest on Hamilton fund, 1895	1,000	
		2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposits from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Deposit from savings of income, 1903		25,000.00
Residuary legacy of Thomas G. Hodgkins, 1907		7,918.69
Deposit from savings of income, 1913		636.94
Part of bequest of William Jones Rhees, 1913		251.95
Deposit of proceeds from sale of real estate (gift of Robert Stanton Avery), 1913		9,692.42
Bequest of Addison T. Reid, 1914		4,795.91
Deposit of savings from income Avery bequest, 1914		204.09

Deposit of savings from income Avery fund, 1915	$1,862.60
Deposit of savings from income Reid fund, 1915	426.04
Deposit of balance of principal $248.05 and income $28.39 Rhees fund, 1915	276.44
Deposit of first payment of Lucy T. and George W. Poore fund, 1915	24,534.92
Total of fund deposited in the United States Treasury	987,600.00

Other resources.

Registered and guaranteed bonds of the West Shore Railroad Co., part of legacy of Thomas G. Hodgkins (par value)	42,000.00
Total permanent fund	1,029,600.00

The first installment to the Lucy T. and George W. Poore fund, amounting to $24,534.92, was received in March, 1915, and was immediately deposited in the United States Treasury to the credit of the permanent fund. Other deposits to this fund during the year were from the income of several funds amounting to $2,565.08, or a grand total of $27,100, making a total now deposited in the Treasury to the credit of the permanent fund of $987,600.

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act organizing the Institution and an act of Congress approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum.

The income of the Institution during the year, amounting to $112,035.90, was derived as follows: Interest on the permanent foundation, $59,310; contributions from various sources for specific purposes, $12,000; first installment of a bequest known as the Lucy T. and George W. Poore fund, amounting to $24,534.92; the original bequest designated as the George H. Sanford fund of $1,020; the balance of the William Jones Rhees fund, amounting to $248.05; and from other miscellaneous sources, $14,922.93; all of which was deposited in the Treasury of the United States.

With the balance of $30,560.13 on July 1, 1914, the total resources for the fiscal year amounted to $142,596.03. The disbursements, which are given in detail in the annual report of the executive committee, amounted to $100,430.17, leaving a balance of $42,165.86 on deposit June 30, 1915, in the United States Treasury and in cash.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1915:

International Exchanges	$32,000
American Ethnology	42,000
Astrophysical Observatory	13,000

National Museum:	
Furniture and fixtures	$25,000
Heating and lighting	46,000
Preservation of collections	300,000
Books	2,000
Postage	500
Building repairs	10,000
Bookstacks for Government bureau libraries	10,000
National Zoological Park	100,000
International Catalogue of Scientific Literature	7,500
Tower telescope, Astrophysical Observatory, Mount Wilson, Cal	2,000
Repairs, Smithsonian Building	16,000
Total	606,000

In addition to the above specific amounts to be disbursed by the Institution there was included under the general appropriation for public printing and binding an allotment of $76,200, to cover the cost of printing and binding the annual report and other Government publications issued by the Institution, and to be disbursed by the Public Printer.

EXPLORATIONS AND RESEARCHES.

The "increase of knowledge" is one of the fundamental objects of the Smithsonian Institution, and toward the accomplishment of that object it has inaugurated and maintained or has participated in astronomical, anthropological, biological, and geological explorations in every portion of the world, resulting in greatly increasing our knowledge of the meteorology, the geography, the fauna and flora, and the ethnology of all lands, and in the acquisition of a large amount of valuable material for the National Museum. The Institution has likewise, through special grants, aided laboratory researches in practically every line of natural science. The extent of these explorations and researches during the last 60 years covers a wide range, although a great deal more of most important work could have been accomplished had adequate funds been available. Friends of the Institution have many times, and particularly during the last few years, generously aided the work through the contribution of funds for specific purposes, but much yet remains undone, and opportunities for undertaking important lines of investigation are constantly being lost through lack of means to carry them into execution.

I will here allude only briefly to some of the activities of the Institution in these directions during the year and for details of other investigations may refer to the appendices containing the reports of those directly in charge of the several branches of the Institution.

GEOLOGICAL EXPLORATIONS IN THE ROCKY MOUNTAINS.

In continuation of my previous geological researches in the Rocky Mountains of Canada and Montana I spent a week during the field season of 1914 at Glacier, British Columbia, where I assisted Mrs. Walcott (née Mary M. Vaux) in measuring the flow of the Illecillewaet and Asulkan Glaciers.

From Glacier we proceeded to White Sulphur Springs, Mont., for the purpose of studying the ancient sedimentary pre-Paleozoic rocks of the Big Belt Mountains. These explorations were made on the eastern and southern slopes of this range, and then extended to the south on the Gallatin, Madison, and Jefferson Rivers.

It was found that the pre-Paleozoic sedimentary rocks were exposed by the uplift of the granite mass forming the summit of Mount Edith of the Big Belt Mountains in such a way that the thickness of the sandstones, limestones, and shales could be readily measured in the numerous sections exposed in the canyons worn by waters descending from the higher points to the valley surrounding the range. Nearly 5 miles in thickness of rock were measured, and in the limestone belts reefs of fossil algal remains were studied and large collections made with the assistance of Mrs. Walcott and Charles E. Resser and sent on to Washington.

It was found that the algal remains were deposited very much in the same manner as those that are now being deposited in many fresh-water lakes, and that many of the forms had a surprising similarity to those being deposited in the thermal springs and pools of the Yellowstone National Park.

In the lower portion of Deep Creek Canyon, southeast of the city of Helena, a deposit of siliceous shale was examined where some years ago I had discovered the remains of crablike animals suggesting in form the fresh-water crayfishes found in the streams and ponds all over the world. These fossils are the oldest animal remains now known, and the algal deposits which occur at intervals for several thousand feet below the shales containing the crustaceans are the oldest authentic vegetable remains. It is also most interesting that two types of bacteria have been found in a fossil state in the rock in association with the algal remains.

On the north side of the Gallatin River two very rich beds of algal remains were found, many of which, on account of the fossil being silicified and embedded in a softer limestone, were weathered out in relief.

For the season of 1915 I have planned some investigations in the Yellowstone Park in order to be able to better interpret the fossil algal remains found in and about the Big Belt Mountains.

STRATIGRAPHIC STUDIES IN CENTRAL TENNESSEE.

Under the joint auspices of the United States Geological Survey and the United States National Museum Dr. E. O. Ulrich and Dr. R. S. Bassler, of the Museum, were engaged for several weeks during the summer of 1914 in a study of debated points in the stratigraphy of the Central Basin of Tennessee with a view to determine accurately the division line between the Chazyan and Black River groups and to secure additional information on the black shale problem.

The well-known marble beds of east Tennessee and associated shales and sandstones of Upper Chazyan age, with a thickness of over 3,000 feet, have never been found in central Tennessee or, in fact, in any area west of the Appalachian Valley. The first problem was therefore to determine either the corresponding rocks in the more western areas or, if such strata were wanting, to discover the unconformity representing this great thickness. It was found that the Lower Chazyan or Stones River rocks of central Tennessee are succeeded directly by the lowest Black River or Lowville formation, and central Tennessee therefore was presumably a land area during the time of deposition of the celebrated east Tennessee marbles.

The second problem entailed further work on the determination of the age of the widespread Chattanooga black shale, which previously had been considered to be middle to late Devonian. In recent years this determination had been questioned, and facts had accumulated showing it to be of younger age. Two features of considerable significance in this problem were the discoveries in northern Tennessee, where the shale is well exposed, that (1) this black shale passes without a discernible break into the overlying Mississippian (Kinderhook) shales, and (2) that the fossils of this overlying shale are of late instead of early Kinderhook age. As a result of this work good collections of several well-preserved faunas were added to the Museum collection.

FOSSIL ECHINODERMS IN WESTERN NEW YORK.

Field work carried on during the summer of 1914 under the supervision of Mr. Frank Springer, for the purpose of adding to the Springer collection of fossil echinoderms in the Museum, was devoted mainly to a careful examination of Silurian rocks exposed along the new Erie Canal in western New York, especially the waste material thrown out in excavations for the canal. The most valuable specimens from this part of New York occur in the Rochester shales of Niagaran age, which weather rapidly into mud upon exposure to the elements, and it was therefore necessary that the new outcrops be examined at once to secure the best results. Numerous specimens

of crinoids and cystids were found, a number of them having, as is rarely the case, root, stem, and crown preserved.

VERTEBRATE FOSSILS IN MONTANA.

Through cooperation with one of the field parties of the United States Geological Survey, Mr. Charles W. Gilmore, of the National Museum, spent three weeks during the summer of 1914 searching for fossil vertebrate remains in the Judith River formation in north central Montana. The most noteworthy discovery was the fragmentary remains of a fossil bird related to *Hesperornis*. It came from practically the same locality as the type of *Coniornis altus* Marsh, and is of importance as showing these bird remains as occurring in the upper part of the Claggett formation, whereas heretofore it was thought that *Coniornis* had come from the lower part of the Judith River formation.

CORAL INVESTIGATIONS.

Dr. T. Wayland Vaughan has for some time been engaged under the auspices of the Carnegie Institution in a study of the growth of corals, their rôle in reef building, and related problems. His field of investigation has been chiefly the coast of Florida, the Bahamas, and other regions of the West Indies. Large collections made by him in those localities have been received by the Museum.

BORNEO AND CELEBES EXPEDITIONS.

Through the generosity of Dr. W. L. Abbott, who for so many years has been a most generous contributor to the zoological and ethnological collections of the Museum, Mr. H. C. Raven conducted a collecting expedition in Borneo for a period of about two years. His work there was completed in September, 1914, having yielded about 3,000 interesting specimens of mammals and birds. Mr. Raven next crossed the Macassar Strait to the Island of Celebes, where he expects to remain for a considerable period and to secure important collections from a region heretofore poorly represented in the National Museum.

EXPEDITIONS TO THE FAR EAST.

Through the liberality of a gentleman who desired to remain unknown, Mr. Arthur de C. Sowerby has continued his zoological explorations in Manchuria and northeastern China and has forwarded a valuable collection of insects and vertebrates, including two wapiti bucks, a roe deer, two bears, and a peculiar rabbit.

Mr. Copley Amory, jr., a collaborator of the National Museum, joined a party accompanying Capt. J. Koren to the northeast coast

of Siberia. It was Mr. Amory's intention to explore such territory as may be practicable from Nijni Kolymsk as a winter base, giving special attention to mammals and birds. When last heard from he had made a trip up the Lesser Ammi River, where he obtained a good number of fossil specimens, also some birds and small mammals.

BIRD STUDIES IN ILLINOIS.

Incidental to continued work on preparation of manuscript of the unpublished volumes of "Birds of North and Middle America" (Bulletin 50, U. S. National Museum), Mr. Robert Ridgway, during the past year, made a careful study of bird life in southern Illinois in order to compare present conditions with those existing half a century ago. It was found that with few exceptions the native birds are greatly decreased in numbers. At least three species (the passenger pigeon, wild turkey, and ruffed grouse) have totally disappeared from the region examined, while several others are on the verge of extermination. A few species, such as the crow blackbird (bronzed grackle) and blue jay, and perhaps the robin, are, apparently, as numerous as they were 50 years ago.

The principal causes which have brought about this greatly diminished bird life are: (1) In the case of the game birds, relentless shooting; (2) greatly reduced breeding and shelter areas, through clearing of forests, cutting away of woody growths along roadsides and fence lines, and drainage of swampy or marshy areas; (3) introduction of the European house sparrow, which has increased to such an extent that it now outnumbers, even on the farms, all the smaller native birds combined, greatly reducing their food supply and monopolizing the nesting sites of such species as the bluebird, purple martin, wrens, swallows, and other birds that nest in cavities or about buildings; (4) invasion of the woods and fields by homeless house cats and destruction of eggs and young (often the parents also) of ground-nesting species by "self-hunting" bird dogs (setters and pointers); and, probably, (5) spraying of orchards.

HENDERSON EXPEDITION IN CUBA.

Since the *Tomas Barrera* expedition to western Cuba, Mr. John B. Henderson, a regent of the Smithsonian Institution, has made two trips to eastern Cuba to supplement the work of that expedition.

One of these visits was to Cardenas Bay, where extensive, as well as intensive, dredgings yielded a lot of interesting marine organisms. The second trip embraced Cubitas Mountains, and was made in quest of land shells, which were needed to elucidate problems in the geographic distribution of the land mollusks.

As heretofore, Mr. Henderson's yacht, the *Eolis*, has been kept busy exploring the Pourtales Plateau. Numerous hauls in all depths

of water have been made, and the material, which has arrived here from time to time, is exceedingly rich in marine invertebrates, particularly mollusks.

This year's efforts have resulted in the discovery of grounds with a more prolific, varied, and interesting fauna than previously known in this region.

BOTANICAL EXPLORATIONS IN SOUTH AMERICA.

Through cooperation with the Carnegie Institution of Washington the Museum was enabled to benefit by an expedition carried on by Dr. J. N. Rose during the summer and fall of 1914 along the west coast of South America in furtherance of his work on the Cactaceæ. About 3,000 specimens of cacti and other plants collected by him have been permanently deposited in the National Herbarium.

Dr. Rose explored a section through central Peru from Callao to Oroya, from sea level to the top of the Andes, at an altitude of 15,665 feet. Cacti were found in the greatest abundance at an altitude of 5,000 to 7,500 feet; but the various species range from a few feet above sea level to as high as 12,000 to 14,000 feet.

A second section was made across southern Peru, from Mollendo to Lake Titicaca via Arequipa. The highest point reached was 14,665 feet. Here also the cacti are found from near sea level nearly to the top of the Andes; but the most remarkable display is on the hills surrounding Arequipa, at an altitude of from 7,000 to 8,500 feet. While the cacti are abundant in both these regions, they are, with only a few possible exceptions, quite distinct. Side trips were made from Arequipa to Juliaca and Cuzco, in Peru, and to La Paz, Oruro, and Comanche, in Bolivia.

On the pampa below Arequipa are found the famous crescent-shaped sand dunes. Each dune or pile of sand is distinct in itself, often separated some distance from any other dune, and occurring, too, on rocky ground devoid of other sand. The dunes are found on the high mesa some 5,250 feet above the sea. They form definite regular piles of sand, each presenting a front 10 to 100 feet wide and 5 to 20 feet high, nearly perpendicular, crescent shaped, and from the crescent-shaped ridge tapering back to the surface in the direction from which the wind blows. These piles of shifting sand go forward about 40 feet a year.

In Chile two sections were made into the interior—one from Antofagasta to Calama, and one from Valparaiso to Santiago. The first is through the rainless deserts of northern Chile, the whole region being practically devoid of all vegetation. The second is across central Chile, the hills and valleys of which are veritable flower gardens, the hills often being a mass of yellow. Various trips were made in the central valley of Chile and one journey along the Longitudinal Railway of Chile extended from Caldera to Santiago. Special trips were made for certain rare plants like *Cereus castaneus*, first collected in 1862 and not since observed until found by Dr. Rose; and *Cactus horridus* and *Cactus Berteri*, described in 1833, but long since discarded by cactus students. In the central valley of Chile is seen that beautiful palm, the only one native of Chile, *Jubaea spectabilis* H. B. K., which often forms forests of considerable extent. From this palm is made the "Miel de Palma" so much used as a sirup on ships and at hotels.

Botanical explorations by Dr. Rose on the east coast of South America were in progress at the close of the fiscal year.

ANTHROPOLOGICAL RESEARCHES IN AFRICA AND SIBERIA.

In connection with the work of the division of physical anthropology in the National Museum, two expeditions were sent out during the year 1914 under the joint auspices of the Smithsonian Institution and the Panama-California Exposition at San Diego.

One of these expeditions was in charge of Dr. V. Schück, anthropologist of Prague, Bohemia, and its objects were: 1, to study the negro child in its native environment, and thereby create a basis of comparison for the study of the negro child in our country; 2, to visit the South African Bushmen for the purpose of obtaining measurements, photographs, and facial casts of the same; and 3, to visit British East Africa in search of the Pygmies. The tribe chosen for the child study were the Zulu, of Natal or Zululand, and over 1,000 children and adolescents of all ages—ages which could be definitely determined—were examined. These data are expected to contribute some very important results to anthropology. The Bushmen were reached in the Kalahari Desert, and besides other results 20 first-class facial casts were obtained of the people, which have since then been installed among the anthropological exhibits at San Diego. As to British East Africa, the work soon after a successful beginning was interrupted by the war.

The second expedition was in charge of Dr. St. Poniatowski, head of the ethnological laboratory at Warsaw. The object of this expedition was to visit a number of the remnants of native tribes in eastern Siberia, among which are found physical types which so closely resemble the American Indian. The expedition reached two such tribes, and secured valuable data, photographs, etc., when its work also was interrupted by the war.

THE NATURAL HISTORY OF MAN.

Some of the results of exploration and field work by the Institution among various races of mankind are shown in connection with the anthropological exhibits of the Panama-California Exposition at San Diego. These exhibits were in preparation for over three years. They are original and much more comprehensive than any previous exhibits in this line, either in this country or abroad. Dr. Hrdlička, under whose direction this exhibit was prepared, describes it as follows:

The exhibits fill five large connecting rooms, which occupy the building of the Science of Man at the Exposition. Four of these rooms are devoted to the natural history of man, while the fifth is fitted up as a modern anthropological laboratory, library, and lecture room. Of the four rooms of exhibits proper, the first is devoted to man's phylogeny, or evolution; the second, to his ontogeny, or life cycle at the present time; the third, to his variation (sexual, individual, racial); and the fourth, to his pathology and death.

The exhibits in room 1, on Human Evolution, consist of: (a) A large series of accurate, first-class casts of all the more important skeletal remains of authentic antiquity; (b) photographic enlargements and water color sketches showing the localities where the specimens were discovered; (c) charts showing the relation of the archeological position of the various finds, and their relation to the extinct fauna and to archeological epochs; (d) a series of sketches by various scientific men showing their conception of the early man, with several illustrations of drawings, statuettes, and bas-reliefs, showing early man as drawn or sculptured by the ancient man himself; and (e) a remarkable series of 10 large busts prepared by the eminent Belgian sculptor, M. Mascré, under the direction of Prof. Rutot, representing early man at different periods of his physical advancement.

The main part of the exhibits in room No. 2, devoted to man's development at the present time, from the ovum onward, are three series of true-to-nature busts, showing by definite age-stages, from birth onward and in both sexes, the three principal races of this country, namely, the "thoroughbred" white American (for at least three generations in this continent on each parental side), the Indian, and the full-blood American negro. These series, which required two and one-half years of strenuous preparation, form a unique exhibit, for nothing of similar nature has ever been attempted in this or any other country. Each set consists of 30 busts, 15 males and 15 females, and proceeds from infants at or within a few days after birth to the oldest persons that could be found. The oldest negro woman is 114. After the new born, the stages are 9 months, 3 years, 6, 10, 15, 20, 28, 35, 45, 55, 65, and 75 years. The utmost care was exercised in ascertaining the age, particularly among the negro and Indian. No choice was made of the subjects beyond that due to the requirements of pedigree, age, and good health. The whites and negroes were obtained, with a few exceptions, in Washington and vicinity, but their places of birth range over a large part of the Eastern, Southern, and Middle States; for the Indian, we chose the Sioux, a large, characteristic, and in a very large measure still pure-blood tribe, and one in which the determination of the ages of the subjects was feasible. Special trips were made to these people, and no pains were spared to get just what was wanted; in the case of the new born, it was actually necessary to wait until they came.

Other exhibits in room 2 show the development, by various stages, of the human brain, the skull, and various other parts of the body. A large series of original specimens show the most closely related animal forms to man at the present time, particularly the anthropoid apes; a series of charts on the walls deal with the phenomena of senility; finally, 10 photographic enlargements show living centenarians of various races.

Human variation is shown in room 3 by 10 sets of large busts representing 10 of the more important races of man; by 200 original transparencies giving racial portraits; by over 100 bronzed facial casts, showing individual variations within some of the more important branches of humanity; and by numerous charts and other exhibits.

In room 4 a series of charts and maps relates to the death rate in various countries, to the principal causes of death in the different parts of the world, and to the distribution of the more common diseases over the earth. Actual pathology is illustrated extensively by prehistoric American material. Many hundreds of original specimens, derived principally from the pre-Columbian cemeteries of Peru, show an extensive range of injuries and diseases, such as have left their marks on the bones. In many instances the injuries are very interesting, both from their extent and the extraordinary powers of recupera-

tion shown in the healing; while among the diseases shown on the bones there are some that find no, or but little, parallel among the white man or even the Indian of to-day. In addition this room contains a series of 60 skulls with pre-Columbian operations (trepanation).

ISLAND OF TIMOR EXPEDITION.

Among the projected expeditions interrupted by the European war was one to the Island of Timor, in the East Indies. This island has been a rich collecting ground for scientific study, though little has been done by the paleontologist. An opportunity was offered for making collections at Timor through the courtesy and interest of Mr. N. E. Crane, a retired engineer, of Pittsburgh, who had planned to visit the island. The fund for this enterprise was contributed by Mr. Crane, Mrs. E. H. Harriman, and Mr. Frank Springer, but the expedition has been postponed for the present.

CLEARING OF FOG BY ELECTRICAL PRECIPITATION.

The fact was long ago scientifically established that all dust and fog particles in the open atmosphere are electrified and subject to dispersion or precipitation, but how to clear fog from a street, along a railway, or from the neighborhood of a ship at sea, and to do it in a manner commercially feasible has been a matter of serious study for many years. The question having recently aroused fresh attention, particularly in the neighborhood of San Francisco, through researches planned by the University of California in cooperation with the United States Lighthouse Service, it was decided by the Smithsonian Institution during the past year to make an appropriation to further this investigation, which is under the general direction of Dr. F. G. Cottrell, who has done so much toward the practical precipitation of dust, smoke, and chemical fumes at large industrial plants. The American Institute of Electrical Engineers has also appointed a committee to cooperate in this great work, and reports on the results of the study are awaited with much interest. The essential element to success in scattering fog seems to be some form of electrical apparatus of very high direct voltage, with facilities for its control and ready application.

RESEARCH CORPORATION.

In previous reports I have called attention to the Research Corporation formed primarily to undertake the development of certain precipitation patents generously offered to the Institution by Dr. F. G. Cottrell. Although it was impracticable for the Smithsonian Institution to administer this work directly, yet there was no objection to the Secretary becoming a member of a distinct organization

that would undertake its development. An independent organization was accordingly formed in 1912 under the laws of the State of New York, the Secretary of the Institution becoming one of the directors of the Research Corporation and a member of the executive committee. The board of directors includes a number of prominent men of wide business experience, such as James J. Storrow, of Lee, Higginson & Co., Boston; Charles A. Stone, of Stone & Webster, Boston; Arthur D. Little, of the Little Chemical Co., Boston; T. Coleman du Pont, of Wilmington, Del.; Elon H. Hooker, president of the Hooker Electrochemical Co., Niagara Falls, N. Y.; Benjamin B. Lawrence, mining engineer, New York; George F. Kunz, of Tiffany & Co.; Frederick A. Goetze, dean of the engineering department of Columbia University, New York; William Barclay Parsons, engineer, of New York; and Hennen Jennings, mining engineer, of Washington.

The principal object of the corporation is to acquire inventions and patents and to make them more available in the arts and industries, while using them as a source of income, and, second, to apply all profiits derived from such use to the advancement of technical and scientific investigation and experimentation through the agency of the Smithsonian Institution and such other scientific and educational institutions and societies as may be selected by the directors.

The chief assets of the corporation at present are the Cottrell patents relating to the precipitation of dust, smoke, and chemical fumes by the use of electrical currents. Dr. F. G. Cottrell, the inventor and donor of these patents, has described their operation and advantages and the progress thus far made in their installation in an article printed in the Smithsonian Report for 1913.

There is now under consideration the acceptance and development of other patents besides those presented by Dr. Cottrell. It is planned that when the funds of the corporation received from royalties and other sources shall have reached $100,000, to apply the income "to the advancement of technical and scientific investigation and experimentation" as provided by the act of incorporation.

Owing to the wide experience of the members of the board and their standing in the business community, it has been possible to do work in connection with the Research Corporation that would have required the expenditure of large sums if undertaken by an ordinary business organization or private individual.

HARRIMAN TRUST FUND.

Aided by the income of a special fund established by Mrs. E. H. Harriman, Dr. C. Hart Merriam, research associate of the Institution, has continued and practically completed his studies of the big bears of America, so that it is now possible to determine the relations

of most of the species and to arrange them in definite groups. Of the true grizzlies there appear to be about 38 species and subspecies representing a dozen groups, and of the brown bears about 10 species, representing 5 groups. Opportunity will now be afforded for study in other fields of biological research.

THE LANGLEY AERODYNAMICAL LABORATORY.

The Langley Aerodynamical Laboratory was reopened under resolution of the Board of Regents adopted May 1, 1913, and on May 23 an advisory committee was organized, as detailed in my report for that year. In my last report I reviewed what had been accomplished up to June 30, 1914, in certain lines of investigation, including the successful flights of the Langley aeroplane built in 1898–1903, and further trials of that machine were described by Dr. A. F. Zahm in an article in the general appendix of the Smithsonian Report for 1914.

During the past year it was found necessary for legal reasons to discontinue the advisory committee as originally organized, and it therefore seemed advisable to call upon Congress to authorize the establishment of a national advisory committee for aeronautics.

Following an urgent appeal by myself and others to the Senate Committee on Naval Affairs, there was inserted in the naval appropriation act (Public, No. 271, 63d Cong.) approved March 3, 1915, the following provision for a national advisory committee for aeronautics.

* * * * * * *

An Advisory Committee for Aeronautics is hereby established, and the President is authorized to appoint not to exceed twelve members, to consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; together with not more than five additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences: *Provided*, That the members of the Advisory Committee for Aeronautics, as such, shall serve without compensation: *Provided further*, That it shall be the duty of the Advisory Committee for Aeronautics to supervise and direct the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions. In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories: *And provided further*, That rules and regulations for the conduct of the work of the committee shall be formulated by the committee and approved by the President.

That the sum of $5,000 a year, or so much thereof as may be necessary, for five years is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available, for experimental work and investigations undertaken by the committee, clerical expenses and supplies, and

necessary expenses of members of the committee in going to, returning from, and while attending, meetings of the committee: *Provided*, That an annual report to the Congress shall be submitted through the President, including an itemized statement of expenditures.

On July 27, 1914, the Institution published a report by Dr. Zahm on European aeronautical laboratories, in which he describes the buildings, equipment, and operations of laboratories in England, France, and Germany.

Although, as above stated, it was not practical to continue the advisory committee of 1913 as originally planned, nevertheless the individual members of the committee have been active in their investigations, and several valuable reports have been received, some of which are as yet confidential or incomplete, one of those being a report on wireless communications to and from air craft.

Mr. Buckingham completed and published a masterly paper on the mathematical principle governing the relations of experimental models of all sorts to those of full-scale machines. Dr. Humphreys published a long paper on the Physics of the Atmosphere. Dr. Zahm helped to design for the United States Army a 200-horsepower biplane, and published a mathematical method of analyzing the stresses sustained by such an aeroplane during flight.

At the annual meeting of the Regents on December 10, 1914, Dr. Alexander Graham Bell, Senator William J. Stone, Representative Ernest W. Roberts, Mr. John B. Henderson, jr., and Secretary Walcott were appointed a committee to consider questions relative to the Langley Aerodynamical Laboratory.

PUBLICATIONS.

The publications of the Smithsonian Institution and its branches during the year comprised a total of 6,753 printed pages, accompanied by 655 plates of illustrations, and the number of copies distributed of these various publications, both pamphlets and bound volumes, aggregated 132,010.

The Institution has for one of its primary objects the "diffusion of knowledge," and this aim is carried out by printing and distributing the results of scientific investigations, accounts of explorations and researches, of progress in the various branches of science, and of development in any phase of human endeavor which would tend to increase "knowledge among men." Of its three series of publications, the Contributions to Knowledge, Miscellaneous Collections, and the annual reports, the first two are issued in limited editions at the expense of the Institution and are sent out to libraries, institutions, and interested individuals throughout the world. The annual reports, containing in addition to the administrative reports a general appendix of original and selected papers showing the recent progress made in all branches of natural and applied science, are

printed under congressional appropriation, so that a larger edition and more widespread distribution is possible.

Under the direction of the Institution are issued the various publications of its branches, (*a*) the Annual Report, the Proceedings, and the Bulletins of the National Museum, including the series of Contributions from the National Herbarium; (*b*) the Annual Reports and Bulletins of the Bureau of American Ethnology; and (*c*) the Annals of the Astrophysical Observatory. These series are all public documents and are printed by means of annual allotments by act of Congress.

Smithsonian Contributions to Knowledge.—The requirements for memoirs in this series are that they be accounts of extended original research constituting important additions to knowledge. Since the first appearance of this series in 1848, 35 quarto volumes containing 150 memoirs have been issued, the most recent one being the "Langley Memoir on Mechanical Flight," in which are recorded the results of the late Secretary Langley's experiments establishing the practicability of heavier-than-air flying machines.

Smithsonian Miscellaneous Collections.—Fourteen papers forming parts of four volumes of this series were issued during the year, among them one paper on Cambrian geology by your Secretary. Another interesting paper was that by Messrs. Abbot, Fowle, and Aldrich recording new solar radiation researches, in the course of which free balloons carrying recording apparatus, ascended to a height of over 15 miles and were found on their descent with the records in good condition. As a result of these and other experiments, the authors abide by their former results, namely, that "the mean value of the 'solar constant' is 1.93 calories per square centimeter per minute." In this series, the sixth revised edition of the Smithsonian Physical Tables was issued, and was practically exhausted at the close of the year, showing the continued popularity and usefulness of this work. The publication of a further edition was being considered at the close of the year. The usual annual account of the Institution's explorations and field work was issued, and being profusely illustrated, was of considerable popular interest.

Smithsonian report.—The report for 1913 was received from the printer and distributed during the year. Separates of the articles forming the general appendix of the 1914 report were issued, the completed volume, however, not being received from the printer until shortly after the close of the fiscal year. Incorporated in the congressional act providing for printing for the Institution and its branches was a clause increasing the edition of the Smithsonian annual reports from 7,000 to 10,000, a very desirable change, as the edition of this volume has heretofore been exhausted almost immediately following its appearance.

Special publications.—Of the opinions rendered by the International Commission on Zoological Nomenclature, which the Institution has published for some years past, Opinion 66 was issued, and the Institution has continued to provide clerical services in connection with the office of the secretary of the commission.

Among other special publications was a short biographical sketch of James Smithson, abridged from the chapter on Smithson by S. P. Langley in the history of the first half century of the Institution.

National Museum publications.—The National Museum issued an annual report, 1 volume of the Proceedings and 41 separate papers forming parts of this and other volumes, 6 bulletins, and 1 volume of Contributions from the National Herbarium.

Bureau of Ethnology publications.—The Bureau of American Ethnology published two bulletins and three miscellaneous publications. Among the latter was a circular of information regarding Indian popular names, to be distributed in response to the numerous letters requesting information of this kind. Four annual reports and five bulletins were in press at the close of the year.

Reports of historical and patriotic societies.—The annual reports of the American Historical Association and the National Society of the Daughters of the American Revolution were submitted to the Institution and transmitted to Congress in accordance with the charters of these organizations.

Allotments for printing.—The allotments to the Institution and its branches under the head of "Public printing and binding" were utilized as far as practicable, although there was a large amount of material which the Public Printer was unable to complete, and this will therefore become a charge against the 1916 allotment.

The allotments for the year ending June 30, 1916, are as follows:

For the Smithsonian Institution: For printing and binding the annual reports of the Board of Regents, with general appendices, the editions of which shall not exceed 10,000 copies	$10,000
For the annual reports of the National Museum, with general appendices, and for printing labels and blanks, and for the Bulletins and Proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half morocco or material not more expensive, scientific books, and pamphlets presented to or acquired by the National Museum library	37,500
For the annual reports and Bulletins of the Bureau of American Ethnology and for miscellaneous printing and binding for the bureau	21,000
For miscellaneous printing and binding:	
International Exchanges	200
International Catalogue of Scientific Literature	100
National Zoological Park	200
Astrophysical Observatory	200
For the annual report of the American Historical Association	7,000
Total	76,200

Committee on printing and publication.—All manuscripts submitted for publication by the Institution or its branches have, as usual, been examined and passed upon by the Smithsonian advisory committee on printing and publication. The committee has also considered various general matters concerning printing and binding. During the year 18 meetings were held and 109 manuscripts acted upon. The personnel of the committee was as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, acting chairman; Dr. C. G. Abbot, director of the Astrophysical Observatory; Dr. Frank Baker, superintendent of the National Zoological Park; Mr. A. Howard Clark, editor of the Smithsonian Institution, secretary of the committee; Mr. F. W. Hodge, ethnologist-in-charge of the Bureau of American Ethnology; and Dr. George P. Merrill, head curator of geology, United States National Museum.

THE SMITHSONIAN LIBRARY.

The formation of a library of science was one of the earliest activities of the Smithsonian Institution and its natural growth during the last 60 or more years has resulted in the accumulation of nearly half a million works bearing on practically every branch of natural science, the fine arts, and the industrial arts. For administrative reasons a large portion of the library, consisting in the main of transactions of learned societies, was in 1866 deposited in the Library of Congress. This deposit is constantly being increased, the accessions during the past year numbering 24,713 items of publications and making the total number of entries to June 30, 1915, 521,616.

The several libraries still directly maintained by the Institution and its branches include the Smithsonian office library; the libraries of the National Museum, comprising over 100,000 titles; the Bureau of American Ethnology, about 35,000 titles; the Astrophysical Observatory; the National Herbarium; and in addition to these should be mentioned the more recently formed aeronautical library, which contains probably the most complete series of works on this subject in the United States. One of the chief contributors to this library during the year was Dr. Alexander Graham Bell, whose gift included a working library of 46 volumes and 156 volumes of newspaper clippings covering the recent years of rapid development of the art of aeronautics.

Among other accessions to the art section of the library during the year I may mention the loan by Mrs. Walcott of nine volumes of Japanese art and about 400 volumes of architectural publications which formed the library of her brother, Mr. George Vaux, of Philadelphia.

The report of the assistant librarian, appended hereto, describes the improvements recently made by the construction of steel stacks in the Smithsonian building for assembling in accessible quarters many general works belonging to the Government bureaus under the Institution which had heretofore been widely scattered in unsuitable rooms.

LUCY T. AND GEORGE W. POORE FUND.

In my last report I referred to a number of bequests then awaiting settlement. One of these was the bequest of George W. Poore, of Lowell, Mass., who died December 17, 1910, and by the terms of his will made the Smithsonian Institution his residuary legatee. As mentioned in my 1910 report, the estate, estimated at about $40,000, is bequeathed under the condition that the income of this sum should be added to the principal until a total of $250,000 should have been reached, and that then the income only should be used for the purposes for which the Institution was created. Although I have heretofore called attention to Mr. Poore's reason for making this bequest, it is so apt and appropriate that I will repeat it here. The will says:

> I make this gift not so much because of its amount as because I hope it will prove an example for other Americans to follow, by supporting and encouraging so wise and beneficent an institution as I believe the Smithsonian Institution to be, and yet it has been neglected and overlooked by American citizens.

In March, 1915, the Institution received from the executors of the Poore estate the first installment of the bequest, amounting to $24,534.92, as noted under the head of finances. It will be known as the Lucy T. and George W. Poore fund.

THE FREER COLLECTION.

In 1906 Mr. Charles L. Freer, of Detroit, Mich., presented to the Institution about 2,300 paintings and other objects of art, and from time to time since then he has supplemented that gift by further generous donations until this wonderful collection now aggregates 4,811 pieces, including 991 paintings, engravings, lithographs, etc., by American artists, and 3,820 oriental works of art, many of them of high historic and intrinsic value. It was stipulated by Mr. Freer in connection with the gift that the collection should remain in his custody during his lifetime, and that he would provide funds for the erection of a suitable building for the permanent preservation of the collection. He is now considering the question of erecting such a building and a committee of the Regents has been appointed "on the securing of a site for the Freer Art Gallery."

THE NATIONAL MUSEUM.

The report of the Assistant Secretary in charge of the National Museum, hereto appended, indicates most gratifying progress in all lines of Museum activities. To the collections there have been many large and most valuable additions, and installation of exhibits, particularly in the new or natural history building, has been greatly advanced and improved.

More than 300,000 specimens were accessioned during the year, over two-thirds of which pertained to paleontology and zoology, one-sixth to botany, and the remainder to anthropology, geology, mineralogy, textiles, and to other divisions of the Museum.

The ethnological exhibits were enriched by a large series of old Japanese art assembled some 30 years ago by the late J. Crawford Lyon; baskets, musical instruments, and other objects from Dutch Borneo, presented by Dr. W. L. Abbott; also many interesting articles pertaining to the American Indians. In American archeology the principal accession was a series of implements and other objects of stone, metal, and terra cotta from various parts of the United States and Mexico, secured through cooperation with the management of the San Diego Exposition. Dr. Alexander Graham Bell added very greatly to the electrical exhibits by his gift of 280 pieces of experimental phonographic apparatus and several relics relating to the early history of the telephone.

Special mention should also be made of the gift of Mr. Hugo Worch of a large number of pianofortes, illustrating the progress and development of piano making from about 1770 to 1850. The earliest of European pianos in the series dates from about 1770 and of American pianos about 1790. Many interesting accessions pertaining to American history are mentioned by the Assistant Secretary in his report, as also important additions to the zoological, geological, and botanical collections. A most notable contribution of mollusks, consisting of a very large collection of specimens from practically every part of the world, was a gift from Mr. John B. Henderson, a Regent of the Institution.

As in previous years, much material was received from the United States Geological Survey, the Bureau of Fisheries, the Department of Agriculture, and other Government establishments, these accumulations from various field researches having served their purpose in the preparation of reports on scientific investigations.

The National Gallery of Art has already outgrown the space allotted to the display of paintings. Each year the additions to the permanent collection of paintings, as well as the loan exhibits, causes more and more embarrassment to those in charge of their installa-

tion, and the time has now come when serious consideration must be given to securing adequate quarters for these national collections.

I can not pass without mention of the very interesting exhibition of laces, embroideries, and other art textiles, as also the historical costumes, especially those representing the several administrations at the White House since the period of President Washington. I will not attempt to describe any of the gowns recently received, further than to say that they include a lavender silk dress worn by Mrs. Fillmore, one of black moiré worn by Mrs. Pierce at the inauguration of President Pierce in 1853, and a pale green brocade worn by Mrs. Cleveland during President Cleveland's first administration.

The division of textiles has greatly increased in popular interest through the installation of a series of machines illustrating methods of manufacture as well as exhibits of the raw and finished products.

Likewise, mineral technology is being illustrated by models and products, showing the manufacture of mica plate from material heretofore thrown away as waste, the preparation of asbestos products, and the manufacture of graphite and its industrial products.

The Museum is participating in the expositions at San Francisco and San Diego, although the very small allotment allowed the Institution and its branches from the appropriation for Government exhibits permitted only a comparatively small display at San Francisco. At the San Diego Exposition, however, for which no appropriation was granted for Government exhibits, it was possible, through cooperation with the exposition management, to prepare an interesting exhibit of physical anthropology and one illustrating American aboriginal industries. The former exhibit, more fully described on a previous page, is an entirely novel one. It illustrates man's evolution, his development or growth, his racial, sexual, and individual variations, and the causes, other than normal senility, which result in the decline of the human organism.

For many years it has been possible to aid the schools and colleges of the country in their teaching of natural history through the distribution of duplicate material. During the past year 163 sets of such duplicates, aggregating 14,843 specimens, were thus distributed. And about 8,000 duplicate specimens, nearly three-fifths of which were plants, were utilized in exchanges with other museums and institutions.

The total number of visitors to the older Museum building during the year was 133,202, and to the new building 321,712. The latter aggregate includes 59,577 Sunday visitors to the new building, the older building not being open on that day.

The Museum issued its usual annual report and series of scientific papers, the total distribution for the year aggregating 54,000 volumes and pamphlets.

BUREAU OF AMERICAN ETHNOLOGY.

The field work of the Bureau of American Ethnology during the last year resulted in the accumulation of a large amount of important data relating in particular to the early inhabitants of the western and southwestern portions of the United States. There was also brought together a great deal of material bearing on the habits, customs, beliefs, institutions, ceremonies, and languages of vanishing tribes of Indians throughout the country. The report of the ethnologist-in-charge, appended hereto, reviews in detail many lines of systematic research now being conducted by the bureau. Among these I may note interesting explorations in New Mexico and Utah among ancient village sites which appear characteristic of peoples probably of a considerable earlier period than those heretofore known from those regions. Ancient earthenware collected by Dr. Fewkes in such sites in the lower Mimbres Valley in New Mexico bear decorations of animals and geometric designs in some measure resembling certain ancient paintings on the walls of caves in France. In southern Arizona are some extensive aboriginal ruins awaiting investigation, which bid fair to add much to our knowledge of the early inhabitants of that region.

Among documents preserved in the Santa Ines Mission in California there has been brought to light an old manuscript of special interest in connection with the study of the former Chumash Indians, and a complete copy of the manuscript has been made for the use of the bureau.

Special researches have been in progress for some years in the preparation of several series of handbooks relating to American Indians. One of these series, devoted to Indian languages, is in course of publication, the first volume already having been issued, under the editorship of Dr. Franz Boas. A Handbook of American Antiquities, the first part of which will soon be ready for the printer, is being prepared by Mr. W. H. Holmes. The "Handbook of American Indians North of Mexico," published some years ago, has had several reprintings, and the public demand for it still continues. A handbook in course of preparation is devoted to Aboriginal Remains East of the Mississippi.

There had been such doubt and discussion as to the probable age of certain Indian mounds in northeastern Kansas and southeastern Nebraska that it seemed important for a representative of the bureau to make an investigation of the facts in the case. This task was undertaken by Mr. Gerard Fowke. His report indicates that instead of dating back many thousands of years, as some had claimed, "it is safe to say that no earthwork, mound, lodge site, or human bones along this part of the Missouri River has been here as long as 10 centuries."

The study and analysis of Indian music is a subject to which the bureau has devoted considerable attention during the last few years, and there have already been published two bulletins on Chippewa music, which have attracted much attention in the musical world. There is now in press an extended account of "Teton Sioux Music" with transcriptions of 240 songs and about 100 illustrations; and a paper on the music of the Ute Indians is in preparation.

The collection of manuscripts pertaining to American Indians which has been accumulated by the bureau during the last 30 years now numbers about 1,700 items. Many of these manuscripts have come to be of priceless value, comprising as they do records which it would be impossible now to duplicate. There was added to this collection during the last year a number of interesting records, including a Laguna Indian dictionary, 49 Arapaho and Gros Ventre notebooks, the war record of "Sitting Bull" depicted in 55 pictographs, and a photostat copy of "A Grammar of the Pottewatomy Language."

The bureau issued two bulletins, and there was in press at the Government Printing Office at the close of the year the twenty-ninth, thirtieth, thirty-first, and thirty-second annual reports, and four bulletins. The completion of several of these works is delayed by the European war, the authors in some cases residing in belligerent countries. The distribution of publications aggregated 10,185 volumes and pamphlets. There were about 500 books added to the library, which now numbers 20,237 volumes, 13,188 pamphlets, and several thousand unbound periodicals.

ASTROPHYSICAL OBSERVATORY.

One of the principal researches by the Astrophysical Observatory during the past year was the continuation of observations as to the intensity of solar radiation at various altitudes, with a view to definitely determine the value of the solar constant of radiation. By means of sounding balloons, to which were attached automatic recording pyrheliometers, successful records were secured up to a height of 25,000 meters or about 15 miles, where the barometric pressure is only one twenty-fifth that at sea level. Director Abbot, in his report and in a special publication (Smithsonian Miscellaneous Collections, Vol. 65, No. 4, June 19, 1915), reviews the observations in solar radiation made at various altitudes from sea level up to the highest practicable mountain peak (Mount Whitney), thence in a balloon as high as man could live, thence to a height of 15 miles, and concludes that the solar constant of radiation is 1.93 calories per square centimeter per minute. Dr. Abbot discusses also the interesting fact that considerable fluctuations of the "solar-constant" values occur from day to day ranging over nearly 10 per cent between the extreme limits,

1.81 and 1.99 calories. In 1913 the radiation of the sun was 2.5 per cent below the mean, and 1 per cent above the mean in 1914. A high average value is said to be indicated for 1915. In concluding his report for the year Dr. Abbot says:

> Short-period fluctuations of solar radiation were large in 1913, but small in 1914. Associated with these quick, irregular fluctuations are found variations of contrast of brightness between the center and edges of the solar disk. Curiously enough, while greater contrast is associated with greater radiation and with numerous sun spots in the general march of the sun's activity, lesser contrast is associated with greater solar radiation in the march of the quick, irregular fluctuations of the sun's emission. This paradox points to two causes of solar radiation—the long period changes may probably be caused by changes of the sun's effective temperature attending the march of solar activity; the quick fluctuations may be ascribed to changes of the transparency of the outer solar envelope.

INTERNATIONAL EXCHANGES.

The operations of the International Exchange Service have been necessarily curtailed for some months because of the European war. The total number of packages handled during the year was 275,756, or 65,911 less than the year before, and their weight was 367,854 pounds, a decrease of 199,131 pounds. There has accumulated, moreover, a large number of packages awaiting opportunity of shipment, particularly to Austria, Belgium, Bulgaria, Germany, Hungary, Montenegro, Roumania, Russia, Servia, and Turkey, which were entirely shut out of the service at the close of the year, although correspondence is in progress to secure renewal of shipment with some of those countries.

One of the important functions of this service is the interchange of official Government documents with various countries, resulting in the building up of a most important division of the Library of Congress. During the past year there was received in this connection from the Chinese Government a set of the Imperial Institute of the Ching Dynasty and other valuable records aggregating 684 volumes.

Fifty-six full sets and 36 partial sets of United States official publications are now sent regularly to depositories abroad, in accordance with treaty stipulations and congressional resolutions. A list of these depositories and detailed statistics of the service are given in the appendix to this report.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The Smithsonian Institution has administered the United States Bureau of the International Catalogue since its organization in 1901. There are 33 of these regional bureaus located in the principal coun-

tries with a central bureau in London, where reference cards are assembled and published annually in 17 volumes covering each branch of science. During the past year there were collected and classified in the Smithsonian office and sent to London 12,386 cards of reference to the scientific literature of the United States for the year 1914, besides 14,027 references for the years 1906 to 1913, or an aggregate of 26,413 cards, making 345,349 references to American literature since 1901.

Through a minute system of classification, the equivalent of a brief digest of the subject contents of each paper, the International Catalogue places before students and investigators references to practically all the scientific literature of the world.

On account of the necessarily high cost of the annual volumes subscriptions to the series are limited as a rule to the most important institutions and libraries, where, however, the catalogue is available to everyone desiring to consult this work.

As in all lines of scientific work, the European war temporarily interferes with the finances and general work of the catalogue and the amount of literature produced in most of the countries at war is greatly curtailed.

NATIONAL ZOOLOGICAL PARK.

There was added to the collections in the National Zoological Park during the past year a number of interesting animals, including 25 species not before represented there. The total accessions aggregated 498. The census of animals on hand June 30, 1915, was 1,397 individuals, representing 151 different species of mammals, 185 of birds, and 22 of reptiles, as compared with 1,362 animals on hand July 1, 1914. The report of the superintendent of the park, on another page, records a detailed systematic list of all the animals, numbering 629 mammals, 696 birds, and 72 reptiles.

Every year since 1890, when the park was established, many specimens have been received through the individual donations of those interested in its growth. Forty-three such donors during the past year contributed 60 animals.

The total number of visitors was 794,530, an increase of about 60,000 over the year preceding, and the largest attendance in the history of the park. Among the visitors were 3,485 students from various schools and classes on special visits to the park for educational purposes.

The superintendent notes among the improvements of the year the construction of a cage and shelter house for pumas; and an out-of-doors inclosure with a small shelter house for a band of 25 rhesus monkeys which thrived there well throughout the winter.

Near the close of the year work was begun on a hospital and laboratory building, the urgent need of which was noted in my last report.

In the sundry civil act making appropriations for the fiscal year ending June 30, 1914, provision was made for the acquisition of about 10 acres of land along the western boundary of the park, but necessary legal proceedings to complete the purchase had not come to a close at the end of the year.

Among the primary objects in establishing the Zoological Park was the "instruction and recreation of the people." To this end the playground department of the District of Columbia has been allowed to install several pieces of apparatus in a meadow tract which has become a favorite resort for picnic parties.

The needs of the park become greater with the growth of the collections and the increasing popularity of the resort as an attractive public institution. The appropriations from year to year, while sufficient for absolute maintenance, have permitted the construction of but few of such permanent buildings as are needed for the adequate care of the animals. Among these urgent needs I may mention an aviary building and a building for the proper housing of elephants, hippopotami, and certain other animals now sheltered in mere temporary quarters.

Accompanying the superintendent's report is an outline map on which are indicated desirable building sites where necessary grading for that purpose would permit the desirable filling of certain ravines now practically useless.

NECROLOGY.

THEODORE NICHOLAS GILL.

Theodore Nicholas Gill was born at New York March 21, 1837, and died at Washington September 25, 1914. The following tribute to his memory was adopted at a meeting of his associates on September 26:

TRIBUTE TO THE MEMORY OF DR. GILL.

Theodore Nicholas Gill, master of arts, doctor of medicine, doctor of philosophy, doctor of laws, associate in zoology in the United States National Museum, died at Washington, D. C., September 25, 1914, in the seventy-eighth year of his age.

His associates in the Smithsonian Institution and its several branches, assembled at a meeting in his memory at the National Museum on September 26, do here record their deep sorrow in the loss of a sincere friend, profound scholar, one of America's foremost men of science, and one officially connected with the Smithsonian Institution in various capacities for more than half a century.

Trained in private schools and by special tutors in New York City, he early acquired a love for natural science which he made his life work, rising to the

highest rank in the field of zoology, and through his critical studies adding greatly to the sum of human knowledge.

As one of the founders of the Cosmos Club; as a professor in the Columbian (now the George Washington) University for more than 50 years; as a member of the American Association for the Advancement of Science, the Philosophical Society, the National Academy of Sciences, and of many other scientific societies in the United States and foreign lands, Dr. Gill was most highly esteemed and was widely known to biologists throughout the world as a man of deep and accurate learning, particularly in the study of his specialty, ichthyology. A man of phenomenal memory, familiar with many languages, he was a veritable cyclopedia of science and knew how to make plain to the layman its technical phraseology. He was a constant and willing source of information and inspiration to all who sought his aid in professional studies.

Through devotion to his chosen calling and his genial disposition Dr. Gill has left to his associates a cherished memory and a brilliant example worthy of emulation.

WILLIAM WOODVILLE ROCKHILL.

William Woodville Rockhill, former ambassador to Russia, Turkey, and other countries, one who had ably filled many other important diplomatic positions in China, Korea, and elsewhere, and had served as Assistant Secretary of State, was born in Philadelphia in 1854 and died in Honolulu, December 8, 1914. From 1888 to 1892 he conducted two scientific missions to China, Mongolia, and Tibet under the auspices of the Smithsonian Institution, resulting in a large accumulation of most interesting and important data bearing on the habits and customs particularly of the then little-known Tibetans. Much of this valuable information was embodied in his "Diary of a Journey through Mongolia and Tibet," published by the Institution. To the National Museum collections he added a large amount of ethnological material resulting from his journeys. Mr. Rockhill was intensely devoted to oriental study and had been a constant collaborator of the Smithsonian Institution throughout all his official career. At the time of his death he was en route to assume his duties as financial adviser to the Chinese Government.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

Appendix 1.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

Sir: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1915:

INTRODUCTORY.

In the last two reports the general status and arrangement of the public collections in all departments were briefly reviewed. Since then the exhibits of anthropology, biology, and geology in the new building have undergone few material changes, though they have received many important additions and there has been an improvement in the condition of a large number of specimens which needed renovation. It having become necessary to provide a place for the larger whale skeletons, which were not transferred at the time of the general moving of the zoological collections, the south hall in the second story of the west wing, previously assigned to marine invertebrates, was allotted to this purpose and the invertebrates were taken to the north side of the building on the same floor. The reinstallations necessitated by these changes were in progress at the close of the year.

The accommodations afforded by the improvised picture gallery in the north main hall have been entirely outgrown and the point has been reached where the paintings must be so crowded as to utterly destroy their effect. There is no other suitable location to which this important collection can be extended and would-be contributors find no encouragement in the conditions. The time has certainly arrived when serious consideration should be given toward providing proper means for sheltering and displaying the art treasures of the Museum, in which connection the interests of the National Gallery of Art are vitally at stake.

The work of renovation of the main hall in the Smithsonian building, which continued throughout the year, prevented the execution of the proposed plans for the enlargement and improvement of the exhibition series of the graphic arts. In the older Museum building the installations, especially in the recently reorganized divisions, steadily progressed with very measurable advancement. In

the division of textiles much material was added, many gaps were filled, and numerous novel features were introduced. In mineral technology, where the construction of models makes progress slower, the number of comprehensive educational features was nevertheless considerably increased, and so many more are in course of preparation that another year should see a wide representation of the subjects covered. Toward the end of the year a section of wood technology was established with the main object of setting forth in a manner to satisfy the artisan and the public the qualities and sources of the woods available for any purpose to which that material is put. It is not doubted that a creditable collection can soon be gathered.

COLLECTIONS.

The additions to the collections, comprised in 1,481 accessions, aggregated approximately 304,647 specimens, which were classified and assigned as follows: Anthropology, 15,140; zoology, 101,928; botany, 51,295; geology and mineralogy, 4,063; paleontology, 129,981; textiles and animal and vegetable products, 1,511; mineral technology, 607; National Gallery of Art, 122. Loans for exhibition were also received to the extent of 1,760 articles, consisting of paintings and sculptures, laces, embroideries and tapestries, costumes and other historical objects, ethnological specimens, etc. The number of lots of material sent in for examination and report amounted to 790, of which about 64 per cent were geological and 28 per cent zoological.

Among the more important gifts to the division of ethnology were a large series of old Japanese art, assembled about 30 years ago by the late J. Crawford Lyon and presented by the Misses Lyon; a collection of baskets, bark cloth, sword hilts in process of making, quivers for blowgun darts, musical instruments, and other objects, gathered in Dutch Borneo by Mr. H. C. Raven, and donated by Dr. W. L. Abbott; examples of modern Egyptian clothing contributed by Mr. Herbert E. Winlock; and interesting articles from the Plains Indians, which belonged to the late Maj. George Henry Palmer, United States Army, presented by Mrs. Palmer. A valuable series of musical instruments, household articles, tools, and other objects from the Ute Indians of the Uintah and Ouray Reservation, southeastern Utah, was purchased. The loans comprised objects from southern Mindanao, P. I., Abyssinia, Japan, China, Egypt, and Europe.

The principal accession in American archeology was secured through the cooperation of the Smithsonian Institution with the management of the Panama-California Exposition at San Diego, and comprised important series of implements and other objects of stone,

metal, and terra cotta from various localities in the United States and Mexico. Many specimens of like nature from the same countries were also received in exchange from the Naturhistoriska Riksmuseum at Stockholm, and the Bureau of American Ethnology transmitted a quantity of pottery displaying a distinct type of decoration from the lower Mimbres Valley, N. Mex. A banner stone of rose quartz, a very remarkable Indian relic and probably one of the finest examples of its kind yet brought to light, from Woodruff County, Ark., and one image of gold and two of gilded copper from Chiriqui, Panama, were purchased. The principal gifts consisted of a notable jade ax from Alta Verapaz, Guatemala, a small stone celt from Ahuachapan, San Salvador, and a clay figurine from Tepecoyo, in the same country, presented by Mr. Emilio Mosonyi, of San Salvador, and a pottery vase from a mound in Marion County, Tenn., contributed by Mr. Clarence B. Moore.

In Old World archeology there were only two relatively important accessions. The first, an exchange from Dr. Rutot, of the Royal Museum of Natural History at Brussels, consisted of 90 Neolithic stone implements from Belgium, representing the first epoch of polished stone culture in Europe, known as the "Spiennian"; the second, a gift from Mr. Herbert E. Clark, of Jerusalem, of 19 stone implements, forming a valuable addition to the present collection from Palestine.

The more important contributions in physical anthropology comprised skeletal material from a Minsi burial place on the Jersey side of the Delaware River, 3 miles below Montague, N. J., one of the most complete and carefully recorded collections of such specimens so far acquired, from Mr. George G. Heye, of New York; similar material from Alabama and Tennessee, from Mr. Clarence B. Moore; eight prehistoric skeletons and four skulls from Bohemia, from Prof. J. Matiegka, of the University of Prague; and three nearly complete and four partial human skeletons, from Montana, collected by Mr. C. W. Gilmore, of the Museum staff.

The electrical collections were enriched by a most noteworthy gift from Dr. Alexander Graham Bell, consisting of 280 pieces of experimental phonographic apparatus and several relics connected with the early history of the telephone. Under a special act of Congress, the Coast and Geodetic Survey transferred a large number of antiquated surveying instruments which are now of much historical importance; and a quantity of guns needed to fill gaps in the collection were deposited by the Navy and War Departments. Of especial interest is a gasoline automobile of 1896, presented by the Olds Motor Works.

The section of musical instruments received during the year such a contribution as places its collection among the most notable of the

kind in the world. The gift came from Mr. Hugo Worch, of Washington, D. C., a student of the history of the pianoforte in America, who has been assembling a collection of these instruments, which he offered to the Museum in order to provide for their permanent preservation. While accommodations for the entire series may not be found, 70 instruments have already been delivered, the selection following lines to best illustrate the progress and development in piano making down to about 1850. Too much praise can not be accorded Mr. Worch for this splendid donation, which now includes 24 examples of European make and 46 of American make. With few exceptions, the latter are the product of manufacturers in Philadelphia, New York, Baltimore, and Boston, and represent, among others, the names of Taws, Albrecht, Harper, Geib, Kearsing, Loud, Hisky, Osborne, Nunns, Goodrich, Stewart, Chickering, Meyer, Babcock, and Wise. The earliest of the American pianos is of date about 1790 and of the European about 1770. While in most cases the examples are no longer in playing shape, the mechanism is preserved, and some remain in excellent condition.

In the section of ceramics the more noteworthy additions consisted of two loans, one including an old porcelain rice bowl and a tea set of cloisonné on porcelain from Miss Julia H. Chadwick, the other being a collection of Chinese and Japanese porcelains from Miss Eliza R. Scidmore. The division of graphic arts received a large number of specimens mainly required for filling gaps in the collections, among the more important being illustrations of a process for color printing from photographs and of the rapid rotary intaglio process, besides many examples of lithographs, collotypes, and other prints.

The additions to the memorial collection of American history were numerous and of great variety, the most important being loans, in which were included a water-color portrait of Washington by James Peale; articles of military equipment carried by Capt. William Walton during the War of the Revolution; a silver tea service of five pieces once the property of Laura Wolcott, daughter of Oliver Wolcott, a signer of the Declaration of Independence; a pair of gold and jeweled earrings formerly belonging to Mrs. Rebecca Madison, niece of President Madison; and three gold medals and one of bronze added to the collection of Rear Admiral Robert E. Peary, United States Navy. There was also a large contribution of silver and bronze coins of the nineteenth century, issues of the United States and several foreign countries; and the collection of postage stamps, envelopes, and post cards was very materially increased.

The exhibition of historical costumes was greatly increased both by gift and loan, most noteworthy being appropriate costumes for representing four additional presidential administrations at the White

House. The earliest of these belonged to Betty Taylor, daughter of President Zachary Taylor, 1849–1850. The next, a lavender silk dress, was worn at the White House by Mrs. Fillmore, wife of President Millard Fillmore, 1850–1853. The third, a black moiré, was worn by Mrs. Pierce on the occasion of the inauguration of her husband, Franklin Pierce, March 4, 1853. The last, a pale-green brocade, was used by Mrs. Cleveland during the first administration of President Cleveland, 1885–1889.

In the section of art textiles the acquisitions, all loans, comprised over 100 pieces of lace, besides embroideries, brocades, velvets, tapestries, etc. Six tapestries of great beauty and value were also lent for a short period by Messrs. P. W. French & Co., of New York. The room containing this collection was entirely renovated and repainted, the materials were also for the most part rearranged, and where necessary new and more effective backgrounds were substituted.

As during many successive years, the Museum was indebted to Dr. W. L. Abbott for large collections of the higher animals, one made at his expense in Dutch East Borneo by Mr. H. C. Raven, the other, composed entirely of mammals, obtained by himself in Kashmir. Of no less importance was a collection from the northwest coast of Cuba, secured during an expedition by Mr. John B. Henderson, comprising at least 10,000 mollusks and other invertebrates, nearly 3,000 fishes, and many reptiles and batrachians. The Bureau of Fisheries made extensive deposits of marine invertebrates and fishes; and Mr. Arthur de C. Sowerby continued to transmit valuable series of vertebrates and insects from little known districts in China. Birds, reptiles, batrachians, fishes, and marine invertebrates from Panama were contributed by Mr. James Zetek; plants and marine invertebrates in large numbers by the Carnegie Institution of Washington; and animals of various groups by the Biological Survey.

Besides those above mentioned, interesting collections of birds were received from Ecuador and Australia. A unique accession consisted of the last of the pair of passenger pigeons which had been so long preserved in the Cincinnati Zoological Gardens, and whose death signalized the absolute extinction of this remarkable form. Additional specimens of reptiles and batrachians were obtained from Texas, California, Mexico, and Baluchistan; and of fishes from the Philippine Islands, Formosa, and Panama.

The most notable contribution of mollusks was a gift from Mr. John B. Henderson of a very large collection of selected and generally identified specimens assembled from practically every part of the world. Eight separate transfers of invertebrates by the Bureau of Fisheries were of much scientific value. Four of these consisted of material that had been studied and described and therefore contained numerous type specimens, and the remainder of new collections from

recent surveys of the steamer *Albatross* on the Pacific coast. Through the courtesy of the Carnegie Institution of Washington, about 1,000 specimens of corals from the Bahama Islands and Florida, 300 specimens from Australia, and many other marine forms were acquired. The Bureau of Entomology was the principal contributor of insects, which belonged mainly to the Hymenoptera, Diptera, and Odonata. Peruvian Diptera to the number of over 3,000, besides several hundred preparations, were presented by Dr. C. H. T. Townsend; and numerous wasps and other insects, by Dr. T. D. A. Cockerell. Two other important collections, consisting of Coleoptera and Hymenoptera, were received from Copenhagen.

The number of plants received was greater than in any of the previous 10 years except 1913. Nearly one-fourth were deposited by the Department of Agriculture, including 7,300 specimens of grasses, of which the larger part will be distributed in sets to scientific establishments. Two other noteworthy collections from the same department consisted of phanerogams from the western United States and western Canada. Important accessions otherwise obtained came from the West Indies, the Philippine Islands, China, the Canary Islands, western South America, Mexico, and several of the States.

Though the accessions in geology were not extensive, they furnished a considerable variety of valuable material. A collection from the Geological Survey was illustrative of the economic phases of the feldspar deposits of the United States. Individual gifts comprised excellent specimens of ferberite-bearing pegmatite from Arizona; tungsten ore and roscoelite-bearing sandstone from Colorado; and a sample of ferro-vanadium made from patronite ores of Minasragra, Peru; besides several slabs of marble for the exhibition series of ornamental stones. The meteorite collection was enriched by specimens from 13 falls, obtained by gift, exchange, and purchase, to which may be added fragments of 12 meteorites deposited by the National Academy of Sciences.

The most important single accession in mineralogy consisted of several hundred specimens of minerals and cut stones, including a suite of unique titantic crystals from an exhausted locality at Bridgewater, Pa., received as a bequest from the late Brig. Gen. William H. Forwood, United States Army. Among the transfers from the Geological Survey were various lots of gem minerals, in both rough and cut form, including many specimens of exceptional value, consisting for the most part of types of new species, or restudied and redescribed material from new localities. From several other sources rare and interesting examples were also obtained, such as one of the largest known nuggets of osmiridium, large crystals of phenacite, tarbuttite, roepperite, pseudomorphs from the Blue Jay Copper Mine, scheelite, large rhodonites, etc. The additions in petrology

consisted, as usual, largely of studied material, representing folio series, deposited by the Geological Survey. Mention should also be made of an interesting collection of obsidians from Iceland, presented by Dr. F. E. Wright, and illustrating his studies on the origin of spherulitic structure.

An extensive series of Devonian fossils, representing the lifelong collecting of Prof. Henry Shaler Williams, and including many faunas not previously represented in the Museum, formed the largest and most important accession in invertebrate paleontology. It was transferred by the Geological Survey, which also deposited nearly 600 specimens of type and other monographic material. Other large acquisitions consisted of about 5,000 specimens of European Paleozoic and Mesozoic fossils; some 6,000 specimens of Ordovician and Silurian fossils from Illinois, Indiana, and Kentucky; and about 5,000 Cambrian fossils from China. A series of Mesozoic sponges from Germany is especially adapted for exhibition purposes, as is also a large slab containing numerous Devonian glass sponges from New York. Additional specimens from the cave deposit at Cumberland, Md., referred to in previous reports, comprising 15 more or less complete skulls and other fragmental material, were obtained through the generous financial aid of Mr. John B. Henderson. Portions of a mastodon discovered at Winamac, Ind., indicate the existence at that place of a more or less complete skeleton, which the Museum has obtained permission to excavate. Other important contributions include 30 dinosaurian skin plates from the Lance formation in Wyoming; a composite skeleton of a dog, and three skulls and lower jaws, from the Rancho La Brea asphalt deposits at Los Angeles, Cal.; and a large part of the skeleton of the extinct swimming reptile, Mosasaurus, from Montana.

The division of textiles received so many and such variety of additions as to render an adequate summation impossible within the compass of this report. Of particular popular interest is a series of machines for ginning, drawing, spinning, and weaving cotton, which it is intended, in part at least, to provide with motive power so as to be able to actually demonstrate to the public the processes of manufacture from the raw material to the finished product. The processes in the manufacture of worsted goods and of carded woolen fabrics are also fully illustrated by a large series of specimens. Besides standard goods of cotton, wool, silk, etc., the contributions include a great array of specialties and novelties, materials recently placed upon the market, or soon to be, in satisfaction of the ever-increasing demand for new stuffs and new patterns. Printed cotton goods, printed cotton draperies, upholstery fabrics; pile fabrics for dress and decorative purpose, including beautiful examples of artificial furs; brocaded dress silks for the fall season of 1915, new printed satins,

pongees, tussah silks, trimming silks, taffeta dress silks in Mexican and Indian designs; satins, crêpes, and chiffons decorated by means of spray printing; machine and hand made laces; embroidered and brocaded Chinese silks; Cashmere shawls; the manufacture of American rugs; oilcloths—these and many samples of other goods were all well represented in the accessions of the year. Additions were also received for the historical collection of textile machinery, including several early appliances marking important stages in the development of the industry.

Following the plans outlined in a previous report, the work of preparing exhibits in mineral technology was actively carried on. The principal ones, including models and products, installed during the year were illustrative of the occurrence, mining, and treatment of rock salt for the manufacture of sodium compounds by the Solvay Process Co., of Syracuse, N. Y.; the manufacture of glass, additional to the models received the previous year, from the Macbeth-Evans Co.; the processes employed in the manufacture of gypsum as a building material at Oakfield, N. Y.; the manufacture of mica plate by a process which permits the utilization of what was formerly thrown away as waste; the occurrence, derivation, and adaptability of abrading materials; asbestos fiber and the manufacture of asbestos products; a by-product coke furnace, its operation, and products; and the manufacture of graphite and its industrial products.

THE NATIONAL GALLERY OF ART.

By a supplemental transfer executed in January, 1915, the splendid gift of Mr. Charles L. Freer, of Detroit, Mich., was increased by 110 articles, of which 8 are American and 102 oriental. The American works comprise 1 oil painting by Dwight W. Tryon, 1 oil painting and 2 silver points by Thomas W. Dewing, and 3 drawings and sketches and 1 lithograph by James McNeill Whistler. The oriental objects consist of 43 Chinese and 7 Japanese paintings, mainly panels, kakemono, and makimono; 14 pieces of pottery, of which 12 are Chinese and 1 each Rakka and Raghes; and 24 pieces of jade, 5 sculptures in stone, and 9 bronzes, all Chinese. By this addition the Freer collection now aggregates 4,811 items of American and oriental art.

The other permanent acquisitions numbered 12, of which the principal donor, as heretofore, was Mr. William T. Evans, of New York, who contributed 4 paintings and 1 bronze, namely: "Moonrise at Ogunquit," by H. Hobart Nichols; "Portrait of Mrs. William T. Evans and Son," by Henry Oliver Walker; "Portrait of William T. Evans," by Wyatt Eaton; "Portrait of Wyatt Eaton," by J. Alden Weir; and a bronze bust inscribed "William Thomas Evans

MCMIV," by J. Scott Hartley. The further contributions were as follows: "Wooded Landscape," oil painting, by Samuel Isham, received from the estate of the artist in accordance with his wish; "Fisher Girl of Picardy," oil painting, by Elizabeth Nourse, presented by Mrs. Elizabeth C. Pilling, of Washington, in memory of her husband, the late John Walter Pilling; "Full Moon," a landscape at Limache, Chile, oil painting, by Alfredo Helsby, presented by the Embassy of Chile at Washington; the original plaster model of the bronze equestrian statue of Lafayette, by Paul Bartlett, erected in the Square of the Louvre, Paris, France, in 1900, as a testimonial from the school children of the United States, presented by the artist; a bronze bust, heroic size, of Viscount Bryce, formerly ambassador of Great Britain to the United States, by Henry Hudson Kitson, presented by the artist; a full-length statue of the goddess Sappho, in white marble, typifying the Muse of Poetry, modeled between 1865 and 1870 by Vinnie Ream Hoxie and presented by Brig. Gen. Richard L. Hoxie, United States Army (retired); and the original plaster cast of the statue of The Falling Gladiator, by William Rimmer, presented by his daughter, Miss Caroline Hunt Rimmer.

The loans to the Gallery aggregated 121 paintings, 2 bronzes, and 2 plaster casts, received from 14 sources. Included in the paintings were 27 portraits by 23 artists, forming a special loan exhibition on behalf of The National Association of Portrait Painters, which was held from March 6 to April 7, 1915, a special view by invitation being given on the first evening. This exhibition, like the corresponding one of the year before, was especially noteworthy.

MEETINGS, CONGRESSES, AND SPECIAL EXHIBITIONS.

The facilities afforded by the new building for meetings, lectures, and congresses were extensively utilized. The Washington Society of the Fine Arts continued its lecture courses, which, as customary, were divided into three series, one being on "The art of to-day," another on "The decorative arts," and the third on "The romantic period of music." Seven interesting lectures on various scientific subjects were given, five under the auspices of the Washington Academy of Sciences, and two under the joint auspices of the same organization and the Biological Society of Washington. The Washington Society of the Archaeological Institute of America provided two lectures, as did also the Audubon Society of the District of Columbia.

The National Academy of Sciences during its regular annual meeting in April used the auditorium for its public sessions, which included two lectures under the William Ellery Hale foundation, and also held a conversazione in the picture gallery and rotunda. The annual meeting of The American Fisheries Society took place in Sep-

tember and October, in the course of which two lectures on the salmon industry of the Pacific coast, illustrated by moving pictures, were given. Accommodations were furnished for two conventions. The first was the twelfth annual convention of the National Rural Letter Carriers' Association, held in August, and the second a joint convention of postmasters from Delaware, Maryland, Virginia, and North and South Carolina, which met in October. Two special exhibitions of exceptional interest on July 16, consisted of illustrations of marine life below the surface of the sea at the Bahama Islands by means of moving pictures. The films were the first of their kind known to have been taken, and this was the first occasion of their public display, arranged through the courtesy of the Submarine Film Corporation.

Two receptions were given by the Regents and Secretary of the Institution, the first, on April 17, in honor of the National Society of the Daughters of the American Revolution, the second, on May 13, to the delegates to The American Federation of Arts, then in session in the city. The auditorium and other rooms were used on a number of occasions by branches of the Department of Agriculture for hearings and meetings, including a series of 12 Saturday lectures under the auspices of the Bureau of Plant Industry.

Outside of the National Gallery of Art, the only special loan exhibition of importance held during the year was one assembled under the auspices of The American Federation of Arts. It relates wholly to industrial art in the United States, was opened on May 13, and will continue until the middle of September of the current year. Favored by a very large number of contributors, including manufacturers, craftsmen, artists, and schools, it has proved one of the most notable displays of its kind ever held in this country, and, while not claiming to be complete, it is remarkably comprehensive and representative. The standard upheld is extremely high, and two things are especially emphasized—the value of beauty in design and the fine quality of artistic products now being made in America.

The Museum is participating in the two California expositions, which, beginning in January and February, respectively, will continue until the close of the calendar year 1915. For preparing Government exhibits to be shown at the larger of these, the Panama-Pacific International Exposition at San Francisco, Congress gave $500,000, of which amount the small and inadequate sum of $23,750 was allotted to the Smithsonian Institution and its branches. The representative of these, by designation of the Secretary, is Mr. W. de C. Ravenel, administrative assistant of the Museum. The display made by the Museum has, in view of the circumstance, been almost entirely restricted to ethnology, of which the most prominent features are

four large family groups, representing the Alaskan Eskimo, the Zulu-Kaffir of southern Africa, the Caribs of British Guiana, and the Dyaks of Borneo. These are supplemented by a series of 10 aboriginal dwelling groups, a large collection of artifacts, and several synoptic series illustrating the history of fire making and illumination, the jackknife, the saw, the spindle and shuttle, and the hafted and perforated stone ax. Outside of ethnology the only material exhibit is a splendid group of the common elk, or wapiti, of the Rocky Mountain region, comprising male, female, and young, but the important Museum exhibits in anthropology, biology, and geology are represented by means of an extensive series of lantern slides for use with the stereomotorgraph.

While the Panama-California Exposition at San Diego received no aid from the Government, the Museum was enabled to take part and also to derive considerable benefit through a cooperative arrangement between the management of the exposition and the Smithsonian Institution, whereby the latter assumed charge of the assembling and installation of an exhibit of physical anthropology and another illustrating certain important industries of the American aborigines. The expenses were entirely defrayed by the exposition company, which allotted $27,000 for the former subject and $5,000 for the latter. Preparations were begun in 1912, and in physical anthropology, under Dr. Aleš Hrdlička, of the Museum staff, entailed extensive explorations which were carried to many quarters of the globe. The collections as finally installed greatly surpass in richness, instructiveness, and harmony anything before attempted in this line. They are divided into four sections, illustrating, respectively, man's evolution; his development or growth; his racial, sexual, and individual variations; and the causes, outside of normal senility, which contribute to the decline of the human organism, as disease and injury. The other exhibit, prepared under the direction of Mr. William H. Holmes, head curator of anthropology, consists primarily of six lay-figure groups, representing the mining of iron ore and pigment materials, and of copper, the quarrying of soapstone, obsidian and building stone, and the arrow makers. These groups are supplemented by extensive series of the implements, utensils, and art works generally of these ancient peoples. Particular interest attaches to these collections, as they have been installed as permanent exhibits in a building specially erected as a museum feature for the city of San Diego. The benefits derived by the National Museum through its participation in this exposition consist in the division of a part of the collections, the opportunity of reproducing many novel features, and the working up and publication of the scientific results of the expeditions which were mainly into new and important fields.

MISCELLANEOUS.

Duplicate specimens of natural history to the number of 14,843, accurately classified and labeled, and put up in 163 sets, were distributed for teaching purposes among the schools and colleges of the country. They consisted mainly of rocks, minerals, ores, fossils, and recent mollusks, though other zoological groups and ethnological and archeological subjects were also represented. In making exchanges 7,927 duplicates were used, over three-fifths being plants. The number of specimens, all belonging to natural history, sent out for study by specialists located elsewhere, was 10,269, the preponderating subjects being plants, insects, marine invertebrates, and fossils.

The total number of visitors to the new building aggregated 262,135 for week days and 59,577 for Sundays, being a daily average of 837 for the former and of 1,145 for the latter. At the older Museum building the attendance for week days (the building not being opened on Sundays) was 133,202, a daily average of 425. The Smithsonian building was closed to the public during five months on account of extensive alterations in progress, and the attendance was thereby reduced to 40,324 persons.

The publications issued during the year comprised 9 volumes and 41 separate papers. The former consisted of the annual report for 1914; volume 47 of the Proceedings; volume 19 of the Contributions from the National Herbarium; and 6 bulletins, 3 of which related to paleontology and 3 to marine animals. The separate papers formed parts of volumes 47, 48, and 49 of the Proceedings. The total number of copies of Museum publications distributed was about 54,000.

The library received 2,209 volumes, 2,530 pamphlets, and 183 parts of volumes, and at the close of the year contained 45,818 volumes and 76,295 pamphlets and unbound papers, or a total of 122,113 titles.

Respectfully submitted.

Richard Rathbun,
Assistant Secretary in Charge,
United States National Museum.

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

September 27, 1915.

Appendix 2.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

Sir: Pursuant to the communication of the Acting Secretary dated July 2, I have the honor to present the following report on the operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1915, conducted in accordance with the act of Congress approved August 1, 1914, making appropriations for the sundry civil expenses of the Government, and with a plan of operations submitted by the ethnologist-in-charge and approved by the Secretary of the Smithsonian Institution. The provision of the act authorizing the researches of the Bureau of American Ethnology is as follows:

> American Ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archæologic remains, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, including payment in advance for subscriptions, $42,000.

SYSTEMATIC RESEARCHES.

As in the past, the systematic researches of the bureau were conducted by its regular staff, consisting of 9 ethnologists, including the ethnologist-in-charge, and of 10 ethnologists during part of the year. These operations may be summarized as follows:

Mr. F. W. Hodge, ethnologist-in-charge, devoted most of his attention during the year to the administration of the affairs of the bureau, but opportunity was found, with the assistance of Miss Florence M. Poast, to add materially to the compilation of the bibliography of the Pueblo Indians, which now comprises about 2,400 titles. Mr. Hodge also read several extended manuscripts submitted for publication by the bureau; he likewise continued to represent the bureau on the Smithsonian advisory committee on printing and publication and the Smithsonian Institution on the United States Geographic Board.

Dr. J. Walter Fewkes, ethnologist, at the beginning of the fiscal year brought to a close his archeological researches in the valley of the lower Rio Mimbres, N. Mex., reference to which was made in the last annual report. These studies of the many village sites of the prehistoric people of the section named lead to the belief that the

ancient habitations were not terraced community houses, such as characterize typical pueblos, but were of an older form, hence Dr. Fewkes assigns them to a period and a people which he designates pre-Puebloan. This conclusion is based not only on the character of the house structures as indicated by their ground plans, but also on the character and decoration of the pottery vessels found under the floors. The most noteworthy feature of this earthenware is the remarkable painted decoration on the inside of the bowls, consisting of representations of men engaged in various pursuits, animals, and geometric designs of exceptional forms, suggesting the culture of the Keres Indians of New Mexico rather than that of other Pueblos. A distinctive feature of some of the animal pictures on the Mimbres pottery is the fusion of two different animal forms, as the antelope and a fish, in a single representation. Dr. Fewkes suggests that the almost constant presence of rectangular and other geometric designs on the bodies of the animals depicted on the pottery may be considered in a sense parallel with certain very ancient paintings on the walls of caves in France, as described by Dr. Capitan and others. The special value of the study of the painted designs on the Mimbres pottery lies in the light which they cast on general problems connected with the culture-genesis and clan migrations of the sedentary Indians of the Southwest. These designs are related, on the one hand, to those on Pueblo painted pottery of northern New Mexico and Arizona and, on the other, to the decorations on the earthenware of the prehistoric inhabitants of the valleys of the southern part of the Sierra Madre Plateau, notably those of the celebrated Casas Grandes in Chihuahua. An illustrated preliminary report, under the title "Archeology of the Lower Mimbres Valley, New Mexico," was prepared by Dr. Fewkes and published in Smithsonian Miscellaneous Collections (Vol. 63, No. 10, pp. 1–53, pls. 1–8, figs. 1–32).

In January Dr. Fewkes visited southern Arizona, where he made several archeological reconnoissances, following the Rio Santa Cruz almost to the Mexican boundary. He visited the old Indian missions of San Xavier del Bac and Tumacacori, and in their vicinity examined extensive aboriginal ruins, which were found to belong to the same type as Casa Grande, Ariz. The group of prehistoric ruins near the dilapidated mission of Tumacacori (which imposing structure, now preserved as a national monument, is greatly in need of repair) presents unusual advantages for thorough archeological investigation, with promise of important collections. The walls of the compound can be traced readily, and if uncovered by excavation would reveal important information on the ancient culture of the Santa Cruz Valley. Similar remains were noted in other parts of this valley and elsewhere in southern Arizona. While in this general area Dr. Fewkes observed that the Papago Indians of the desert have been

little affected by civilization, retaining many of their original customs, beliefs, and ceremonies, and a wealth of folklore.

Dr. Fewkes visited also the ruins of a large pueblo compound on the road between Phoenix and Tempe, chiefly for the purpose of determining the advisability of its excavation and repair, as an effort is being made by citizens of Phoenix to preserve the ruins with a view of having the compound created a national monument and receiving adequate scientific treatment.

Leaving Arizona in February, Dr. Fewkes proceeded again to the Mimbres Valley, but found the weather unpropitious for field work except for excursions with the view of locating sites for possible future excavation. He returned to Washington about the middle of the month and continued the preparation of his memoir on "Antiquities of the West Indies," which is to include the results of archeological research conducted in the Greater and the Lesser Antilles under the joint auspices of the bureau and the Heye Museum of New York, as referred to in a previous report. In connection with this work Dr. Fewkes visited New York for the purpose of studying recently acquired collections, in the Heye Museum, illustrating the culture of the ancient inhabitants of the West Indies.

The greater part of May was devoted by Dr. Fewkes to the completion of a paper on "Prehistoric Hopi Pottery Designs," which comprises 138 manuscript pages, 12 plates, and 105 figures. In this article the author treats of the pictography on the ceramics of the ancient village dwellers of the East Mesa of the Hopi of northwestern Arizona, including the Keres and Tewa colonists of early times, as well as the designs of the more modern period. The memoir considers in detail the probable genesis of modern Hopi symbolic figures, and devotes attention also to their connection with clan and other sociologic groups.

The opening of the fiscal year found Mr. James Mooney, ethnologist, engaged in field studies among the Cherokee Indians of North Carolina, which were continued until the middle of September. Mr. Mooney devoted his efforts especially to the further collection and translation of the sacred formulas of the Indians named, together with the collection, for botanical identification, of the plants mentioned in the formulas, with others of Indian economic importance. The remainder of the fiscal year was spent by Mr. Mooney in the office, most of the time being devoted to the final elaboration of the Cherokee formulas, of varying length, originally written down by the priests of the tribe in the native Cherokee alphabet and used by them for purposes of medicine, love, hunting, fishing, agriculture, protection, etc. Each formula consists usually of a prayer or a song, or both, in an archaic and highly figurative form of the language, followed by brief directions couched in the everyday language, and

relating to the manner of the ceremony or the plants to be used in the prescription. The printed formula will consist of three parts, namely, transliteration, translation, and explanation. The glossary will comprise perhaps 4,000 words, largely archaic and otherwise unusual in form. The botanical appendix will deal with the names and uses of from 500 to 700 plants mentioned in the formulas, nearly all of which have already been collected and botanically identified. There will also be an extended chapter on Cherokee religion and mythology. Approximately a third of the transliterations and translations have been written in final form from the interlinear notebooks, and half of the work has been glossarized on cards.

Considerable time was spent by Mr. Mooney in furnishing special information for use in answering inquiries of correspondents.

Dr. John R. Swanton, ethnologist, in addition to supervising the final work incident to the publication, as Bulletin 45, of "Byington's Choctaw Dictionary," edited by himself in conjunction with Mr. H. S. Halbert, devoted attention to the study of the Creek Indians, to which reference is made in former reports. The first draft of his memoir on the Creeks is practically completed, but the amount of material was found to be so great that it has seemed best to separate it into two, if not three, sections. The first of these, embracing a discussion of the location and classification of the southern tribes, their early history, and their population, Dr. Swanton is now revising, incorporating new material and making such changes as fuller information has shown to be necessary. It is hoped that this section may be ready for publication at a comparatively early date.

Through an Alibamu Indian living in Texas the bureau has been able to add several hundred words and a few pages of text to the Alibamu material gathered by Dr. Swanton.

During the first three months of the year Mr. J. N. B. Hewitt, ethnologist, completed the translating and editing of a collection of texts and legends for the memoir on "Seneca Myths and Fiction" to be published in the Thirty-second Annual Report, consisting of material originally collected in native texts and in English by the late Jeremiah Curtin and Mr. Hewitt. This material, aggregating 2,300 pages, besides 350 notes and additions by Mr. Hewitt, was submitted early in October for publication. Subsequently, and as opportunity was afforded throughout the year, Mr. Hewitt devoted special attention to the preparation of material for a grammatical sketch of the Iroquois languages, especially as spoken by the Mohawk, Onondaga, and Cayuga, for incorporation in the "Handbook of American Indian languages."

In December Mr. Hewitt visited the Grand River Reservation in Canada for the purpose of prosecuting his studies among the Indians dwelling thereon. A serious epidemic of smallpox interfered some-

what with his work, but with the efficient assistance of Mr. William K. Loft, a Mohawk speaker, Mr. Hewitt was able to make a critical phonetic and grammatic study of portions of the Mohawk texts relating to the league of the Iroquois, recorded by him in former years. Work was also done in recording a selected list of Mohawk verbs for comparative use, and with the painstaking aid of Mrs. Mary Gibson, widow of the late noted chief John Arthur Gibson, Mr. Hewitt was able to supply the Cayuga equivalents to this list, as well as to record other vocabulary terms of the Cayuga. From Mrs. Gibson also was obtained an extended text in Cayuga relating to the origin and the ritual of the death feast of the women. On the same reservation Mr. Hewitt, with the aid of Mr. Hardy Gibson, a Cayuga chief, elucidated certain mooted points in regard to the ritual significance of a number of words and phrases employed in the chants of the condoling and installation council of the Iroquois league. From Miss Emily Carrier, a mixed-blood Nanticoke, he obtained a list of 50 Nanticoke words. This short list is of singular interest, as the Nanticoke dialect of the Algonquian stock has become practically extinct through absorption of its speakers by the Iroquois-speaking peoples. Mr. Hewitt also made about 70 photographs, principally of persons.

On his return to Washington on January 15 Mr. Hewitt at once resumed his analytic study of the Mohawk, Onondaga, and Cayuga dialects for the purpose of obtaining proper material for the preparation of the grammatic sketch above referred to.

In addition to these investigations, Mr. Hewitt furnished much information for use in preparing replies to inquiries from correspondents, some of them requiring considerable research. No fewer than 130 such letters were answered by means of data supplied by Mr. Hewitt. As in the past, he performed the duties connected with the custodianship of manuscripts, which required more than the usual time and effort owing to the preparation of more thoroughly fireproof quarters and transfer of the manuscripts thereto, as will later be mentioned. During June Mr. Hewitt was engaged in reading the first proofs of "Seneca Myths and Fiction."

Mr. Francis La Flesche, ethnologist, was engaged during the year chiefly in assembling his notes on the No^{n}'zhizho^{n}, or fasting degree, of the tribal rites of the Osage called No^{n}'ho^{n}zhi^{n}ga Ie Ita, or Sayings of the No^{n}'ho^{n}zhi^{n}ga. Of the seven degrees, the No^{n}'zhizho^{n} is said to be the longest and the next in importance to the Níkie degree; it is also said that this degree contains nearly all the symbols and ceremonial forms (wégaxe), for which reason it is regarded as higher in rank than the other degrees, excepting the Níkie. From information given by Watsémo^{n}i^{n} of the Black Bear gens and by Waxthízhi of the Puma gens, both of the Ho^{n}'ga dual division, their version of the ritual of the No^{n}'zhizho^{n} degree is composed of 116 songs, 14 wígie

(parts of the ritual that is spoken), and a number of ceremonial acts and forms. Waxthízhi, from whom the songs and wígie were obtained, gave 14 wígie and 74 songs; he was unable to give the entire 116 songs, having lost some of them by reason of long disuse of the ritual. To the close of the year 206 pages of this ritual have been completed by Mr. La Flesche: these comprise 9 wígie with literal and free translations, 25 songs with translations, and explanations of the songs, ceremonial acts, and movements, as well as of the various symbols and paraphernalia used in the ceremonies.

Mr. La Flesche's work on the No^{n}'zhizho^{n} ritual has twice been interrupted by visiting Osage, from whom, however, further information has been obtained concerning the great war rites of the Osage people. First, Wáthuxage, who visited Washington in the autumn of 1914, gave the ritual of the Waxobe degree of the Tsízhu Washtage gens, of which he was a member. The wígie and songs of this ritual cover 76 typewritten pages, including the music, which has been transcribed from the dictaphone. Besides the Waxobe ritual, Wáthuxage gave, in fragmentary form, the Níkie ritual of his gens; this covers 20 typewritten pages, including the music of the songs, which also have been transcribed from the dictaphone. The translations of the songs and wígie of these rituals have yet to be made and the explanatory texts written. Wáthuxage died in May, 1915.

The second interruption was by Xuthá Wato^{n}i^{n} and Watsémo^{n}i^{n}, from whom additional information was obtained. The former gave three of the wígie: Wígie Tonga or Great Wígie, Kíno^{n} Wígie or Symbolic Painting Wígie, and Wazhóigathe Wígie or Gentile Symbol Wígie, which it was his part to recite at the tribal ceremonies. These cover 37 typewritten pages. Besides the three wígie, Xuthá Wato^{n}i^{n} gave the ritual of the Níkie degree of his gens. The wígie and songs of the ritual, including the music, comprise 15 pages. The translations of the three wígie, and the wígie and songe of the Níkie ritual, have yet to be made and the explanatory notes assembled. Watsémo^{n}i^{n} gave another version of the Nídse Waçpe Wígie, or Black Bear Wígie, which he had already given some time ago. This new version is the one recited when the widow of a deceased member of the No^{n}'ho^{n}zhi^{n}ga is admitted to take his place in the order; it comprises 6 typewritten pages and will form a part of the No^{n}'zhizho^{n} ritual. This informant also gave some information concerning his great grandfather, who was a prominent "medicine-man." The notes recorded from the dictation of Watsémo^{n}i^{n} have yet to be transcribed. The story will form a part of the chapter on the Wako^{n}dagi, or "medicine-men."

Mrs. M. C. Stevenson, ethnologist, continued her researches among the Tewa Indians of New Mexico, but failing health prevented her

from completing the final revision of the manuscript of her memoir as she had hoped, and it remained unfinished at the time of her unfortunate death, on June 24, in the suburbs of Washington. It is believed, however, that when an opportunity of fully examining Mrs. Stevenson's completed manuscript and notes is afforded, it will be found in condition for publication after the customary editorial treatment. Mrs. Stevenson was an efficient and industrious investigator of the ethnology of the Pueblo Indians, to which subject she had devoted many years of her life, giving special attention to the Sia, the Zuñi, and the Tewa Tribes. Three memoirs on these Indians, published in the annual reports, are replete with information on the subjects of which they treat, and there is no doubt that when Mrs. Stevenson's memoir on the Tewa Indians finally appears much valuable knowledge will be added to that which she has already given on the sedentary Indians of the extreme Southwest.

With the opening of the fiscal year Dr. Truman Michelson proceeded to Wisconsin in the hope of obtaining ethnologic and linguistic information regarding the Stockbridge Indians residing in that State. It was found that, with respect to the language of this remnant tribe, about a dozen members remembered isolated words, but only one could dictate connected texts, half a dozen of which were recorded. Although knowledge of the language is now too limited to enable restoration of the grammar, enough material was obtained to show that Stockbridge was intimately related to Pequot and Natick, as well as to Delaware-Munsee. The Stockbridges have long since abandoned all their native customs and beliefs, consequently their ethnology may be regarded as beyond recovery.

While in Wisconsin Dr. Michelson procured also ethnologic and linguistic notes on the Menominee. A visit to the Brotherton Indians resulted in the acquirement of little information excepting historical data, as these people have become greatly modified.

Dr. Michelson next visited Tama, Iowa, for the purpose of renewing his researches among the Fox Indians, to which he has been devoting his energies for some time. He was especially successful in obtaining accounts of the mythical origin ascribed to the Fox people, given in the form of rituals, and he gave attention also to the phonetics of the Fox language. A noteworthy result of Dr. Michelson's Fox investigations was the acquirement, through Horace Powashiek, of a complete translation of the two most important Fox myths—the Culture Hero and Mother of All the Earth.

At the request of the Davenport Academy of Sciences, Dr. Michelson conducted some archeological excavations for that institution at its own expense, leave of absence having been granted him for that purpose. En route to Washington, he examined the Sauk and Fox collections in the Field Museum of Natural History at Chicago.

In the office, Dr. Michelson paid special attention to the observations on the Sauk and Fox by early writers, especially by the authors in the Annals of the Propaganda Fide, and by Marston, Long, Carver, Beltrami, and others. With the view of definitely settling the question of the relationship of the Yurok and Wiyot languages of California to the Algonquian linguistic stock, Dr. Michelson devoted further study to the subject, reaching the conclusion that whether or not further material would prove these languages to be divergent members of Algonquian, the existing data do not warrant such a classification. Dr. Michelson also devoted attention to the linguistic classification of Potawatomi, based on certain grammatical treatises by the late Father Gailland in possession of St. Mary's College at St. Marys, Kans., which the bureau was permitted to copy through the courtesy of Rev. George Worpenberg, S. J., librarian of the college. By these studies Dr. Michelson concludes from the verbal pronouns of Potawatomi that it belongs to the Ojibwa division of the central Algonquian languages, but that the language is further removed from Ojibwa, Ottawa, and Algonkin than any of these is from the others.

Mr. John P. Harrington, ethnologist, became a member of the staff of the bureau, with the approval of the Civil Service Commission, on February 20, from which time until the close of May he finished 600 pages of manuscript and more than 3,000 slips of linguistic information regarding the Chumash Indians of California, the result of researches conducted by him before entering the service of the bureau. He also has, in various stages of elaboration, a quantity of other Chumash ethnologic and linguistic material in the preparation of which for publication satisfactory progress is being made. At the end of May Mr. Harrington proceeded to Santa Ines Mission, where, among its documents, he found an old manuscript bearing the title "Padron que contiene todos las Neofitas de esta Mision de la Purisima Concepcion con expresion de su edad, y partida de Bautismo segun se halla hoy dia 1° de Enero de 1814," by Father Mariano Payeras, of the greatest importance to the study of the former Chumash Indians of La Purisima and Santa Ines. A complete copy of this splendid manuscript, which does not seem to have been known to historians, was made by Mr. Harrington, who also extracted a considerable amount of other material from the mission records. While at Santa Ines Mr. Harrington located the site of the former large rancheria of Nojoguí (which had not before been known), and also the site of the rancheria of Itias, mentioned in the records. On June 19 Mr. Harrington visited Arroyo Grande, where he worked for a week with a poor, sick old woman, the sole survivor of the San Luis Obispo Indians, for which reason, to use Mr. Harrington's own expression, "the words of her language are precious

beyond the power of money to buy," especially as her speech is the most archaic of all the Chumashan dialects. For the convenience of his field studies Mr. Harrington has established headquarters at Los Angeles, where he has been granted the facilities of the Southwest Museum by the courtesy of its officials.

SPECIAL RESEARCHES.

The preparation of the second volume of the "Handbook of American Indian Languages," under the editorship of Dr. Franz Boas, honorary philologist, has progressed slowly, on account of the impossibility of sending proofs to Russia, where the author of the section on the Chukchee and Eskimo resides. The chapter on Siuslaw, by Dr. Frachtenberg, has been corrected and made up in pages, forming pages 431 to 605 of the second volume. At the beginning of the year Dr. Boas concluded his collection of Kutenai material, which was studied preliminary to the writing of the grammar of this language. The texts collected by him were written out, and the completed manuscript, consisting of 263 pages of Indian texts and 269 pages of translation, has been submitted and set in type, forming 125 galleys. The texts include some material collected by the late Dr. A. F. Chamberlain, which was acquired by the bureau and was revised by Dr. Boas.

Much time has been spent by Dr. Boas in work on his memoir, "Tsimshian Mythology," to accompany the thirty-first annual report. During the fiscal year 1913–14 the tales themselves had been set up. During the year now under consideration the manuscript of the discussion of this material was completed and put in type; it forms pages 394 to 867 of the annual report. In the mechanical work of preparing the manuscript Dr. Boas was assisted by Miss H. A. Andrews, who, besides the preparation of manuscript and proof reading, did much of the laborious work of extracting and collating material needed for the investigation.

The manuscript on Eskimo mythology, intrusted to Waldemar Bogoras and accepted for publication, together with an introduction by Mr. Ernest Hawkes, is held in abeyance, owing to the impossibility at the present time of communicating with the author in Russia.

Dr. L. J. Frachtenberg, special ethnologist, left Washington on July 6, 1914, going directly to Oregon for the purpose of concluding his investigations of the language, mythology, and culture of the Kalapuya Indians, commenced during the previous fiscal year. After a short trip to the Siletz and Grand Ronde Agencies in northwestern Oregon for the purpose of interviewing all available informants, he proceeded to Chemawa, Oreg., where he conducted his Kalapuya investigations until December, and completed them at the Grand Ronde Agency between December 13 and 20, which time was

spent chiefly in the collection of linguistic material for a comparative study of the Kalapuya dialects. Special attention was given to the Yamhill and Yonkalla variations. Dr. Frachtenberg's field work proved highly successful. He obtained 30 myths, tales, historical narratives, and ethnographic descriptions, told in the various Kalapuya dialects, an unusually large amount of grammatical notes, sufficient material for a linguistic map showing the original distribution of the several Kalapuya dialects, and some data on Kalapuya ethnology. A glance at this material reveals some interesting facts: The Kalapuya Indians in former times were the most powerful and numerous family of Oregon. They claimed the whole of the fertile valley of the Willamette, extending from the Coast Range to the Cascade Mountains, their settlements reaching as far north as the present Portland and as far south as the middle course of Umpqua River, an area of approximately 12,000 square miles. These Indians were placed on the Grand Ronde Reservation in 1857, at the close of the Rogue River war. Previous tribal wars and frequent epidemics of smallpox and other infectious diseases have reduced the Kalapuya tribes to such an extent that Dr. Frachtenberg has found but a mere handful of survivors, hence the time is not far off when the stock will become extinct.

The Kalapuya family embraces a large number of tribes, the most important of which are: (1) Atfalati (or Wapato Lake), living formerly on the banks of the Tualatin River; (2) Yamhill, claiming the banks of the river of the same name; (3) Lakmayuk, who obtained their name from the river Luckiamute; (4) Marys River (Calapooia proper), whose settlements were situated along the banks of the Calapooia and Marys Rivers; (5) Yonkalla, the most southerly Kalapuya tribe; (6) Ahantsayuk, also called Pudding River Indians; and (7) Santiam, who formerly lived on the banks of Santiam River. These tribes speak varieties of the Kalapuya language, which show remarkable lexicographic diversities. Morphological differentiations exist also, but are chiefly of a phonetic nature. All differences between the dialects seem to have been caused by a geographic distribution, resulting in the three subdivisions mentioned in the last annual report. Long and continued contact of the Kalapuya Indians with white settlers has resulted in a complete breaking down of the native culture and mode of living; consequently the ethnologic data obtainable were very meager and in most cases were given as information obtained through hearsay.

In the early part of January Dr. Frachtenberg made a short trip to the Siletz Agency for the purpose of settling a few questions pertaining to Alsea phonetics. In view of the fact that the allotment made for his field researches during the fiscal year became exhausted Dr. Frachtenberg was obliged to remain in the field until the close

of June. On January 15 he resumed the work of preparing a grammatical sketch of the Alsea language, which was finished late in May; this consists of 158 sections, approximating 600 manuscript pages. During June he was engaged in typewriting this grammatical sketch, which will be published in part 2 of the "Handbook of American Indian Languages."

In addition to his field investigations Dr. Frachtenberg corrected the proofs of his grammatical sketch of the Siuslaw language, special attention being given to the insertion of the proper references taken from his Lower Umpqua texts, printed in the Columbia University Contributions to Anthropology.

Mr. W. H. Holmes continued the preparation of the "Handbook of American Antiquities" whenever his exacting duties in behalf of the National Museum permitted. Part 1 of this work is well advanced toward completion; much attention has been given to part 2, and the preparation of the numerous illustrations is well in hand.

During the month of July, Mr. Gerard Fowke was engaged, under instructions from the bureau, in making limited archeological investigations in northeastern Kansas and southeastern Nebraska, the purpose of which was to ascertain the value of certain recent determinations regarding the age of the prehistoric aboriginal occupancy of this region. Respecting the large mounds, the age of which has been under discussion, Mr. Fowke reports that three points must be taken into consideration in fixing a definite age for these remains, as follows:

1. The relics found in and around the lodge sites, except for the markings on some of the pottery, are in no wise different from those found on the sites of villages which were occupied when Lewis and Clark came through here.

2. Fairly solid bones of animals, and occasionally human bones, are found in the bottoms of the lodge sites, even where these are damp most of the year. In the pits, where such remains are preserved by ashes, this would not mean much; but where they are found in clayey earth it is evident that "thousands of years" is a meaningless term to apply to them.

3. Persons who claim these "thousands of years" for pretty much everything they find in the ground, must explain why it is that while the bones and implements of these assumed "ancients" are found in such quantities and in such good preservation, those of later Indians should have entirely disappeared.

The only tenable theory of age is the amount of accumulation in the depressions of the lodge sites. Above the clay which formed the roof, and is next to the floor now, is a depth of material sometimes, it is said, as much as 20 or even 22 inches of mingled silt, decayed vegetation, and soil from the surrounding wall. It is used as an argument of age; that as these sites are on hilltops where there can be no inwash, this depth must indicate a very remote period for their construction. But a large amount of the earth thrown out into the surrounding ring or wall will find its way back into the depression. The water will stand in them a good part of the year, and the soil remain damp even in prolonged drought; vegetation is thus more luxuriant than on the outside, and its decay will fill up rather rapidly. In addition, much sand blows

from the prairies as well as from the bottom lands, and whatever finds its way into the pit will stay there; it will not blow away again, as it would in open ground. Weeds also will catch and retain much of this dust, which would pass on over a dry surface. Consequently the allowance of an inch in a century, which is the most that advocates of great age will allow for accumulation, is too small.

The topography of the region was essentially the same when these remains were constructed as it is now. The hills and valleys were as they now exist; the erosion has been very slight as compared with that which has taken place since the loess was brought above the water to which it owes its origin. This statement is fully proved by the position of the mounds and lodge sites. Any estimate of age must be only conjecture at best; but it is safe to say that no earthwork, mound, lodge site, or human bones along this part of the Missouri River has been here as long as 10 centuries.

With regard to the discoveries of human remains at exceptional depths in loess formations on Longs Hill, near Omaha, Mr. Fowke states that excavation of the site has been so exhaustive that further investigations are out of the question, and that determinations of age, therefore, must rest, in the main at least, with the published statements of the original explorers.

During recent years observers have reported the existence of mounds and other evidences of prehistoric occupancy in western Utah; these reports, however, contained little definite information regarding the character of existing ruins and described only briefly the artifacts associated with them. The possible relationship of such remains with those of the ancient pueblo dwellers of Arizona, New Mexico, and Colorado suggested the necessity of a preliminary examination of the western Utah field, with the view of determining the nature and range of former settlements, and also the desirability of more detailed investigations. This work of reconnoissance was commenced by the bureau in May and extended through the close of the fiscal year, the field observations being made by Mr. Neil M. Judd, of the National Museum. A group of small mounds near Willard, on the northeastern shore of Great Salt Lake, were first examined. Many other mounds in this locality have been completely destroyed by cultivation during recent years, and of those remaining all show modifications resulting from recent tillage. Four mounds were selected for special investigation, and from these sufficient information was gathered to indicate the chief characteristics of the primitive dwellings over which the mounds had accumulated.

Following the work at Willard, an examination was made of certain well-defined mounds on the outskirts of Beaver City, in Beaver County, where three house sites of the Willard type were found in close proximity to larger mounds containing groups of dwellings. Two weeks' work resulted in the complete excavation of one house group comprising 16 rooms and the partial examination of a still larger group. The Beaver mounds, like those at Willard,

have resulted from the gradual accumulation of drifting sand and dust over the fallen walls of more or less permanent dwellings. Unlike the isolated structures at Willard, however, the mounds at Beaver City disclosed groups of associated rooms, arranged with some degree of regularity and exhibiting a certain unity of purpose. In each of the two groups studied, small series of contiguous rooms were uncovered, but the majority were single compartments separated from the other dwellings by varying distances. The walls of these primitive dwellings at Beaver were built of adobe, sometimes placed in wide layers but more often forming a solid mass. No openings that could be identified definitely as doors were found in any of these walls; this fact, together with the comparative abundance of circular stone slabs, leads to the belief that entrance to the dwellings was gained through roof openings which could be closed with the stone disks. Post holes in several floors, with charred fragments of cedar logs, and masses of clay bearing impressions of logs, willows, and grass, give a fairly complete indication as to the nature of the roof construction. Large timbers crossed in the direction of the shorter dimensions, their ends resting upon the side walls of the rooms; when necessary these were supported by upright timbers. The roof beams in turn supported lesser timbers with layers of willows and grass. Layers of clay, varying in thickness from 1 inch to 6 inches with the unevenness of roof materials, covered the grass, thus completing a truly substantial shelter.

Four small mounds, similar to those at Beaver City, were excavated at Paragonah, in Iron County. These contained one room only, but there are larger mounds in the vicinity whose superficial indications suggest as many if not more rooms than the group at Beaver. Twenty years ago, it is reported, there were about 100 mounds in this vicinity; to-day more than half of them have disappeared through cultivation of the soil.

A brief examination was made by Mr. Judd of several house sites overlooking the Rio Virgen, near St. George, in the extreme southwestern corner of the State. From this village eastward to Kanab only a few mounds were noted, although cowboys reported the existence of others in the vicinity of Short Creek, on the Utah-Arizona line.

From Kanab as a base, the mounds in Johnson Canyon and the small cliff houses in Cottonwood Canyon were visited and partially examined. From superficial observations the former were judged to contain the remains of house structures similar to those at Beaver and Paragonah, although the availability of suitable stone for building purposes has resulted in its partial substitution for adobe, with certain accompanying structural modifications.

Several caves in Cottonwood Canyon 12 miles westward from Kanab contained evidences of human occupancy. The walls of nearly all bear pictographs of more than ordinary interest, and three of the caves visited sheltered the remains of small dwellings, the most interesting of which is a group of four detached rooms and one circular kiva. The walls of these are of stone with a rather greater proportion of mud plaster than is common in cliff dwellings of the Southwest. The ceremonial room measures 14 feet in diameter, but, except in its lack of recesses, does not differ greatly from similar structures in ruins previously reported throughout the San Juan drainage.

Mr. Judd's preliminary observations among a limited number of ruins in western Utah indicate the former existence of a people whose dwellings developed in natural sequence from single earth-covered shelters, such as those at Willard, to groups of more permanent structures like those at Beaver, Paragonah, and elsewhere, and finally to allied cliff houses similar to those in Cottonwood Canyon. The construction of these several types of houses and the character of the artifacts found in them point to close relationship between their builders and the better-known pre-Puebloan peoples of New Mexico, Arizona, and Colorado. Whether these primitive structures in Utah actually antedate the communal dwellings in the States named or whether they represent an offshoot from the more highly developed Pueblo culture is a point not yet determined. The relationship is certain, however, and future investigation may be expected to determine its limits. It is hoped that the opportunity to continue this investigation may soon be afforded, as the progress of agriculture in most of the areas investigated by Mr. Judd is resulting in the rapid disappearance of all superficial evidences of aboriginal occupancy.

En route to Washington from Utah, Mr. Judd spent a day at the so-called "Spanish diggings," the ancient quarries in Wyoming where generations of western Indians quarried the flint and chert utilized in the manufacture of various weapons and household implements.

Excellent progress has been made in the study and analysis of Indian music, to which subject Miss Frances Densmore has devoted special attention. The principal work in this direction has been the completion of the manuscript on "Teton Sioux Music," consisting of 1,067 pages, in addition to transcriptions of 240 songs and about 100 illustrations. This material was submitted in June for publication. Miss Densmore also made considerable progress in the preparation of a paper on the music of the Ute Indians, 92 pages of manuscript, 28 transcriptions of songs, 11 analyses of songs, and 8 original photographic illustrations being submitted. This work is not yet finished.

Mr. D. I. Bushnell, jr., has continued the preparation of the "Handbook of Aboriginal Remains East of the Mississippi," under a small allotment by the bureau for this purpose, and has made steady progress. During the year circulars were addressed to county officials in those sections from which no information had been received, and good results were obtained. The thanks of the bureau are due Mr. Arthur C. Parker, State archeologist of New York, for a large body of valuable data regarding the archeological sites in New York, and to Mr. Warren K. Moorehead, of Phillips Academy, Andover, Mass., for similar information respecting aboriginal remains in the State of Maine, derived from his personal observations.

Mr. James R. Murie, as opportunity offered, continued his studies of the ceremonies of the Pawnee Indians, under a small allotment by the bureau. During the year Mr. Murie submitted, as a result of these investigations, a manuscript of 266 pages on "The New Fire Ceremony" of the Pawnee.

Dr. A. L. Kroeber, of the University of California, has made good progress in the preparation of the "Handbook of the Indians of California." At the inception of this work it was believed practicable to confine the treatment to a very limited number of pages. By reason of the great diversity in the languages and the culture of the Indians of California, past and present, however, it was found that no adequate treatment of the subject was possible within the limits originally prescribed, consequently the handbook when published will comprise approximately 200 pages. Dr. Kroeber expects to submit the manuscript in readiness for publication in the early part of 1916.

The "List of Works Relating to Hawaii" has been added to from time to time by the surviving compiler, Prof. Howard M. Ballou, of Honolulu. Mr. Felix Neumann has devoted attention to its editorial revision, but it was found at the close of the year that much work of a mechanical nature remained to be done before plans for publication could be completed.

MANUSCRIPTS.

As in the past the valuable collection of manuscripts of the bureau has been in the immediate custody of Mr. J. N. B. Hewitt, whose work in this direction was considerably increased by reason of the necessity of returning the manuscripts to the newly fireproofed room in the north tower of the Smithsonian building and reclassifying them. For the first time the manuscripts of the bureau, which now number about 1,700 items, many of which are of priceless value, are believed to be safe from possible fire, being contained in steel cases or on steel shelves, surrounded by brick, cement, and terra-cotta walls, floor, and ceiling. In addition to manuscripts submitted for imme-

diate publication or elsewhere referred to in this report, the following accessions were made during the year:

Laguna Indian Dictionary. Deposited by the wife and son of the late John B. Dunbar, of Bloomfield, N. J.

Dr. A. L. Kroeber. Forty-nine Arapaho and Gros Ventre notebooks, six packages of slips containing an Arapaho vocabulary, and a carbon copy of a study of Arapaho dialects.

War record of Sitting Bull, depicted in 55 pictographs, with a letter of authentication. Deposited by Dr. D. S. Lamb, of the Army Medical Museum.

J. P. Dunn. The third part of the translation of the anonymous Miami-Peoria Dictionary, the original of which is in the John Carter Brown Library at Providence, R. I.; 36 pages, *Assomer* to *Bercer*.

Photostat copy of "A Grammar of the Pottewatomy Language," by Rev. Maurice Gailland, the original of which is in possession of St. Mary's College at St. Marys, Kans.; 452 pages.

Note should here be made of the great usefulness of the photostat apparatus acquired by the bureau during the last fiscal year, which has enabled the photographic copying at slight cost of various manuscripts, field notes, and rare books and pamphlets needed for reference in the researches of the bureau. These copies have been made in the photographic laboratory of the bureau by Mr. Albert Sweeney, assistant to Mr. De Lancey Gill, illustrator.

PUBLICATIONS.

The editorial work of the bureau has been continued by Mr. J. G. Gurley, editor, who from time to time has been assisted by Mrs. Frances S. Nichols. The publications issued during the year were:

Bulletin 46. "Byington's Choctaw Dictionary," edited by John R. Swanton and Henry S. Halbert.

Bulletin 58. "List of Publications of the Bureau," which appeared in August, 1914, with a second impression in May, 1915.

Miscellaneous publications:

No. 10. Circular of Information Regarding Indian Popular Names.

No. 11. Map of Linguistic Families of American Indians North of Mexico. This map, which is a revision of the linguistic map published in Bulletin 30 (Handbook of American Indians), was reprinted in advance from the plate in the report on "Indian Population in the United States and Alaska," subsequently published by the Bureau of the Census.

No. 12. List of Indian words denoting "man," prepared in placard form for use in the Smithsonian exhibit at the Panama-Pacific Exposition.

The status of other publications now in press is as follows:

Twenty-ninth annual report. The "accompanying paper" of this report is "The Ethnogeography of the Tewa Indians," by J. P. Harrington, a work presenting many technical difficulties. The solution of these was retarded by the illness of the author, which resulted in his incapacity for several months to deal with the various questions arising in connection with the text. The reading of the proof has been carried forward as rapidly as circumstances would permit, and at this time the entire report is paged with exception of the list of

place names, 2,650 in number, and the index. Considerable progress has been made in the final reading of the page proof. The number of pages in the volume (estimated) will be 660, with 21 plates, 31 maps, and 1 diagram.

Thirtieth annual report. This report, which contains as "accompanying papers" "The Ethnobotany of the Zuñi Indians," by Mrs. M. C. Stevenson, and "Animism and Folklore of the Guiana Indians," by Walter E. Roth, has been "made up" and read through three page proofs. At the end of the year the report (453 pages) was practically ready for the bindery.

Thirty-first annual report. With this report is incorporated a memoir on "Tsimshian Mythology," by Dr. Franz Boas. Of this material less than half (365 pages) had been paged at the beginning of the fiscal year. With the progress of the work a large amount of new matter has been inserted, necessitating considerable revision from time to time and the reading of several galley and page proofs of the greater part of the memoir. At this writing the make-up has been carried through page 682, and Dr. Boas looks forward to paging the remaining material at an early day. The memoir will contain in all about 850 pages, with 3 plates and 24 text figures.

Thirty-second annual report. The memoir accompanying this report is entitled "Seneca Fiction, Legends, and Myths," the material of which was collected by the late Jeremiah Curtin and J. N. B. Hewitt and edited by the latter. The manuscript reached the bureau for publication about the middle of October and when the fiscal year closed more than one-fourth (82 galleys) had been set up. The number of pages will approximate 900.

Bulletin 40. "Handbook of American Indian Languages," part 2 (Boas). During the year two sections of the above-named handbook have received attention—the Chukchee (Bogoras) and the Siuslaw (Frachtenberg). After the former had been put into page form to the extent of 50 pages work thereon had to be suspended by reason of the impossibility of communicating with the author of the section, who is in Russia. The Siuslaw section (75 galleys) is now at the Government Printing Office for paging. Two of the "illustrative sketches" of part 2 of this bulletin, namely, Takelma (Sapir), 298 pages, and Coos (Frachtenberg), 133 pages, have already appeared in separate form.

Bulletin 55. "The Ethnobotany of the Tewa Indians" (Robbins, Harrington, and Freire-Marreco). After the manuscript of this bulletin had been prepared by the other authors here named and had passed into galley proof, Miss Freire-Marreco incorporated therewith additional material to the extent of greatly enlarging and practically recasting the memoir. Subsequently, on account of the European war it was found impracticable to get from Miss Freire-Marreco the proof sent to her for correction and in the absence of her revision the task of putting the bulletin into final form has proved difficult. Half of the material, however, has been paged and it will be possible to complete the work in the near future.

Bulletin 57. "An Introduction to the Study of the Maya Hieroglyphs" (Morley). The first proof of this publication bearing the author's corrections reached the bureau the middle of September. Since then two additional proofs have been revised, the character of the material being such as to require great care and exactness in the work. The author is now engaged in a final reading of the pages. Unfortunately the progress of the work has been delayed several months by his absence in Central America. The volume will contain, when completed, about 320 pages, with 32 plates and 85 figures.

Bulletin 59. "Kutenai Tales" (Boas and Chamberlain). The manuscript of this bulletin was received in March and, after being edited, was placed in the hands of the Public Printer. By the middle of June the first proof, complete (125 galleys), had been forwarded to Dr. Boas.

Bulletin 61. "Teton Sioux Music" (Densmore). The material of this bulletin, comprising 1,067 pages of manuscript, and copy for 80 plates, 20 text figures, and 263 folios of music, was approved for publication in June, too late for inclusion by the Printing Office under the bureau's allotment for this fiscal year.

As during the last few years, the correspondence arising from the large demand for the publications of the bureau has been in the immediate charge of Miss Helen Munroe and Mr. E. L. Springer, of the Smithsonian Institution, assisted during part of the year by Mr. Thomas F. Clark, jr., and later by Mr. William A. Humphrey. The distribution has been made, in accordance with law, by the superintendent of documents on order of the bureau. The total number of publications issued during the fiscal year was 10,185, distributed as follows:

Annual reports	1,239
Bulletins	8,515
Contributions to North American Ethnology	25
Introductions	8
Miscellaneous	398
Total	10,185

This total shows a decrease of 2,634 volumes in comparison with the year 1913–14, due largely to the retention in the transmission of certain publications to Europe by reason of the war.

ILLUSTRATIONS.

The preparation of illustrations for the publications of the bureau and of photographic portraits of the members of visiting Indian deputations has continued in charge of Mr. De Lancey Gill, illustrator, assisted by Mr. Albert Sweeney. The photographic work during the year may be classed as follows:

Portrait negatives of visiting delegations (Crow, Osage, Chippewa, and Sioux Tribes)	10
Negatives of ethnologic subjects to illustrate publications	52
Development of negatives exposed by field parties	548
Photographic prints for distribution and for office use	690
Photographic prints for publication and for office use	120
Photographic prints for exhibition purposes	115
Small photographic prints distributed chiefly for scientific purposes	350
Drawings prepared for illustrations	30
Photostat copies (pages) of books and manuscripts	1,452

In addition Mr. Gill gave the usual attention to the critical examination of engraver's proofs of illustrations designed for the publications of the bureau, submitted by the Public Printer.

In the last report mention was made of a series of photographs of Indian subjects that has been exhibited successively by the New York Public Library, the Library Commission of Indiana, and the Providence Public Library. In September, 1914, in response to the

request of the Public Library of Haverhill, Mass., this series of pictures was sent for public exhibition in that library. In addition, collections of photographs of Indian subjects, designed to illustrate in part the work of the bureau, were sent for exhibition at the Panama-Pacific Exposition in San Francisco and at the Panama-California Exposition in San Diego.

LIBRARY.

The reference library of the bureau has been in the continuous charge of Miss Ella Leary, librarian, assisted by Mrs. Ella Slaughter until her death on November 1, 1914, and subsequently by Charles B. Newman, messenger boy. During the year 997 books were accessioned, but of this number only 448 were newly acquired, the remainder being represented by the binding and by entry on the records of serial publications that had been in possession of the bureau for some time. Of these accessions 138 volumes were acquired by purchase and 310 by gift or through exchange. The serial publications currently received number about 700, of which only 17 are obtained by subscription, the remainder being received by exchange of the bureau's reports and bulletins. Of pamphlets, 294 were acquired. The number of volumes bound was 678. The library contained 20,237 volumes, 13,188 pamphlets, and several thousand unbound periodicals at the close of the year. The number of books borrowed from the Library of Congress for the use of the staff of the bureau in prosecuting their researches was about 450.

The new steel bookstacks in the eastern end of the main hall of the Smithsonian building, referred to in the last annual report, were finished and placed at the disposal of the bureau in August, when the work of reinstallation of the library was undertaken by the librarian and promptly carried to completion. The facilities afforded by the new stacks are an improvement over those of the old library equipment, while safety is greatly increased.

COLLECTIONS.

The following collections were acquired by the bureau or by members of its staff and transferred to the National Museum, as required by law:

Model of Cherokee packing basket from the East Cherokee Reservation, Swain County, N. C. Collected by James Mooney, Bureau of American Ethnology. (57699.)

179 archeological objects from the lower Mimbres Valley and an earthenware vase from Casas Grandes, Chihuahua, Mexico. Collected by Dr. J. Walter Fewkes, Bureau of American Ethnology. (57777.)

Three stone figurines from the Tewa Indians of New Mexico. Collected by Mrs. M. C. Stevenson, Bureau of American Ethnology. (58129.)

Snipe flute of the Sioux Indians. Received from Rev. A. McG. Beede, of North Dakota. (58254.)

Five archeological objects from Virginia. Gift of Dr. W. B. Barham, of Newsoms, Va.; and a necklace presented by Mrs. J. R. Kello and her daughter, Miss Hattie Kello. (58177.)

PROPERTY.

The most valuable property of the bureau consists of its library (of which brief statistics have been given), a collection of unpublished manuscripts, and several thousand photographic negatives. Comparatively little of this material could be duplicated. The other property of the bureau is described in general terms in the last annual report. The total cost of furniture, typewriters, and other apparatus acquired during the fiscal year was $553.35.

MISCELLANEOUS.

QUARTERS.

The quarters of the bureau have been improved by the completion of the library bookstacks, previously referred to, and the installation of additional electric lights in the library and in one of the office rooms.

PERSONNEL.

The personnel of the bureau has been changed by the appointment of Mr. John P. Harrington, ethnologist, on February 20; the death of Mrs. Matilda Coxe Stevenson, ethnologist, on June 24; the death of Mrs. Ella Slaughter, classified laborer, on November 1, 1914; the transfer of Thomas F. Clark, jr., to the National Museum; the appointment of William Humphrey, stenographer and typewriter; and the appointment of Dennis Sullivan, messenger boy. The correspondence of the bureau and other clerical work has been conducted with the assistance of three clerks and a stenographer and typewriter.

Respectfully submitted.

F. W. Hodge,
Ethnologist-in-Charge.

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

Appendix 3.

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, 1915:

The system of international exchanges is based on the convention and the resolutions of Congress briefly referred to below:

Convention between the United States and several other countries for the international exchange of official documents and scientific and literary publications, concluded at Brussels in 1886 and proclaimed by the President of the United States in 1889. (Stat., XXV, 1465.) (Since the ratification of this convention, several additional Governments have signified their adherence thereto; while a number of other countries, though they have not officially adhered to the convention, have established international exchange bureaus.)

Resolution providing for the exchange of certain public documents, approved March 2, 1867. (Stat., XIV, 573.) This resolution provides that 50 copies of all documents printed by order of either House of Congress, and also 50 copies of all publications issued by any bureau or department of the Government, shall be placed at the disposal of the Joint Committee on the Library for exchange with foreign countries through the agency of the Smithsonian Institution.

Joint resolution to regulate the distribution of public documents to the Library of Congress for its own use and for international exchange, approved March 2, 1901. (Stat., XXXI, 1464.) By this resolution it is provided that, in lieu of the 50 copies of the publications referred to in the above-mentioned resolution, there shall be placed at the disposal of the Library of Congress for its own use and for international exchange 62 copies of such documents, with the privilege, at the request of the Librarian, of enlarging this number to 100.

Joint resolution for the purpose of more fully carrying into effect the convention concluded at Brussels in 1886 in reference to the immediate exchange of the official journal, approved March 4, 1909. (Stat., XXXV, 1169.) This resolution provides that such number as may be required, not exceeding 100 copies, of the daily issue of

the Congressional Record shall be supplied to the Library of Congress for distribution, 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 estimate submitted for the support of the service during 1915 was $32,200, including the allotment for printing and binding, and this amount was granted by Congress. The repayments from private and departmental sources for the transportation of exchanges aggregated $4,819.41, making the total available resources for carrying on the Exchange Service $37,019.41.

During the year 1915 the total number of packages handled was 275,756, a decrease of 65,911, as compared with the preceding year. The weight of these packages was 367,854 pounds, a decrease of 199,131 pounds. These decreases were caused by the suspension of shipments to a number of countries on account of the European war, as explained below.

The number and weight of the packages of different classes are indicated in the following table:

	Packages.		Weight.	
	Sent.	Received.	Sent.	Received.
			Pounds.	*Pounds.*
United States parliamentary documents sent abroad	135,050		74,126	
Publications received in return for parliamentary documents		2,305		5,817
United States departmental documents sent abroad	73,634		145,549	
Publications received in return for departmental documents		4,976		9,389
Miscellaneous scientific and literary publications sent abroad	39,164		80,448	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		20,627		52,525
Total	247,848	27,908	300,123	67,731
Grand total	275,756		367,854	

It should be added that the disparity between the number of packages dispatched and those received in behalf of the Government is not so great as indicated by these figures. Packages sent abroad usually contain only a single publication each, while those received in return often comprise many volumes. In the case of publications received in exchange for parliamentary documents and some others the term "package" is applied to large boxes containing a hundred or more publications. No lists of these are made in the Exchange Office, as the boxes are forwarded to their destinations unopened. It is also a fact that many returns for publications sent abroad reach their destinations direct by mail and not through the Exchange Service.

Of the 1,653 boxes used in forwarding exchanges to foreign agencies for distribution, 220 contained full sets of United States official documents for authorized depositories and 1,433 were filled with departmental and other publications for depositories of partial sets and for miscellaneous correspondents. The total number of boxes sent abroad during 1915 was 812 less than the preceding year. This decrease was due to the suspended shipments to certain countries owing to the inability of the Institution to secure transportation facilities for forwarding consignments to the various exchange agencies, which condition has been brought about by the European war.

Owing to the disturbed conditions which existed in Europe and the interruption to transportation facilities, shipments to all European countries were suspended during August and a part of September, 1914. On September 17 transmissions were resumed to Great Britain, and during the month of October to Denmark, Holland, Italy, Norway, Portugal, Spain, and Sweden. Through the courtesy of the minister of the Netherlands at Washington, arrangements were made to send consignments to Switzerland by way of Rotterdam, and transmissions to that country were resumed on November 2. On December 8 shipments were resumed to Greece, and on January 23 to France. At the close of the fiscal year, therefore, the only countries to which shipments were not being made were Austria, Belgium, Bulgaria, Germany, Hungary, Montenegro, Roumania, Russia, Serbia, and Turkey. Steps are being taken through the Department of State to send exchanges for Germany to the American consul general at Rotterdam for reforwarding to the German exchange agency in Berlin, and it is hoped that the exchange of publications with Germany will be resumed at an early date. Through the assistance of the Department of State, arrangements have also been made for the forwarding of exchange consignments from Germany to the United States through the American consul general at Rotterdam.

The Russian Commission of International Exchanges was approached with a view to sending exchange consignments to Petrograd by way of Archangel during the summer months, but the commission replied that, as the route in question presents so many difficulties and is so encumbered, it would prefer not to make use of it, and not to renew the sendings until after the conclusion of peace and the reestablishment of the regular communications.

The number of boxes sent to each foreign country and the dates of transmission are shown in the following table:

Consignments of exchanges for foreign countries.

Country.	Number of boxes.	Date of transmission.
Argentina	44	July 16, Sept. 9, Nov. 17, Dec. 17, 1914; Jan. 27, Feb. 26, Apr. 22, May 20, June 22, 1915.
Austria	10	July 8, 1914.[1]
Belgium	5	July 11, 1914.[1]
Bolivia	6	Oct. 8, Dec. 10, 1914; Jan. 28, May 10, June 16, 1915.
Brazil	33	July 16, 20, Oct. 19, Nov. 18, 20, Dec. 17, 1914; Jan. 27, Feb. 26, Apr. 22, May 20, June 22, 1915.
British Colonies	24	July 31, Sept. 17, 25, Oct. 26, Nov. 7, Dec. 5, 1914; Jan. 2, 16, 23, Feb. 6, Mar. 8, 20, Apr. 20, May 1, 29, June 12, 19, 1915.
British Guiana	4	Oct. 31, 1914; Mar. 12, May 7, 1915.
Canada	....	July 20, Nov. 20, 1914; Jan. 21, Mar. 31, May 29, 1915.
Chile	23	July 16, Oct. 19, Nov. 18, Dec. 17, 1914; Jan. 28, Feb. 26, Apr. 23, May 20, June 22, 1915.
China	32	Oct. 28, Nov. 4, 1914; Jan. 2, 30, Mar. 2, Apr. 12, May 13, June 12, 1915.
Colombia	15	Oct. 20, Dec. 17, 1914; Jan. 28, Feb. 27, May 15, June 16, 1915.
Costa Rica	12	Oct. 21, Dec. 17, 1914; Jan. 28, Feb. 27, May 5, June 16, 1915.
Cuba	5	July 20, Nov. 20, 1914; Jan. 21, Mar. 31, May 29, 1915.
Denmark	32	July 24, Oct. 10, Nov. 12, Dec. 14, 1914; Jan. 14, Feb. 20, Mar. 30, May 4, June 4, 1915.
Ecuador	6	Oct. 31, Dec. 17, 1914; Jan. 28, Feb. 27, May 5, June 16, 1915.
Egypt	11	July 24, Nov. 16, 1914; Jan. 12, May 22, June 23, 1915.
France	292	July 3, 1914; Jan. 23, Feb. 23, Apr. 30, May 14, 29, June 14, 1915.
Germany	6	July 7, 1914.[1]
Great Britain and Ireland	347	July 3, 11, 18, 31, Sept. 17, 25, Oct. 26, Nov. 7, 23, Dec. 5, 12, 19, 26, 1914; Jan. 2, 9, 16, 23, 30, Feb. 6, 13, Mar. 12, 27, Apr. 20, 24, May 1, 8, 15, 22, 29, June 5, 12, 19, 26, 1915.
Greece	11	Oct. 9, Dec. 8, 1914; Mar. 13, May 10, June 22, 1915.
Guatemala	5	Oct. 31, 1914; Jan. 28, Feb. 27, May 7, June 17, 1915.
Haiti	5	July 20, Nov. 20, 1914; Jan. 21, Mar. 31, May 29, 1915.
Honduras	5	Oct. 31, 1914; Jan. 28, Feb. 27, May 7, June 17, 1915.
Hungary	3	July 8, 1914.[1]
India	62	July 3, 16, 31, Sept. 17, 25, Oct. 26, Nov. 7, Dec. 5, 26, 1914; Jan. 16, 30, Feb. 6, 13, Mar. 8, 20, Apr. 10, 24, May 1, 8, 15, 22, 29, June 12, 19, 26, 1915.
Italy	91	July 18, Oct. 7, Nov. 12, Dec. 11, 1914; Jan. 13, Feb. 12, Mar. 11, Apr. 12, May 11, 25, June 11, 25, 1915.
Jamaica	6	Oct. 8, Dec. 8, 1914; Jan. 28, Mar. 12, May 10, June 22, 1915.
Japan	54	July 15, Nov. 28, Dec. 22, 1914; Jan. 26, Feb. 26, May 4, June 4, 1915.
Korea	5	Jan. 2, Mar. 12, May 12, June 22, 1915.
Liberia	4	July 24, Nov. 16, 1914; Mar. 12, May 12, 1915.
Lourenço Marquez	2	Dec. 10, 1914; Mar. 10, 1915.
Manitoba	5	July 20, Nov. 20, 1914; Jan. 21, Mar. 31, May 29, 1915.
Mexico	5	July 20, Nov. 20, 1914; Jan. 21, Mar. 31, May 29, 1915.
Netherlands	38	Oct. 12, Nov. 3, Dec. 9, 1914; Jan. 6, Feb. 10, Mar. 10, Apr. 13, May 13, 27, June 14, 26, 1915.
New South Wales	26	July 14, Oct. 2, Nov. 14, Dec. 15, 1914; Feb. 24, Apr. 8, May 8, June 8, 1915.
New Zealand	26	July 14, Oct. 2, Nov. 14, 1914; Feb. 24, Apr. 9, May 8, June 8, 1915.
Nicaragua	5	Oct. 31, 1914; Jan. 28, Feb. 27, May 7, June 17, 1915.
Norway	23	July 24, Oct. 10, Nov. 12, Dec. 14, 1914; Jan. 14, Feb. 20, Mar. 30, May 4, June 4, 1915.

[1] Shipments temporarily suspended on account of the European war.

Consignments of exchanges for foreign countries—Continued.

Country.	Number of boxes.	Date of transmission.
Ontario	5	July 20, Nov. 20, 1914; Jan. 21, Mar. 31, May 29, 1915.
Palestine	1	June 30, 1915.
Paraguay	6	Oct. 31, Dec. 4, 1914; Jan. 28, Feb. 27, Mar. 12, May 5, 1915.
Peru	19	July 16, Oct. 20, Nov. 18, Dec. 17, 1914; Feb. 27, Apr. 20, May 20, June 22, 1915.
Portugal	16	July 24, Oct. 9, Nov. 12, Dec. 14, 1914; Feb. 20, Mar. 30, May 4, June 4, 1915.
Quebec	5	July 20, Nov. 20, 1914; Jan. 21, Mar. 31, May 29, 1915.
Queensland	17	July 14, Oct. 2, Nov. 14, Dec. 15, 1914; Feb. 24, Apr. 9, May 8, June 8, 1915.
Russia	9	July 9, 1914.[1]
Salvador	5	Oct. 31, 1914; Jan. 28, Feb. 27, May 7, June 17, 1915.
Siam	4	Dec. 10, 1914; Mar. 12, May 12, June 22, 1915.
South Australia	23	July 14, Oct. 2, Nov. 14, Dec. 15, 1914; Jan. 20, Feb. 24, Apr. 9, May 8, June 8, 1915.
Spain	24	Oct. 9, Nov. 16, 1914; Jan. 12, Feb. 17, May 7, June 7, 1915.
Sweden	59	July 9, Oct. 15, Dec. 1, 1914; Jan. 6, Feb. 10, Mar. 10, 19, Apr. 29, May 26, June 24, 1915.
Switzerland	42	July 11, Nov. 2, Dec. 8, 1914; Feb. 9, Mar. 11, Apr. 28, May 14, 28, 1915.
Syria	2	July 25, Oct. 28, 1914.[1]
Tasmania	14	July 18, 31, Sept. 25, Oct. 26, Nov. 7, Dec. 5, 1914; Jan. 2, 16, Feb. 13, Apr. 20, June 19, 1915.
Trinidad	5	Oct. 8, Dec. 10, 1914; Jan. 25, May 10, June 22, 1915.
Turkey	3	July 25, Oct. 28, 1914.[1]
Union of South Africa	30	July 23, Oct. 30, Dec. 10, 1914; Jan. 12, Feb. 16, Apr. 30, May 27, June 25, 1915.
Uruguay	17	July 16, Oct. 20, Nov. 18, Dec. 17, 1914; Jan. 28, Feb. 27, Apr. 23, May 20, June 22, 1915.
Venezuela	11	Oct. 20, Dec. 17, 1914; Jan. 28, Feb. 29, May 5, June 16, 1915.
Victoria	25	July 14, Oct. 2, Nov. 14, Dec. 15, 1914; Jan. 20, Feb. 24, Apr. 8, May 8, June 8, 1915.
Western Australia	20	July 3, 31, Sept. 17, 25, Oct. 26, Nov. 7, Dec. 5, 12, 1914; Jan. 16, 23, Feb. 6, 13, Mar. 8, 20, Apr. 20, June 12, 1915.
Windward and Leeward Islands.	3	Dec. 10, 1914; Mar. 12, June 22, 1915.

[1] Shipments temporarily suspended on account of the European war.

With the exception of one package for the chief secretary to the government of Madras, India, and one for the undersecretary to the government of the United Provinces, Allahabad, India—each containing 12 United States governmental documents—no consignments have, so far as the Institution has been informed, been lost during the year, which is considered remarkable in view of the number of ships sunk by war vessels.

A number of boxes have been detained at several ports of debarkation owing to the fact that the vessels on which they were forwarded have been interned. Wherever possible the Institution has obtained the release of these consignments and they have been

sent forward to their destinations. At the close of the year one box for Sofia, one for Serbia, and two for Syria, all forwarded from New York July 2, 1914, per steamship *Barbarossa*, were held at Bremen, Germany, and four boxes for Pretoria, forwarded from New York July 10, 1914, per steamship *Rauenfels*, were held at Bahia, Brazil. With the exception of the latter, these consignments will probably be held until the close of the war. The Institution is endeavoring to have the boxes for the Government Printing Works at Pretoria released and forwarded from Bahia to destination.

During the year the Institution has obtained for the Library of Congress from the Chinese Government, in exchange for the full series of United States official documents sent to China, a set of the Imperial Institutes of the Ching Dynasty and of the Imperial Records Relative to the Suppression of Rebellions. These valuable works comprise a total of 684 volumes. Many other foreign governmental documents have been obtained through the Exchange Service for the Library of Congress. In special instances, when requested to do so, the Institution has used the facilities of the Exchange Service to procure publications for both foreign and domestic governmental and scientific establishments. Quite a number of requests of foreign organizations for publications have been received from American consular officers through the Department of State.

Owing largely to the efforts of Mr. Vittorio Benedetti, recently appointed chief of the Italian office of International Exchanges, the service between Italy and the United States has been very much improved during the year. Mr. Benedetti has presented the Institution with a typewritten copy of an account prepared by him of the origin and development of the International Exchange Service. A translation will be made of this interesting document and placed in the archives of the exchanges for reference.

The act making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1916, included a provision authorizing the Government branches under the direction of the Smithsonian Institution to exchange typewriters, adding machines, and other labor-saving devices in part payment for like articles. This office exchanged four typewriting machines during the year.

The multigraph duplicating machine supplied by the Institution, which has been in use in the Exchange Office since 1908, has been replaced by a new machine. This multigraph, with stand, cost $283.50, and was purchased from the appropriation for the International Exchanges. It has been found to be very useful in the printing not only of circular letters, but of envelopes, labels, and other forms.

The walls, ceilings, floors, and woodwork of the government and shipping rooms were painted during the year and the government room was provided with a large sorting table 27 feet 3 inches long, 2 feet 10½ inches wide, and 3 feet high, with drop leaf at end and two drawers and shelves. There are only two windows in the government room, and on account of the thickness of the walls of the Smithsonian Building these admitted very little light. The windows in that room have therefore been splayed, with the result that the lighting has been greatly improved.

Another room has been assigned by the Institution for the use of the Exchange Office, which has facilitated the handling of the many packages received for transmission through the service.

The unsatisfactory electric lighting system throughout the Exchange Office has been very much improved by the installation of a semi-indirect lighting system. The washroom provided for the use of the employees has been fitted up with two lavatories.

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS.

In accordance with treaty stipulations and under the authority of the congressional resolutions of March 2, 1867, and March 2, 1901, setting apart a certain number of documents for exchange with foreign countries, there are now sent regularly to depositories abroad 56 full sets of United States official publications and 36 partial sets.

The partial set of publications sent to Ceylon has in the past been forwarded in care of the American consul at Colombo. The consul now informs the Institution that the documents in question are deposited in the Record Department of the Library of the Colonial Secretary's Office, and consignments will therefore be sent direct to that office in the future.

The recipients of full and partial sets are as follows:

DEPOSITORIES OF FULL SETS.

ARGENTINA: Ministerio de Relaciones Exteriores, Buenos Aires.

AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.

AUSTRIA: K. K. Statistische Zentral-Kommission, Vienna.

BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the Grand Duchy of Baden.)

BAVARIA: Königliche Hof- und Staats-Bibliothek, Munich.

BELGIUM: Bibliothèque Royale, Brussels.

BOMBAY: Secretary to the Government, Bombay.

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: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
COLOMBIA: Biblioteca Nacional, Bogotá
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Secretaria de Estado (Asuntos Generales y Canje Internacional), Habana.
DENMARK: Kongelige Bibliotheket, Copenhagen.
ENGLAND: British Museum, London.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
GLASGOW: City Librarian, Mitchell Library, Glasgow.
GREECE: Bibliothèque Nationale, Athens.
HAITI: Secrétairerie d'État des Relations Extérieures, Port au Prince.
HUNGARY: Hungarian House of Delegates, Budapest.
INDIA: Department of Education (Books), Government of India, Calcutta.
IRELAND: 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: Instituto Bibliográfico, Biblioteca Nacional, Mexico.
NETHERLANDS: Library of the States General, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Storthingets Bibliothek, Christiania.
ONTARIO: Legislative Library, Toronto.
PARIS: Préfecture de la Seine.
PERU: Biblioteca Nacional, Lima.
PORTUGAL: Bibliotheca Nacional, Lisbon.
PRUSSIA: Königliche Bibliothek, Berlin.
QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
QUEENSLAND: Parliamentary Library, Brisbane.
RUSSIA: Imperial Public Library, Petrograd.
SAXONY: Königliche Oeffentliche Bibliothek, Dresden.
SERBIA: Section Administrative du Ministère des Affaires Étrangères, Belgrade.
SOUTH AUSTRALIA: Parliament Library, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Fédérale, Berne.
TASMANIA: Parliamentary Library, Hobart.
TURKEY: Department of Public Instruction, Constantinople.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WÜRTTEMBERG: Königliche Landesbibliothek, Stuttgart.

DEPOSITORIES OF PARTIAL SETS.

ALBERTA: Provincial Library, Edmonton.
ALSACE-LORRAINE: K. Ministerium für Elsass-Lothringen, Strassburg.
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: Minister of Foreign Affairs, Sofia.
CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
ECUADOR: Biblioteca Nacional, Quito.
EGYPT: Bibliothèque Khédiviale, Cairo.
FINLAND: Chancery of Governor, Helsingfors.
GUATEMALA: Secretary of the Government, Guatemala.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Grossherzogliche Hof Bibliothek, Darmstadt.
HONDURAS: Secretary of the Government, Tegucigalpa.
JAMAICA: Colonial Secretary, Kingston.
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: Lieutenant Governor, Valetta.
MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.
NEW BRUNSWICK: Legislative Library, Fredericton.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
NORTHWEST TERRITORIES: Government Library, Regina.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PANAMA: Secretaria de Relaciones Exteriores, Panama.
PARAGUAY: Oficina General de Inmigracion, Asuncion.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
ROUMANIA: Academia Romana, Bucharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
UNITED PROVINCES OF AGRA AND OUDH: Under Secretary to Government, Allahabad.
VIENNA: Bürgermeister der Haupt- und Residenz-Stadt.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNALS.

There are now 33 countries with which the immediate exchange of official journals with the United States is carried on, the Government of Costa Rica having been added during the year. A complete list of the Governments to which the Congressional Record is now sent is given below:

Argentine Republic.
Australia.
Austria.
Baden.
Belgium.
Brazil.
Buenos Aires, Province of.
Canada.

Costa Rica.
Cuba.
Denmark.
France.
Great Britain.
Greece.
Guatemala.
Honduras.
Hungary.
Italy.
Liberia.
New South Wales.
New Zealand.
Portugal.
Prussia.
Queensland.
Roumania.
Russia.
Serbia.
Spain.
Switzerland.
Transvaal.
Union of South Africa.
Uruguay.
Western Australia.

LIST OF BUREAUS OR AGENCIES THROUGH WHICH EXCHANGES ARE TRANSMITTED.

The following is a list of the bureaus or agencies through which exchanges are transmitted:

Algeria, *via* France.

Angola, *via* Portugal.

Argentina: Comisión Protectora de Bibliotecas Populares, Reconquista 538, Buenos Aires.

Austria: K. K. Statistische Zentral-Kommission, Vienna.

Azores, *via* Portugal.

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

Bolivia: Oficina Nacional de Estadística, La Paz.

Brazil: Serviço 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: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.

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

Costa Rica: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.

Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.

Ecuador: Ministerio de Relaciones Exteriores, Quito.

Egypt: Government Publications Office, Printing Department, Cairo.

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

Germany: Amerika-Institut, Berlin, N. W. 7.

Great Britain and Ireland: Messrs. William Wesley & Son, 28 Essex Street, Strand, London.

Greece: Bibliothèque Nationale, Athens.

Greenland, *via* Denmark.

Guadeloupe, *via* France.

Guatemala: Instituto Nacional de Varones, Guatemala.

GUINEA, *via* Portugal.

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

HONDURAS: Biblioteca Nacional, Tegucigalpa.

HUNGARY: Dr. Julius Pikler, Municipal Office of Statistics, Váci-utca 80, Budapest.

ICELAND, *via* Denmark.

INDIA: India Store Department, India Office, London.

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: His Imperial Japanese Majesty's Residency-General, Seoul.

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

LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.

LUXEMBURG, *via* Germany.

MADAGASCAR, *via* France.

MADEIRA, *via* Portugal.

MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.

MOZAMBIQUE, *via* Portugal.

NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.

NEW GUINEA, *via* Netherlands.

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

NEW ZEALAND: Dominion Museum, Wellington.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

NORWAY: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.

PANAMA: Secretaria de Relaciones Exteriores, Panama.

PARAGUAY: Servicio de Canje Internacional de Publicaciones, Sección Consular y de Comercio, Ministerio de Relaciones Exteriores, Asuncion.

PERSIA: Board of Foreign Missions of the Presbyterian Church, New York City.

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

PORTUGAL: Serviço de Permutações Internacionaes, Inspecção Geral das Bibliothecas e Archivos Publicos, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

ROUMANIA: Academia Romana, Bucharest.

RUSSIA: Commission Russe des Échanges Internationaux, Bibliothèque Imperiale Publique, Petrograd.

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SERBIA: Section Administrative du Ministère des Affaires Étrangères, Belgrade.

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 des Échanges Internationaux Bibliothèque Fédérale Centrale, Berne.

SYRIA: Board of Foreign Missions of the Presbyterian Church, New York.

TASMANIA: Secretary to the Premier, Hobart.

TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.

TUNIS, *via* France.
TURKEY: American Board of Commissioners for Foreign Missions, Boston.
UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WINDWARD AND LEEWARD ISLANDS: Imperial Department of Agriculture, Bridgetown, Barbados.

Respectfully submitted.

C. W. SHOEMAKER,
Chief Clerk International Exchange Service.

DR. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

AUGUST 24, 1915.

APPENDIX 4.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to submit herewith a report concerning the operations of the National Zoological Park during the fiscal year ending June 30, 1915.

The sundry civil act approved August 1, 1914, provided $100,000 for improvement and maintenance. The cost of food for the animals during the year was about $23,000, being slightly less than the previous year, when it attained the highest figure yet reached; extensive repairs were required on roads and a considerable amount had to be expended on some of the buildings, all of which reduced the amount available for additional improvements.

ACCESSIONS.

Eighty-eight animals were born and hatched in the park. Among these were a South American tapir, an Arabian camel, 4 otters, 5 bears, a beaver, and various other mammals and birds.

The accessions included altogether 25 species not hitherto represented in the collection, and although considerably greater in number than during the previous year, included few of importance, as the supply of foreign animals was largely cut off by the war. A specimen of Przewalski's horse was secured as were various other animals of less note; a considerable number of waterfowl were also added.

EXCHANGES.

Eighty-two animals were secured through exchange, including 4 pumas, a jaguar, a palm civet and other mammals, a considerable number of birds, and a few reptiles.

GIFTS.

Mr. H. H. Bailey, Newport News, Va., a whistling swan.
Mr. H. B. Barber, Washington, D. C., a great horned owl.
Mr. D. L. Barton, Washington, D. C., an alligator.
Mrs. O. L. Beardsley, Washington, D. C., three spermophiles.
Mrs. B. O. Billingsby, Jules Station, Va., a skunk.
Miss Lillian Birney, Washington, D. C., an alligator.
Mr. F. D. Bradford, Washington, D. C., four alligators.
Mr. M. E. Bruce, Philadelphia, Pa., two yellow-naped parrots.

EUROPEAN BROWN BEAR AND CUBS, BORN JANUARY 15, 1915. THE FATHER WAS AN ALASKAN BROWN BEAR.

Mr. John Buckey, Washington, D. C., an alligator.
Mr. Joseph H. Curtis, Washington, D. C., a woodchuck.
Mrs. J. B. Dodson, Washington, D. C., an opossum.
Mr. G. A. Durfee, Washington, D. C., a grass parrakeet.
Mr. C. C. Estes, Washington, D. C., two cottontail rabbits.
Mrs. Sheldon Evans, Washington, D. C., a white-fronted parrot.
Mr. E. Fabre, Washington, D. C., a red-shouldered hawk.
Mrs. George Fowler, Philadelphia, Pa., a white-throated capuchin.
Mr. F. A. Frazer, Spotsylvania, Va., a Cooper's hawk.
Mr. James Frazier, Washington, D. C., a silver pheasant.
Brother Geraptin, Franciscan Monastery, Washington, D. C., two mocking birds.
Mr. C. G. Hoffman, Remington, Va., a barn owl.
Mr. J. M. Johnson, Washington, D. C., a bald eagle.
Mrs. D. C. Laws, Port Limon, Costa Rica, a white-throated capuchin.
Mrs. Arthur Lee, Washington, D. C., a silver-blue tanager.
Mr. Oscar M. Link, Washington, D. C., a sparrow hawk.
Mr. E. A. McIlhenny, Avery Island, La., six blue-winged teal.
Mr. Vinson W. McLean, Washington, D. C., a diamond rattlesnake.
Mr. Lester Martin, Washington, D. C., a raccoon.
Mr. Fred. Mertens, Washington, D. C., a bald eagle.
Mr. A. M. Nicholson, Orlando, Fla., a diamond rattlesnake.
Mr. John M. Pickrell, Washington, D. C., a diamond rattlesnake.
Mr. Edw. S. Schmid, Washington, D. C., a screech owl, two barn owls, and a spreading adder.
Mr. Fred. Schnaebele, Washington, D. C., an alligator.
Dr. R. W. Shufeldt, Washington, D. C., a black snake and a barred owl.
Mrs. C. B. Strong, Washington, D. C., a merganser.
Mrs. Swyhart, Washington, D. C., a horned lizard.
Mr. E. Thomas, Washington, D. C., an alligator.
Mr. Samuel G. Walker, Weld, W. Va., a bay lynx.
Mr. William Whyte, Washington, D. C., an alligator.
Hon. Woodrow Wilson, Washington, D. C., an opossum.
Mr. D. E. Winstead, Washington, D. C., an alligator.
Mr. N. P. Wood, North Mountain, W. Va., a green snake.
Unknown donor, a red fox.
Unknown donor, a Gila monster.

LOSSES.

The most noteworthy loss during the year was the death by rupture of the aorta of the largest of the Alaskan brown bears, caught as a small cub in May, 1901. He had attained a weight of 1,160 pounds. A Coke's hartbeest and several monkeys died from tuberculosis, two pronghorn antelopes from necrotic stomatitis, a lion from pericarditis, and a large bison bull (the "ten-dollar buffalo") from the effects of old age. Quail disease was again brought into the collection in a shipment of birds received from the southwestern United States and caused the death of more than half of the quail in the collection. A few waterfowl, also, died from aspergillosis, and there was some loss of birds from attacks by predatory animals

roaming at large in the park, though it was less than during the previous year. Forty-one of the animals that died were transferred to the National Museum. Autopsies were made, as usual, by the Pathological Division of the Bureau of Animal Industry, Department of Agriculture.[1]

ANIMALS IN THE COLLECTION JUNE 30, 1915.

MAMMALS.

Green monkey (*Cercopithecus callitrichus*)	1
Mona monkey (*Cercopithecus mona*)	3
Diana monkey (*Cercopithecus diana*)	1
Bonnet monkey (*Macacus sinicus*)	1
Macaque monkey (*Macacus cynomolgus*)	2
Pig-tailed monkey (*Macacus nemestrinus*)	3
Rhesus monkey (*Macacus rhesus*)	31
Brown macaque (*Macacus arctoides*)	2
Japanese monkey (*Macacus fuscatus*)	3
Moor macaque (*Macacus maurus*)	1
Chacma (*Papio porcarius*)	1
Hamadryas baboon (*Papio hamadryas*)	2
Mandrill (*Papio maimon*)	1
White-throated capuchin (*Cebus hypoleucus*)	4
Brown monkey (*Cebus fatuellus*)	3
Mongoose lemur (*Lemur mongoz*)	2
Ring-tailed lemur (*Lemur catta*)	1
Polar bear (*Thalarctos maritimus*)	2
European brown bear (*Ursus arctos*)	2
Kadiak bear (*Ursus middendorffi*)	1
Yakutat bear (*Ursus dalli*)	1
Alaskan brown bear (*Ursus gyas*)	2
Kidder's bear (*Ursus kidderi*)	2
Hybrid bear (*Ursus kidderi-arctos*)	2
Himalayan bear (*Ursus thibetanus*)	1
Japanese bear (*Ursus japonicus*)	1
Grizzly bear (*Ursus horribilis*)	3
Black bear (*Ursus americanus*)	9
Cinnamon bear (*Ursus americanus*)	2
Sloth bear (*Melursus ursinus*)	1
Kinkajou (*Cercoleptes caudivolvulus*)	1
Cacomistle (*Bassariscus astuta*)	1
Gray coatimundi (*Nasua narica*)	4
Raccoon (*Procyon lotor*)	11
American badger (*Taxidea taxus*)	3
European badger (*Meles taxus*)	2
Common skunk (*Mephitis putida*)	3
Tayra (*Galictis barbara*)	1
American marten (*Mustela americana*)	4
Fisher (*Mustela pennantii*)	1
Mink (*Putorius vison*)	16
Common ferret (*Putorius putorius*)	1
Black-footed ferret (*Putorius nigripes*)	1
North American otter (*Lutra canadensis*)	5
Eskimo dog (*Canis familiaris*)	14
Dingo (*Canis dingo*)	1
Gray wolf (*Canis occidentalis*)	4
Coyote (*Canis latrans*)	2
Woodhouse's coyote (*Canis frustror*)	3
Red fox (*Vulpes pennsylvanicus*)	5
Swift fox (*Vulpes velox*)	1
Arctic fox (*Vulpes lagopus*)	1
Gray fox (*Urocyon cinereo-argenteus*)	4
Spotted hyena (*Hyæna crocuta*)	1
Indian palm civet (*Viverra civettina*)	1
Common genet (*Genetta genetta*)	2
Cheetah (*Cynailurus jubatus*)	2
Sudan lion (*Felis leo*)	3
Kilimanjaro lion (*Felis leo sabakiensis*)	1
Tiger (*Felis tigris*)	2
Puma (*Felis oregonensis hippolestes*)	4
Jaguar (*Felis onca*)	1
Leopard (*Felis pardus*)	3
Black leopard (*Felis pardus*)	1
Canada lynx (*Lynx canadensis*)	1
Bay lynx (*Lynx rufus*)	8
Spotted lynx (*Lynx rufus texensis*)	2
California lynx (*Lynx rufus californicus*)	1
Steller's sea lion (*Eumetopias stelleri*)	1
California sea lion (*Zalophus californianus*)	2
Northern fur seal (*Callotaria alascana*)	1
Harbor seal (*Phoca vitulina*)	1
Fox squirrel (*Sciurus niger*)	9
Western fox squirrel (*Sciurus ludovicianus*)	8
Gray squirrel (*Sciurus carolinensis*)	40
Black squirrel (*Sciurus carolinensis*)	20
Albino squirrel (*Sciurus carolinensis*)	1
Thirteen-lined spermophile (*Spermophilus tridecimlineatous*)	2
Prairie dog (*Cynomys ludovicianus*)	60
Woodchuck (*Marmota monax*)	2
Alpine marmot (*Marmota marmotta*)	1

[1] The causes of death were reported to be as follows: Enteritis, 20; gastritis, 2; gastroenteritis, 1; quail disease, 20; pneumonia, 8; tuberculosis, 10; congestion of lungs, 4; pleurisy, 1; aspergillosis, 4; congestion of liver, 5; rupture of liver, 1; nephritis, 1; peritonitis, 1; septicemia, 2; pyemia, 1; septic endometritis, 1; pericarditis, 3; rupture of aorta, 1; hemorrhage on spinal cord, 1; visceral gout, 2; chronic arthritis, 1; impaction of intestine, 1; necrotic stomatitis, 2; anemia, 3; wound infection, 1; accident, 2; undetermined, 7.

American beaver (*Castor canadensis*)	5
Coypu (*Myocastor coypus*)	2
European porcupine (*Hystrix cristata*)	4
Indian porcupine (*Hystrix leucura*)	1
Canada porcupine (*Erethizon dorsatus*)	1
Canada porcupine (*Erethizon dorsatus*), albino	1
Viscacha (*Lagostomus trichodactylus*)	1
Mexican agouti (*Dasyprocta mexicana*)	1
Azara's agouti (*Dasyprocta azaræ*)	1
Crested agouti (*Dasyprocta cristata*)	2
Hairy-rumped agouti (*Dasyprocta prymnolopha*)	2
Paca (*Cœlogenys paca*)	2
Guinea pig (*Cavia cutleri*)	13
Patagonian cavy (*Dolichotis patagonica*)	2
Capybara (*Hydrochœrus capybara*)	1
Domestic rabbit (*Lepus cuniculus*)	15
African elephant (*Elephas oryotis*)	2
Indian elephant (*Elephas maximus*)	1
Brazilian tapir (*Tapirus americanus*)	4
Wild horse (*Equus przewalskii*)	1
Grevy's zebra (*Equus grevyi*)	2
Zebra-horse hybrid (*Equus grevyi-caballus*)	1
Zebra-donkey hybrid (*Equus grevyi-asinus*)	1
Grant's zebra (*Equus burchelli granti*)	1
Collared peccary (*Dicotyles angulatus*)	3
Wild boar (*Sus scrofa*)	1
Northern wart hog (*Phacochœrus africanus*)	2
Hippopotamus (*Hippopotamus amphibius*)	2
Guanaco (*Lama huanachus*)	2
Llama (*Lama glama*)	7
Alpaca (*Lama pacos*)	3
Vicugna (*Lama vicugna*)	1
Bactrian camel (*Camelus bactrianus*)	2
Arabian camel (*Camelus dromedarius*)	4
Sambar deer (*Cervus unicolor*)	3
Philippine deer (*Cervus philippinus*)	1
Hog deer (*Cervus porcinus*)	9
Barasingha deer (*Cervus duvaucelii*)	15
Axis deer (*Cervus axis*)	8
Japanese deer (*Cervus sika*)	12
Red deer (*Cervus elaphus*)	8
American elk (*Cervus canadensis*)	10
Fallow deer (*Cervus dama*)	5
Virginia deer (*Odocoileus virginianus*)	15
Mule deer (*Odocoileus hemionus*)	1
Columbian black-tailed deer (*Odocoileus columbianus*)	1
Cuban deer (*Odocoileus sp.*)	1
Blessbok (*Damaliscus albifrons*)	1
White-tailed gnu (*Connochœtes gnu*)	1
Defassa water buck (*Cobus defassa*)	1
Indian antelope (*Antilope cervicapra*)	4
Arabian gazelle (*Gazella arabica*)	2
Sable antelope (*Hippotragus niger*)	1
Nilgai (*Boselaphus tragocamelus*)	3
Congo harnessed antelope (*Tragelaphus gratus*)	2
Tahr (*Hemitragus jemlaicus*)	4
Common goat (*Capra hircus*)	2
Angora goat (*Capra hircus*)	1
Circassian goat (*Capra hircus*)	5
Barbary sheep (*Ovis tragelaphus*)	13
Barbados sheep (*Ovis aries-tragelaphus*)	8
Anoa (*Anoa depressicornis*)	1
Zebu (*Bibos indicus*)	3
Yak (*Poëphagus grunniens*)	5
American bison (*Bison americanus*)	17
Hairy armadillo (*Dasypus villosus*)	3
Wallaroo (*Macropus robustus*)	4
Red kangaroo (*Macropus rufus*)	1
Bennett's wallaby (*Macropus ruficollis bennetti*)	1
Virginia opossum (*Didelphys marsupialis*)	2

BIRDS.

Mocking bird (*Mimus polyglottos*)	2
Catbird (*Dumetella carolinensis*)	1
Japanese robin (*Liothrix luteus*)	2
Laughing thrush (*Garrulax leucolophus*)	2
Australian gray jumper (*Struthidea cinerea*)	4
Bishop finch (*Tanagra episcopus*)	4
Cut-throat finch (*Amadina fasciata*)	8
Zebra finch (*Amadina castanotis*)	4
Black-headed finch (*Munia atricapilla*)	5
Three-colored finch (*Munia malacca*)	6
White-headed finch (*Munia maja*)	9
Nutmeg finch (*Munia punctularia*)	6
Java sparrow (*Munia oryzivora*)	13
White Java sparrow (*Munia oryzivora*)	12
Sharp-tailed grass finch (*Poëphila acuticauda*)	1
Silver-bill finch (*Aidemosyne cantans*)	2
Chestnut-breasted finch (*Donacola castaneothorax*)	6
Napolean weaver (*Pyromelana afra*)	4
Madagascar weaver (*Foudia madagascariensis*)	4
Red-billed weaver (*Quelea quelea*)	8
Paradise weaver (*Vidua paradisea*)	7
Red-crested cardinal (*Paroaria cucullata*)	2
Common cardinal (*Cardinalis cardinalis*)	2
Siskin (*Spinus spinus*)	5
Saffron finch (*Sycalis flaveola*)	13
Yellow hammer (*Emberiza citrinella*)	1
Common canary (*Serinus canarius*)	5
Linnet (*Linota cannabina*)	4
Cowbird (*Molothrus ater*)	1
Glossy starling (*Lamprotornis caudatus*)	1
Malabar mynah (*Poliopsar malabaricus*)	2
European raven (*Corvus corax*)	1
American raven (*Corvus corax sinuatus*)	1

Rocky Mountain jay (*Perisoreus canadensis capitalis*) — 3
White-throated jay (*Garrulus leucotis*) — 1
Blue jay (*Cyanocitta cristata*) — 3
American magpie (*Pica pica hudsonica*) — 3
Red-billed magpie (*Urocissa occipitalis*) — 1
Yellow tyrant (*Pitangus sulphuratus rufipennis*) — 1
Giant kingfisher (*Dacelo gigas*) — 2
Concave-casqued hornbill (*Dichoceros bicornis*) — 1
Reddish motmot (*Momotus subrufescens*) — 1
Sulphur-crested cockatoo (*Cacatua galerita*) — 3
White cockatoo (*Cacatua alba*) — 5
Leadbeater's cockatoo (*Cacatua leadbeateri*) — 2
Bare-eyed cockatoo (*Cacatua gymnopis*) — 3
Roseate cockatoo (*Cacatua roseicapilla*) — 13
Yellow and blue macaw (*Ara ararauna*) — 2
Red and yellow and blue macaw (*Ara macao*) — 7
Red and blue macaw (*Ara chloroptera*) — 2
Great green macaw (*Ara militaris*) — 1
Cuban parrot (*Amazona leucocephala*) — 1
Orange-winged amazon (*Amazona amazonica*) — 1
Festive amazon (*Amazona festiva*) — 1
Porto Rican amazon (*Amazona vittata*) — 1
Yellow-shouldered amazon (*Amazona ochroptera*) — 2
Yellow-fronted amazon (*Amazona ochrocephala*) — 2
Yellow-naped amazon (*Amazona auripalliata*) — 2
Yellow-headed amazon (*Amazona levaillanti*) — 2
Blue-fronted amazon (*Amazona æstiva*) — 2
Lesser vasa parrot (*Coracopsis nigra*) — 1
Banded parrakeet (*Palæornis fasciata*) — 2
Love bird (*Agapornis pullaria*) — 1
Shell parrakeet (*Melopsittacus undulatus*) — 4
Great horned owl (*Bubo virginianus*) — 10
Arctic horned owl (*Bubo virginianus subarcticus*) — 1
Barred owl (*Strix varia*) — 4
Sparrow hawk (*Falco sparverius*) — 3
Bald eagle (*Haliæetus leucocephalus*) — 12
Alaskan bald eagle (*Haliæetus leucocephalus alascanus*) — 1
Golden eagle (*Aquila chrysaëtos*) — 2
Harpy eagle (*Thrasaëtus harpyia*) — 1
Crowned hawk eagle (*Spizaëtus coronatus*) — 1
Rough-legged hawk (*Archibuteo lagopus sancti-johannis*) — 1
Cooper's hawk (*Accipiter cooperi*) — 1
Venezuelan hawk — 1
Caracara (*Polyborus cheriway*) — 3
Lammergeyer (*Gypaëtus barbatus*) — 1
South American condor (*Sarcorhamphus gryphus*) — 1
California condor (*Gymnogyps californianus*) — 3
Griffon vulture (*Gyps fulvus*) — 2
Cinereous vulture (*Vultur monachus*) — 2
Egyptian vulture (*Neophron percnopterus*) — 1
Turkey vulture (*Cathartes aura*) — 4
Black vulture (*Catharista urubu*) — 2
King vulture (*Gypagus papa*) — 2
Snow pigeon (*Columba leuconota*) — 2
Red-billed pigeon (*Columba flavirostris*) — 4
White-crowned pigeon (*Columba leucocephala*) — 2
Band-tailed pigeon (*Columba fasciata*) — 4
Mourning dove (*Zenaidura macroura*) — 7
Peaceful dove (*Geopelia tranquilla*) — 2
Zebra dove (*Geopelia striata*) — 12
Collared turtle dove (*Turtur risorius*) — 17
Cape masked dove (*Œna capensis*) — 4
Australian crested pigeon (*Ocyphaps lophotes*) — 6
Wonga-wonga pigeon (*Leucosarcia picata*) — 4
Nicobar pigeon (*Calœnas nicobarica*) — 2
Red-billed curassow (*Crax carunculata*) — 1
Wild turkey (*Meleagris gallopavo silvestris*) — 5
Peafowl (*Pavo cristata*) — 60
Peacock pheasant (*Polyplectron chinquis*) — 1
Silver pheasant (*Euplocamus nycthemerus*) — 1
European quail (*Coturnix communis*) — 1
Bobwhite (*Colinus virginianus*) — 3
Curaçoa crested quail (*Eupsychortyx cristatus*) — 4
Scaled quail (*Callipepla squamata*) — 1
Valley quail (*Lophortyx californica vallicola*) — 3
Gambel's quail (*Lophortyx gambeli*) — 1
Massena quail (*Cyrtonyx montezumæ*) — 1
American coot (*Fulica americana*) — 5
Great bustard (*Otis tarda*) — 1
Common cariama (*Cariama cristata*) — 1
Demoiselle crane (*Anthropoides virgo*) — 7
Crowned crane (*Balearica pavonina*) — 2
Whooping crane (*Grus americana*) — 1
Sand-hill crane (*Grus mexicana*) — 6
Australian crane (*Grus australasiana*) — 1
European crane (*Grus cinerea*) — 1
Indian white crane (*Grus leucogeranus*) — 1
Ruff (*Machetes pugnax*) — 1
Black-crowned night heron (*Nycticorax nycticorax nævius*) — 10
Snowy egret (*Egretta candidissima*) — 3
Great white heron (*Herodias egretta*) — 1
Great blue heron (*Ardea herodias*) — 2
Great black-crowned heron (*Ardea cocoi*) — 1
Boatbill (*Cancroma cochlearia*) — 2
Black stork (*Ciconia nigra*) — 1

Marabou stork (*Leptoptilus dubius*)	1
Wood ibis (*Mycteria americana*)	2
Sacred ibis (*Ibis æthiopica*)	3
White ibis (*Guara alba*)	13
Roseate spoonbill (*Ajaja ajaja*)	2
European flamingo (*Phœnicopterus roseus*)	2
Whistling swan (*Olor columbianus*)	6
Mute swan (*Cygnus gibbus*)	6
Black-necked swan (*Cygnus melancoryphus*)	2
Black swan (*Chenopis atrata*)	3
Spur-winged goose (*Plectropterus gambensis*)	1
Muscovy duck (*Cairina moschata*)	2
White muscovy duck (*Cairina moschata*)	1
Wood duck (*Aix sponsa*)	13
Mandarin duck (*Dendronessa galericulata*)	10
Cape Barren goose (*Cereopsis novæ-hollandiæ*)	2
Lesser snow goose (*Chen hyperboreus*)	3
Greater snow goose (*Chen hyperboreus nivalis*)	1
Ross's goose (*Chen rossi*)	2
American white-fronted goose (*Anser albifrons gambeli*)	5
Barred-head goose (*Anser indicus*)	2
Chinese goose (*Anser cygnoides*)	2
Canada goose (*Branta canadensis*)	12
Hutchins's goose (*Branta canadensis hutchinsii*)	3
Cackling goose (*Branta canadensis minima*)	2
Upland goose (*Chloëphaga magellanica*)	1
White-faced tree duck (*Dendrocygna viduata*)	2
Fulvous tree duck (*Dendrocygna bicolor*)	2
Wandering tree duck (*Dendrocygna arcuata*)	6
Ruddy sheldrake (*Casarca ferruginea*)	1
Mallard (*Anas platyrhynchos*)	19
East Indian black duck (*Anas sp.*)	6
Black duck (*Anas rubripes*)	2
European widgeon (*Mareca penelope*)	2
Chilean widgeon (*Mareca sibilatrix*)	2
Pintail (*Dafila acuta*)	2
Blue-winged teal (*Querquedula discors*)	5
Rosy-billed pochard (*Metopiana peposaca*)	2
Red-headed duck (*Marila americana*)	9
American white pelican (*Pelecanus erythrorhynchos*)	9
European white pelican (*Pelecanus onocrotalus*)	2
Roseate pelican (*Pelecanus roseus*)	2
Brown pelican (*Pelecanus occidentalis*)	5
Australian pelican (*Pelecanus conspicillatus*)	2
Florida cormorant (*Phalacrocorax auritus floridanus*)	15
Water turkey (*Anhinga anhinga*)	3
Great black-backed gull (*Larus marinus*)	1
American herring gull (*Larus argentatus smithsonianus*)	3
Laughing gull (*Larus atricilla*)	2
South African ostrich (*Struthio australis*)	6
Somali ostrich (*Struthio molybdophanes*)	1
Common cassowary (*Casuarius galeatus*)	1
Common rhea (*Rhea americana*)	2
Emu (*Dromæus novæ hollandiæ*)	2

REPTILES.

Alligator (*Alligator mississippiensis*)	22
Painted box tortoise (*Cistudo ornata*)	2
Duncan Island tortoise (*Testudo ephippium*)	2
Albemarle Island tortoise (*Testudo vicina*)	1
Horned lizard (*Phrynosoma cornutum*)	1
Gila monster (*Heloderma suspectum*)	2
Regal python (*Python reticulatus*)	3
Common boa (*Boa constrictor*)	5
Cook's tree boa (*Corallus cookii*)	1
Anaconda (*Eunectes murinus*)	1
Velvet snake (*Epicrates cenchris*)	2
Spreading adder (*Heterodon platyrhinus*)	1
Black snake (*Zamenis constrictor*)	1
Coach-whip snake (*Zamenis flagellum*)	1
Water snake (*Natrix sipedon*)	3
Common garter snake (*Eutænia sirtalis*)	3
Texas water snake (*Eutænia proxima*)	2
Pine snake (*Pituophis melanoleucus*)	5
King snake (*Ophibolus getulus*)	2
Water mocassin (*Ancistrodon piscivorus*)	6
Copperhead (*Ancistrodon contortrix*)	1
Diamond rattlesnake (*Crotalus adamanteus*)	5

STATEMENT OF THE COLLECTION.

ACCESSIONS DURING THE YEAR.

Presented	60
Purchased	225
Born and hatched in the National Zoological Park	88
Received in exchange	82
Deposited in National Zoological Park	43
Total	498

SUMMARY.

Animals on hand July 1, 1914	1,362
Accessions during the year	498
	1,860
Deduct loss (by exchange, death, return of animals, etc.)	463
On hand June 30, 1915	1,397

Class.	Species.	Individuals.
Mammals	151	629
Birds	185	696
Reptiles	22	72
Total	358	1,397

VISITORS.

The number of visitors to the park during the year, as determined by count and estimate, was 794,530, a daily average of 2,176. This was the largest year's attendance in the history of the park. The greatest number in any one month was 153,452 in April, 1915, an average per day of 5,115.

Sixty-two schools, classes, etc., visited the park, with a total of 3,485 individuals.

IMPROVEMENTS.

A cage for pumas was built near the lion house. The cage is 22 by 28 feet, 10 feet high, and attached to it is a well-built shelter house, which provides four compartments for the animals and ample space for the keeper in caring for them.

In order to provide for keeping a band of rhesus monkeys out of doors throughout the year, a small shelter house with thick wooden walls was built and connected with it a yard 25 feet square. Twenty-five monkeys were placed there in October; all came through the winter in good shape except one, which was taken out as it appeared to suffer from the cold.

A new machine lathe was added to the shop equipment, replacing one of inferior type which had been in use since the early years of the park. A tool grinder and power hack saw were also installed and overhead equipment of shafting and pulleys arranged for the several machines. A food chopper and bone grinder, with motor for driving them, were put in at the food house.

For the convenience of the increasing number of people who enter at the south end of the park, a foot bridge was constructed there across the creek. A small rustic shelter was also built near the new stone bridge.

The most important improvement undertaken was a building for hospital and laboratory. The construction of this was begun near the end of the year, part of the cost being met from this year's appropriation and the balance to come from the appropriation for the following year. The total cost is expected to be about $5,000. The building will be of stone, 30 by 56 feet, and one story high. There will be a room at each end fitted up for the accommodation of animals, and between these a laboratory room, 16 by 27 feet. Each room will be provided with four skylights. The location selected for the building is entirely separate from all other animal quarters, but yet easy of access for those who will have charge of the animals that are kept in it.

The cost of these improvements was as follows:

Hospital and laboratory (1915 appropriation)	$2,300
Cage and house for pumas	1,325
Outdoor cage and house for monkeys	250
Additional machine-shop equipment	700
Additional equipment for food house	250
Footbridge	325
Rustic shelter at new stone bridge	210

MAINTENANCE OF BUILDINGS, INCLOSURES, ETC.

The roads and walks in the park had received almost no repair since 1910, when a special appropriation was made for that purpose. Their condition had become so bad that repairs had to be made early in the year. The roads were extensively patched and given a general surfacing throughout with tar and crushed stone, over 2 miles of roadway being thus treated. Portions of the walks were repaired in the same manner. The total area of roads and walks repaired was 8,330 square yards. The ford near Klingle Road also had to be thoroughly repaired, and toward the close of the year it became necessary to pave with concrete the ford on the driveway to Cathedral Avenue, which, from the effects of high water and heavy ice in the creek, had become impassable. The total cost of this road work was $4,075 (upper ford $325, lower ford $615).

It was also necessary to clean out and repair the larger pond for waterfowl, in which an extensive bank of sand and mud had been deposited at time of flood by the water supply from the creek; this cost $850.

Progressive deterioration of the temporary bird house again made repairs necessary there. The wooden floor, which had already been rebuilt twice, was replaced with concrete, as was also a part of the wooden foundation. The cost of this work was $700. This building is an example of the ultimate costliness of cheap temporary construction.

The roof of the office building had to be reshingled and some other repairs made at a cost of $400.

The section of the heating main between the temporary bird house and the antelope and elephant houses was repaired and a considerable part of the pipe replaced. A new hot-water boiler, for auxiliary heating of snake cases, was also put in at a total cost of $500.

ALTERATION OF THE WEST BOUNDARY OF THE PARK.

The acquisition of the land required to extend the park to Connecticut Avenue from Cathedral Avenue to Klingle Road, for which an appropriation of $107,200 was made in the sundry civil act for the fiscal year ending June 30, 1914, has not yet been accomplished.

There was great delay at several stages in the proceedings for the condemnation of the land. A special survey and map of the property involved was required; the preliminary proceedings were then postponed from time to time in order that the property owners interested might submit arguments regarding the instructions to be given to the jury of condemnation; the work of the jury in arriving at the value of the land to be taken and the amount of benefits which should be assessed against neighboring property occupied several months; the hearing by the court of objections on the part of property owners to the verdict further delayed the matter, especially as the time of that court from November, 1914, to May, 1915, was almost entirely occupied by the contest in an important will case. Changes in the personnel of the court and of the Government attorneys also operated to delay and complicate the matter. The court finally, on June 28, 1915, confirmed the verdict of the jury as regards the awards of damages for land to be taken and a portion of the benefits assessed against neighboring property, but set aside the verdict as to benefits in all cases where the owners of the property had filed exceptions to the verdict. The amount awarded for the land to be taken was $194,438.08, and to this is to be added the cost of the proceedings, $2,203.35, making a total of $196,641.43. The benefits were assessed at $66,013.50, but a considerable part was set aside by the court. The exact amount that is involved in this decision of the court has yet to be determined by the Government attorneys upon examination of the land records.

The total amount required to purchase the land and meet the costs of condemnation will therefore be considerably greater than the sum that was appropriated, so that an additional appropriation will have to be obtained in order to secure all of the land for which the act provides.

ROCK CREEK INTERCEPTING SEWERS.

The District of Columbia completed the construction of the main intercepting sewer through the park in October, 1914, and shortly thereafter built a large connecting sewer to this from the intercepting sewer that had been constructed through the park some years before. In accomplishing this work there was necessarily a considerable amount of destruction and defacement of natural features along the line of the work. The District authorities and the contractor have removed the excavated material and restored the ground to its original condition so far as that is practicable, but some expenditure on the part of the park and considerable time will be required to bring it again into satisfactory condition.

PLAYGROUND PRIVILEGE.

At its request, the playground department of the District of Columbia was allowed to install several pieces of apparatus on a meadow near which is a favorite resort of picnic parties. The apparatus has been quite largely used. Objectionable features thus far have been some temporary disfigurement of an attractive part of the park and the tendency to extend playground operations beyond the area that was allotted for that purpose.

IMPORTANT NEEDS.

BUILDINGS.

The importance of providing certain permanent buildings for housing the collection and for other purposes has been urged for several years past, but, with the scanty means available, all that could be done was to provide, from two yearly appropriations, a small building to meet the bare necessities of a hospital and laboratory. An aviary building is still a most urgent need, and repeated efforts have been made to secure an appropriation for this purpose. A building to accommodate elephants, hippopotami, and certain other animals whose requirements as to housing and care are similar will soon be a necessity, as the present temporary quarters are already too small and insecure for the young animals, which are rapidly growing and acquiring formidable strength.

The need of a public-comfort and restaurant building has been stated repeatedly and attention called to the fact that the facilities which it has been possible thus far to provide are altogether inadequate and not befitting a public institution of this character.

Gatehouses should be provided at the principal entrances, all of which are at considerable distance from the exhibition buildings, and

they should include a small room for watchmen and limited toilet facilities for visitors.

PREPARATION OF SITES FOR BUILDINGS.

The park includes but little ground that is even comparatively level, and in order to provide a building site of any considerable extent it is usually necessary to grade off a hill or fill up a valley. This involves the destruction of the trees and shrubs on the area and their replacement after the grading is completed by others required about the building for shade and ornament. Early preparation of such sites is highly desirable, in order that the planting may be done in advance and as much time as possible utilized for growth, especially of trees for shade. The site that has been selected for the aviary will require grading over practically the entire area needed for the building, the attached outdoor cages, and the walks about them. This would involve the excavation and removal of some 14,000 cubic yards of earth. The location is indicated at *A* on the accompanying map, which also shows where the excavated material could be used to fill a deep, narrow valley adjoining the bear yards at *B*. Nearly 70,000 square feet of ground would thus be made available at the aviary site and some 34,000 square feet would be added to the usable area where the fill is made. It is estimated that the cost of this work would be about $4,000, and it is recommended that Congress be asked to appropriate that sum for the purpose.

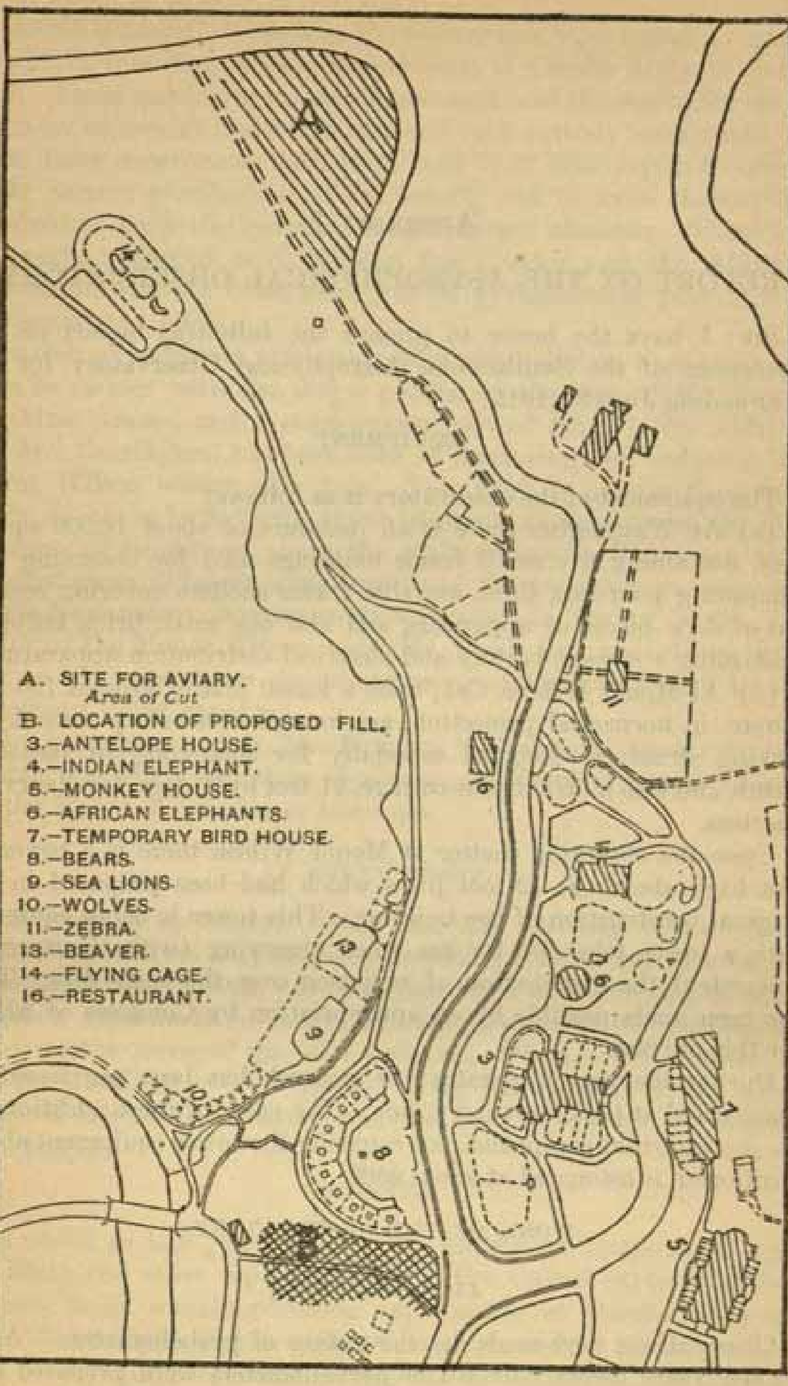
ADDITIONS TO THE COLLECTION.

Attention is again called to the desirability of adding to the exhibit some of the more important animals which it still lacks, such as anthropoid apes, rhinoceros, giraffe, African buffalo and antelopes, and the mountain sheep and goat of our own country.

Respectfully submitted.

FRANK BAKER,
Superintendent.

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


A
A. SITE FOR AVIARY.
Area of Cut
B. LOCATION OF PROPOSED FILL.
3.–ANTELOPE HOUSE.
4.–INDIAN ELEPHANT.
5.–MONKEY HOUSE.
6.–AFRICAN ELEPHANTS.
7.–TEMPORARY BIRD HOUSE.
8.–BEARS.
9.–SEA LIONS.
10.–WOLVES.
11.–ZEBRA.
13.–BEAVER.
14.–FLYING CAGE.
16.–RESTAURANT.
16
13
9
10
8
3
4
5

Appendix 5.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

Sir: I have the honor to present the following report on the operations of the Smithsonian Astrophysical Observatory for the year ending June 30, 1915:

EQUIPMENT.

The equipment of the observatory is as follows:

(*a*) At Washington there is an inclosure of about 16,000 square feet, containing five small frame buildings used for observing and computing purposes, three movable frame shelters covering several out-of-door pieces of apparatus, and also one small brick building containing a storage battery and electrical distribution apparatus.

(*b*) At Mount Wilson, Cal., upon a leased plat of ground 100 feet square, in horizontal projection, are located a one-story cement observing structure, designed especially for solar-constant measurements, and also a little frame cottage, 21 feet by 25 feet, for observer's quarters.

Upon the observing shelter at Mount Wilson there is a tower 40 feet high above the 12-foot piers which had been prepared in the original construction of the building. This tower is being equipped with a tower telescope for use when observing (with the spectrobolometer) the distribution of radiation over the sun's disk. This has been made possible by an appropriation by Congress of $2,000 for this purpose.

During the year apparatus for research has been purchased or constructed at the observatory shop. The value of these additions to the instrumental equipment, not counting the tower equipment above mentioned, is estimated at about $500.

WORK OF THE OBSERVATORY.

AT WASHINGTON.

Observations were made for the testing of pyrheliometers. As in former years several silver-disk pyrheliometers were prepared and sent abroad by the Institution after standardization at the Astrophysical Observatory.

Several automatic recording pyrheliometers were raised to great heights in sounding balloon experiments at Omaha early in July, 1914. These instruments were all recovered, and the one which made the most successful flight was received back entirely uninjured. A great many experiments were made with it at Washington to investigate certain peculiarities of its record, and to more thoroughly standardize its pyrheliometric and barometric elements. These experiments consumed much time of the director and Mr. Aldrich. The results reached from these balloon pyrheliometer records will be summarized below.

Further experiments were made with sky-radiation apparatus.

As in former years the major portion of the time of Mr. Fowle and Miss Graves, and a considerable part of that of Mr. Aldrich and Mr. Carrington, has been used in measuring and reducing the Mount Wilson bolographic data. This work is heavier than formerly, as it now includes the tower-telescope observations on the distribution of brightness along the sun's diameter. These are now made at seven different wave lengths of the spectrum on each day that solar-constant measurements are secured. Owing to the demands of the Mount Wilson work, Mr. Fowle has devoted but little time to his research on the transmission of long-wave rays in air containing water vapor.

The instrument maker, Mr. Kramer, was occupied mainly on the construction of sky-radiation apparatus, and on many improvements for the Mount Wilson tower telescope.

AT MOUNT WILSON.

Observations by Messrs. Abbot and Aldrich were continued at Mount Wilson from July to about November 1, 1914, and were begun again about June 1, 1915. As in former years measurements of solar radiation were made on every favorable day, with the purpose of following the course of the solar variation. On each day of observation the distribution of brightness along the diameter of the solar image of the tower telescope was also observed at seven different wave lengths.

AT OMAHA.

As stated in last year's report, Mr. Aldrich, in cooperation with Dr. Blair and other representatives of the United States Weather Bureau, made sounding-balloon experiments at Omaha early in July, 1914. Three flights with automatic recording pyrheliometers were made on July 1, 9, and 11, respectively. The first was made at night, with electric lamps for recording, as a test of certain anticipated sources of error. In the second flight the instrument was

much damaged when landing and remained a great while undiscovered, so that the record was quite spoiled. Apparently, too, the clockwork had stopped before reaching a very great elevation. The third flight was highly successful.

RESULTS OF BALLOON PYRHELIOMETRY.

A complete account of the balloon pyrheliometers, the circumstances of the flights, and the results obtained has been published in a paper by Messrs. Abbot, Fowle, and Aldrich, entitled, "New Evidence on the Intensity of Solar Radiation Outside the Atmosphere" (Smithsonian Miscellaneous Collections, vol. 65, No. 4, 1915). The following is a summary of the principal results:

In the flight of July 11, 1915, the balloons reached an elevation of approximately 25,000 meters, or 81,000 feet. The pressure of the air remaining above the instrument was approximately 3 centimeters, or 1.25 inches of mercury, about one twenty-fifth of the barometric pressure at sea level. Seven readable measurements of solar radiation were recorded at various levels. Of these the three near highest elevation were the best. Their mean gives a value of 1.84 calories per square centimeter per minute, as the intensity of solar radiation at mean solar distance, at noon on July 11, at the altitude of about 22,000 meters, or 72,000 feet. It appears reasonable to add about 2 per cent for the quantity of solar radiation absorbed and scattered by the air above the instrument. This gives 1.88 calories as a value of the solar radiation outside the atmosphere, on this day, according to the balloon pyrheliometry. Unfortunately no solar-radiation measurements were secured on Mount Wilson on July 11, but the result falls well within the range of values for the solar constant of radiation which have been obtained by the bolometric method at various stations, and compares well with the mean of these values, 1.93 calories.

UNIFORMITY OF ATMOSPHERIC TRANSMISSION AT MOUNT WILSON.

In solar-constant measurements on Mount Wilson the atmospheric transmission for vertical rays is determined in the following manner for numerous spectrum wave lengths:

Spectrobolographic observations are made at different zenith distances of the sun, usually between 75° and 30°. Between these limits the length of the path of the rays within the atmosphere is proportional to the secant of the zenith distance. Knowing the length of path and the intensity of the transmitted rays, the coefficient of transmission for any ray is readily computed. In this determination it is assumed that the atmosphere remains unchanged in transparency during the whole period of observation. Several

critics have objected against the Mount Wilson measurements that a progressive decrease of transparency occurs during the morning hours, and especially during the period ordinarily used in our observations, so that our estimates of atmospheric transmission are in their view too high, and our solar-constant values too low in consequence. It has been suggested by one critic that the period during which the zenith distance of the sun changes from 85° to 75° would be more suitable for the work.

To test this matter, observations were begun at sunrise on September 20 and 21, 1914, and continued until 10 o'clock, the usual closing time. These days were exceptionally clear and very dry, and seemed well suited to give excellent solar-constant values. The conditions of experiment, discussion of observations, and results are given in full in the paper by Abbot, Fowle, and Aldrich above cited. The principal results are these: No considerable difference in transmission coefficients appeared whether these were based on the whole morning's observations, on the range of air masses usually employed, or on the range recommended by the critic above mentioned. Six solar-constant values were derived for the two days, based on these three different treatments of the data. All six values fall between 1.90 and 1.95 calories per square centimeter per minute, in good agreement with values obtained as usual on other days. The experiments confirm the view that the atmospheric transparency above Mount Wilson is sufficiently uniform for the purposes of solar-constant investigations.

LONG-PERIOD VARIATION OF THE SUN.

In the year 1913 the solar activity, as judged by the prevalence of sun spots, was less than at any time for about a century. The mean of all solar-constant values obtained at Mount Wilson from July to October, 1913, inclusive, was 1.885 calories per square centimeter per minute. This value falls 2.5 per cent below the mean value for the years 1905 to 1912, which was 1.933 calories.

Beginning September 9, 1913, observations of the distribution of radiation along the diameter of the solar disk were secured on about 45 days of September, October, and November. These showed that the increase (or contrast) of brightness of the center of the sun's disk over that which prevails near the edge was less than that which was found from Washington observations of the years 1905 to 1907.

In the year 1914 the solar activity became distinctly greater than in 1913. The number of spots, to be sure, was not great, but other phenomena joined in showing that the period of maximum sun spots was about to come. The mean of all solar-constant values obtained at Mount Wilson from June to October, inclusive, was 1.950 calories.

This value is 3.5 per cent above that of 1913 and 1 per cent above the mean for former years. Indications are that the value for 1915 will also fall very high.

The contrast of brightness between the center and edges of the solar disk was greater in 1914 than in 1913, and, in fact, almost as great as was found from Washington work of 1905 to 1907.

These facts confirm the result derived from earlier observations, namely, the solar emission of radiation varies along with the solar activity as revealed by sun spots and other phenomena. Higher values of solar radiation prevail at times of greater solar activity, as expressed by sun spots. The connection does not, however, appear to be a strictly numerical one between solar radiation and sun spot numbers. In the return of solar activity presaged in 1914 the solar radiation rose almost to its maximum value before the number of sun spots had greatly increased. Associated with these changes, greater contrast of brightness between the center and edges of the solar disk prevails when the solar activity is greater.

SHORT-PERIOD VARIATION OF THE SUN.

In the year 1913, as in former years, considerable fluctuations of the solar-constant values occurred from day to day. The values found ranged over nearly 10 per cent between the extreme limits 1.81 and 1.99 calories, but seldom more than 3 per cent in any 10-day interval. The periods of fluctuation were irregular, as heretofore. Associated with these fluctuations, though perhaps not strictly connected numerically, the contrast of brightness between center and edges of the solar disk also varied. Curiously enough, however, the correlation between solar-constant values and contrast values proves to be of opposite sign for these short irregular fluctuations to that which attends the long-period changes which are associated with the general solar activity. In other words, in the progress of the sun spot cycle *high* solar-constant values and *increased* contrast between center and edges of the solar disk are associated together with numerous sun spots, but for the *short* irregular period fluctuations of solar radiation, *higher* solar-constant values are associated with *diminished* contrast of brightness along the diameter of the solar disk. The year 1914 was singularly free from large fluctuations of solar radiation. The extreme range of solar-constant values was only 4 per cent between limits 1.91 and 1.99 calories. Accordingly the year was not very favorable for testing the relation just described. Nevertheless, the results tend to confirm rather than disprove the conclusion reached that for short, irregular fluctuations of the solar radiation high values are associated with less contrast of brightness between the center and edges of the sun.

The somewhat paradoxical conclusions above stated seem capable of explanation as follows: Associated with the great increase of solar activity attending the maximum of the sun spot cycle, increased convection is continually bringing fresh hot material to the sun's surface, so that the effective solar temperature is then higher, and greater emission of radiation prevails. At such a time the contrast, which would be zero if the solar temperature were zero, is naturally also increased. As for the quick, irregular fluctuations, it must be supposed that the sun's outer envelope hinders somewhat the passage of radiation from within outward. This hindrance is greater at the edges of the sun's disk, where the path of the rays in the line of sight is oblique, than it is at the center of the sun's disk. Suppose now that the obstructive property of these layers varies from day to day. When their transparency is increased the solar radiation must *increase;* but as the effect will be most conspicuous at the edge of the solar disk, where the path of the rays is longest, the *contrast* of brightness between center and limb must thereby *decrease.*

Two kinds of causes may, therefore, contribute to the sun's variability. The one, a change of effective temperature attending the general march of solar activity, may cause the variability of long period. The other, a change of opacity of the outer solar layers, may cause the variability of short irregular period.

SUMMARY.

Successful records of the intensity of solar radiation up to 25,000 meters were secured by means of automatic recording pyrheliometers attached to sounding balloons. The mean of the three highest values reduced to mean solar distance is 1.84 calories per square centimeter per minute. Making 2 per cent allowance for scattering and absorption in the air above (which gave a barometric pressure only about one twenty-fifth of that at sea level), the value 1.88 calories is obtained as the probable intensity of solar radiation outside the atmosphere at mean solar distance on this day. This value falls near the mean of numerous values obtained by spectrobolometric observations on Mount Wilson.

Experiments begun at sunrise and continued until 10 o'clock on September 20 and 21, 1914, indicate great constancy of transparency of the atmosphere above Mount Wilson, and yield solar-constant values independent of the altitude of the sun. These results confirm the substantial accuracy of the Mount Wilson observations of the solar constant of radiation.

The radiation of the sun was 2.5 per cent below the mean, according to the average of observations extending from July to October,

1913, inclusive, and 1 per cent above the mean from similar studies extending from June to October, 1914, inclusive. A high average value for 1915 is indicated.

The contrast of brightness between the center and edges of the solar disk was less in 1913 than in 1905 to 1907, but was restored to the earlier condition in 1914.

Short-period fluctuations of solar radiation were large in 1913, but small in 1914. Associated with these quick, irregular fluctuations are found variations of contrast of brightness between the center and edges of the solar disk. Curiously enough, while greater contrast is associated with greater solar radiation and with numerous sun spots in the general march of the sun's activity, lesser contrast is associated with greater solar radiation in the march of the quick, irregular fluctuations of the sun's emission.

This paradox points to two causes of solar variation—the long-period changes may probably be caused by changes of the sun's effective temperature attending the march of solar activity; the quick fluctuations may be ascribed to changes of the transparency of the outer solar envelopes.

Respectfully submitted.

C. G. Abbot,
Director Astrophysical Observatory.

Dr. C. D. Walcott,
Secretary of the Smithsonian Institution.

Appendix 6.

REPORT ON THE LIBRARY.

Sir: I have the honor to submit the following report upon the operations of the library of the Smithsonian Institution and its branches for the fiscal year ending June 30, 1915:

In common with other libraries of the world, the Smithsonian library has had to confront a serious situation during the last year. This was the difficulty experienced in the securing of current parts and the completing of sets of the publications of learned institutions and scientific societies that have been received from European sources for many years. Some of these series have ceased publication, others have been published with fewer pages and in smaller editions, while still others have been issued but not forwarded, all due largely to the military service required of the contributors and publishers at this time at the front and the risk involved in transportation. Notwithstanding these conditions, the efforts to keep the library exchanges alive have been continued with marked success.

ACCESSIONS.

During the fiscal year a total of 26,928 packages of publications were received, of which 25,097 came through the mails and 1,831 through the International Exchange Service. The correspondence necessary in connection with these receipts numbered about 1,400 letters, requesting publications and acknowledging them, and 5,148 acknowledgments on the regular form.

The publications for the Smithsonian library were entered, accessioned, and forwarded to the Smithsonian deposit in the Library of Congress each day as received, numbering in all 24,713 publications, as follows: 3,043 volumes, 1,179 parts of volumes, 1,763 pamphlets, 17,410 periodicals, 594 charts, and 724 parts of serials to complete sets. The numbers in the accession record run from 517,777 to 521,616. There were catalogued during the year 3,451 publications, of which 1,000 were charts. Four thousand one hundred and twenty-two volumes were recatalogued from the old records and entered in the new catalogue. The cards typewritten and filed in the catalogue numbered 4,038.

The sending to the Library of Congress of public documents presented to the Smithsonian Institution, without stamping and recording, has been continued, and 4,675 were forwarded in this way.

The accessions for the office library, which includes the Astrophysical Observatory and the National Zoological Park, numbered 561 publications, distributed as follows: 351 volumes, 35 parts of volumes, and 40 pamphlets, for the office library; 72 volumes, 11 parts of volumes and 25 pamphlets for the Astrophysical Observatory, and 21 volumes and 6 pamphlets for the National Zoological Park.

Complete sets of inaugural dissertations and technological publications from 12 universities and technical high schools were received from the following places: Baltimore, Basel, Copenhagen, Delft, Ithaca, Lund, Paris, Philadelphia, Toulouse, and Zürich.

EXCHANGES.

The sendings from Europe have been restricted compared with those of former years, but there has been no cessation in the efforts to secure new exchanges and missing parts in the series, and many have been received. The new series added to the library numbered 48, and all of the 387 want cards for the series searched in the Library of Congress were considered and some action taken on each at the Smithsonian Institution, with the result that 82 sets of publications of learned institutions and scientific societies in the Smithsonian division were entirely or partially completed by the supplying of 460 parts; in the same way 254 parts of 48 sets were supplied to the periodical division, and for the part of the deposit in the general classification 10 parts of 4 sets.

Among the more important of these series secured for the Smithsonian library may be cited the following:

Australia:

Sydney, New South Wales.—Royal Anthropological Society of Australasia. Science of Man.

Belgium:

Brussels.—Académie Royale de Belgique. Bulletin, Classe des lettres. Association des industriels de Belgique pour l'étude et la propagation des engins et mésures propres à préserver les ouvriers des accidents du travail. Rapport.

St. Nicholas.—Cercle archéologique du pays de Waes. Annales.

England:

London.—Agricultural Economist and Horticultural Review.
Royal Geographical Society. Geographical Journal.

Birmingham.—Birmingham Natural History and Microscopical Society. Report.

France:

Nice.—Association Procincials des architectes français. Bulletin.

Paris.—Société Française de Physique. Résumé des communications.

Germany:

Berlin.—Berliner Missionsgesellschaft. Berliner Missions-Berichte.
Deutscher Fischerei-Verein. Zeitschrift fuer Fischerei.

Darmstadt.—Historischer Verein fuer das Grossherzogthum Hessen. Quartalblätter.

Dresden.—K. Oeffentliche Bibliothek. Papyrus-Fragment aus der Kgl. Oeff. Bibliothek zu Dresden.

Munich.—K. Bayerische Akademie der Wissenschaften. Abhandlungen, Denkschriften Gelehrte Anzeiger Sitzungsberichte.

India:

Calcutta.—Medical and Sanitary Departments of India. Scientific Memoirs by the Officers of the Medical and Sanitary Departments.

Italy:

Florence.—Societa Botanica Italiana. Bullettino.

Siam:

Bangkok.—Siam Society. Journal.

The exchange of publications with historical societies in this country and abroad has been continued, resulting in many additions both in the form of new exchanges and the supplying of missing parts.

READING ROOM.

In the reading room the current foreign and domestic scientific periodicals have been in constant use by the staff and the members of the scientific bureaus of the governmental establishments in Washington, and there are now 294 titles on the shelves. Three thousand five hundred and three publications from the reading and reference rooms were circulated during the year. Of these 3,161 were single numbers of periodicals, and 342 were bound volumes.

THE AERONAUTICAL LIBRARY.

One of the important collections of reference works at the Institution is that relating to aeronautics, and is, in all probability, the most complete series on this subject in the United States. The collection had its origin with Secretary Langley when he was carrying on his aeronautical experiments, at which time he was able to secure many early works that can not now be purchased.

One of the chief contributors during the year was Dr. Alexander Graham Bell, a Regent of the Institution, whose gift consists of his working library on the subject, numbering 46 volumes, and another series of 153 volumes of newspaper clippings relating to the important period when the Wright brothers were making their initial flights.

The additions to the collection during the year, including those from Dr. Bell, were 256.

ART ROOM.

Mrs. Charles D. Walcott has added to the collection of works on art an exceptionally valuable loan, consisting of nine magnificent volumes on Japanese art, fully illustrated in color. Mrs. Walcott has also deposited the architectural publications, numbering 394 volumes, and parts of serial publications which formed the library of her brother, George Vaux, an architect of prominence in the city of Philadelphia.

EMPLOYEES' LIBRARY.

The employees' library has also received a contribution from Mrs. Walcott by the deposit of a collection of popular works, numbering 145 volumes.

NEW STEEL STACKS.

The work on the new steel stacks for the books belonging to the libraries of the Government bureaus under the Smithsonian Institution has been continued, and at the close of the year this work is nearly completed. With the passage of the appropriation bills in August, 1914, the additional sum of $10,000 became available, and immediately an order was issued for the erection of as much of the second half of the stacks in the west end of the main hall as the money available would permit. Those in the east end were completed in August, and the moving of the library of the Bureau of American Ethnology to its new quarters was accomplished within a very short time. The old wooden galleries in the west end were then removed, and this part of the hall was turned over to the contractors for the erection of stacks. Congress having appropriated an additional sum of $6,500 during the last session, the steel stacks were practically finished at the close of the year.

The libraries of the Government bureaus under the Institution have heretofore been cared for in the bureau offices and wherever there was space for shelving. Proper classification and arrangement were impossible, owing to lack of space, and much time was lost in looking for references. The new stacks have a capacity of 100,000 volumes, and make it possible for the first time to bring all publications relating to one subject together, so that each is available for consultation.

UNITED STATES NATIONAL MUSEUM.

It seems desirable, after a period of a third of a century, to briefly review the growth and progress that have been made in the Museum library. The formation of a working library in the National Museum in 1881 was largely due to the increased activity in investi-

gations and the need of reference works for the curators in their study of the collections which were moved from the Smithsonian Building to the separate building erected for the Museum.

A nucleus was begun in the northwest corner of the Museum building with a collection of publications for the most part made up of standard zoological and industrial works and bound pamplets, composing the library of Spencer Fullerton Baird, second Secretary of the Smithsonian Institution, which he had presented to the Museum. The Library has grown steadily until it now occupies not only the old rooms, but additional larger quarters in the new building as well as space for the special libraries in the various sections. Within a year after the first books had been brought together there were 5,450 volumes and 4,750 pamphlets; in all, 10,200 publications. Now, in the thirty-fifth year of its existence, there are 45,818 bound volumes, 76,295 pamphlets, forming a collection of 122,113 titles, from which the duplicates have been removed.

The system of arrangement has been modified to some extent, but the plan upon which the Museum library was organized has been continued, in that the general library has retained all books treating of more than one subject, such as periodicals, proceedings of societies, dictionaries, and encyclopedias, together with such monographs as are not constantly needed in the sectional libraries; and the sectional libraries have had assigned to them only those publications which relate to the work of the department or division. A little more than a year ago the general library and works relating to anthropology, biology, and geology were moved to new quarters in the new building, where up-to-date facilities for the consultation of publications have been provided.

This left the old rooms where the library had had its inception free, and the space thus made vacant is now being used for the accumulation of another collection of works of reference of equal importance relating to history and the collections of arts and industries of a technical nature, which are being developed in the older Museum Building. While this library has but recently been started, the indications are that it will have a growth equal to that of the parent library, and it promises to become one of the most important technical series of publications in the country.

The establishment of sectional libraries of special reference works bearing on the collections has been of importance to the curators, and the number has been increased in proportion to the growth of the Museum. Beginning with 8 in 1881, there are now 33 collections of publications on special subjects.

Considering the ways and means for adding to the library in the early days, its growth has been remarkable. The library for the first 18 years was dependent largely for its increase upon the exchange

of the publications of the Museum descriptive of its collections in the various fields of science. This plan for increasing the library was very successful, but it did not provide books of reference, in part published at a loss, which could only be secured by purchase. In 1898 an appropriation of $2,000 was made by Congress for the purchase of such books, but this sum was barely adequate then, and while the appropriation has been continued, it has not been increased. This lack of sufficient funds will be more keenly felt in the very near future, owing to the present conditions in Europe and the inability of the scientific societies and institutions abroad to supply even exchange copies.

ACCESSIONS.

The Museum library now contains 45,818 volumes, 76,295 pamphlets and unbound papers, and 124 manuscripts. The accessions during the year covered by this report number 2,209 volumes, 2,530 pamphlets, and 183 parts of volumes.

CATALOGUING.

The books catalogued number 1,550, pamphlets 2,530, and the total number of cards made 4,664; completed volumes of periodicals catalogued, 756; parts of publications, 183; parts of periodicals, 9,805; new periodical cards made, 389.

The old catalogue of the Museum library was entered on cards of about twice the size of the standard card now in use without sufficient information for the proper identification of the publication. For a number of years the recataloguing of these publications on standard cards has been carried on as the other work permitted until at the present time only the publications in the sectional libraries remain. With the continued increase in the work it is hardly possible to do more than recatalogue 100 volumes in a year, but with additional help this work could be completed at once, and would be of great value to the Museum in connection with reference work.

EXCHANGES.

The existing conditions in Europe have interfered to some extent with the securing of new exchanges as well as with the receipt of publications which have been coming for many years. In the matter of exchanges and the securing of publications needed to complete the series 297 letters were written, with the result that many new titles of publications issued in series were added to those already coming. The receipts of publications from abroad have been delayed, and in many cases the institutions and societies are holding the

sets and series until it will be safe to transmit them. Also, for economic reasons, only limited editions with fewer pages are issued, which gives a special value to those received.

LOANS.

The use of the library has been largely by the scientific staff of the Museum, but other departments of the Government, particularly the Department of Agriculture, have availed themselves of the opportunity of consulting the publications relating to the various branches of science. During the year the loans from the general library numbered 12,492 publications, which includes 5,272 books assigned to the sectional libraries, 3,020 books borrowed from the Library of Congress, 111 from the Department of Agriculture library, 72 from the United States Geological Survey, 44 from the Army Medical Museum and Library, and 13 from other places. From the Museum shelves there were borrowed 3,960 volumes.

One of the important matters considered during the latter part of the year was the return of books that had been borrowed from the Library of Congress on the older records, and while only the charges for books coming under the first three letters of the alphabet were acted upon, the indications are that those running back as far as 1876 will be cleared up. During the year 3,437 books were returned to the Library of Congress and 294 to other libraries.

BINDING.

The binding of volumes received in separate parts is still a serious matter, and it is hoped that some provision can be made at an early date, so that all of them may be bound. To cite an instance, there are now in the technical series of recently catalogued works over 100 volumes that should be bound at once, in order that they may be preserved intact.

There were 812 volumes prepared for binding and sent to the Government bindery.

GIFTS.

Gifts of importance have been received from the following persons: Dr. Charles Doolittle Walcott, Mrs. Richard Rathbun, Dr. William Healey Dall, Dr. Oliver Perry Hay, Dr. Charles W. Richmond, Mr. George C. Maynard, Dr. Robert W. Shufeldt, Mr. Austin Hobart Clark, Mr. Robert Ridgway, Dr. Joseph Nelson Rose, Dr. I. M. Casanowicz, Mr. William R. Maxon, and also the library of the late Dr. Theodore Nicholas Gill has been presented by Mr. Herbert A. Gill.

DALL COLLECTION.

Dr. William Healey Dall contributed 162 titles, at a cost of about $60, as additions to the collection of books relating to mollusks which has been brought together by him as curator of that division, as a reference library. These and the publications previously received now number approximately 7,662 titles.

BOTANICAL LIBRARY.

A large collection of botanical books, the property of Dr. Edward L. Greene, which had been on deposit in the United States National Museum since 1904, was withdrawn during the year as it was impracticable to secure the sum of $20,000 required for their purchase.

TECHNOLOGICAL SERIES.

In this branch of the library, which has only recently been formed, and which is cared for in the older Museum Building, special efforts have been made to put the classes of publications in more convenient places and to make them more accessible for consultation. Those relating to music, ceramics, photography, and botany have been critically examined, recatalogued, and put in order on the shelves. Those of the following classes have not as yet been considered: Art and architecture, physics, chemistry, history, literature, sociology and economy, and political science.

This branch of the library is very deficient in general reference books, such as an exhaustive encyclopedic work, technical dictionaries, and dictionaries of some of the foreign languages, and while a few of these works can be purchased during the present year, there will not be money available to secure them all.

The additions to this part of the library numbered 1,061 volumes, 3,573 parts of volumes, and 2,631 pamphlets and 4 maps.

The cataloguing for the year numbered 660 volumes, 1,131 pamphlets, and 4 maps, requiring 1,406 cards. The number of periodicals entered on the records were 801 volumes and 6,253 parts of volumes. Special efforts have been made to catalogue the entire collection in the library, and until this is completed the record for cataloguing will not cover the receipts. Books and pamphlets loaned during the year, in addition to those from the general library, numbered 258 volumes and 346 pamphlets, while there were consulted in the reading room about 520 publications. In addition to the work on the catalogue, about 800 volumes and 7,000 pamphlets and parts of volumes were filed on the shelves, to be added to the records later.

In the scientific depository set of printed cards from the Library of Congress about 30,000 were filed alphabetically by authors. This index will be of great value when the subject cards are included, as

it will then contain a complete reference list of publications available on all subjects considered in the Museum.

SECTIONAL LIBRARIES.

While progress has been made in the revision of the records for reference publications which are permanently deposited in the sectional libraries it has not been possible to carry the systematic checking very far, and my recommendation of last year that a competent cataloguer be employed to do this special work is renewed. While this condition is largely due to the overcrowded condition of the library for so many years, it is essential to the work of the Museum that the sectional libraries should be in perfect order and that the records in the main library should be complete.

The following is a complete list of the sectional libraries:

Administration.
Administrative assistant's office.
Anthropology.
Biology.
Birds.
Botany.
Comparative anatomy.
Editor's office.
Ethnology.
Fishes.
Geology.
Graphic arts.
History.
Insects.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Materia medica.
Mechanical technology.
Mesozoic fossils.
Mineralogy.
Mineral technology.
Mollusks.
Oriental archeology.
Paleobotany.
Parasites.
Photography.
Physical anthropology.
Prehistoric archeology.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate paleontology.

BUREAU OF AMERICAN ETHNOLOGY.

This library is administered under the direct care of the ethnologist-in-charge, and an account of its operations will be found in the report of that bureau.

ASTROPHYSICAL OBSERVATORY.

Publications relating to astrophysics have been assembled in the bookcases just completed in the east end of the main hall of the Smithsonian Building. This situation is convenient to the observatory, and the new facilities make it possible for the first time to properly classify this library. During the year there were added 72 volumes, 11 parts of volumes, and 25 pamphlets. Fifty-five volumes were bound.

NATIONAL ZOOLOGICAL PARK.

This library contains publications relating to the work of the park in the care of the animals, reports of other zoological parks, and a few works on landscape gardening. The number of publications received was very small as compared with the previous year, and this may be due to the fact that none of the parks abroad, except that at Gizeh, Egypt, issued any publications. During the year there were received 21 volumes and 6 pamphlets.

SUMMARY OF ACCESSIONS.

The following statement summarizes the accessions during the year, with the exception of the library of the Bureau of American Ethnology:

To the Smithsonian deposit in the Library of Congress, including parts to complete sets	7,303
To the Smithsonian office, Astrophysical Observatory, and National Zoological Park	560
To the United States National Museum	4,922
Total	12,785

Respectfully submitted.

Paul Brockett,
Assistant Librarian.

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

APPENDIX 7.

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

SIR: I have the honor to submit the following report on the operations of the United States Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1915:

This international cooperative enterprise has since 1901 published annual classified index catalogues of the current scientific literature of the world. The following-named branches of science are represented each year by a separate volume: Mathematics, mechanics, physics, chemistry, astronomy, meteorology, mineralogy, geology, geography, paleontology, general biology, botany, zoology, anatomy, anthropology, physiology, and bacteriology.

All of the first 10 annual issues of 17 volumes each have been published, together with 15 volumes of the eleventh issue, 9 volumes of the twelfth issue, and 2 volumes of the thirteenth issue; a total of 196 regular volumes in addition to several special volumes of schedules, list of journals, etc.

The 15 volumes of the eleventh issue published are mathematics, mechanics, physics, chemistry, astronomy, meteorology, mineralogy, geology, geography, paleontology, general biology, botany, zoology, anatomy, and anthropology.

The nine volumes of the twelfth issue published are mathematics, mechanics, physics, chemistry, astronomy, geography, paleontology, general biology, and zoology.

The two volumes of the thirteenth issue published are mathematics and zoology.

During the year there were 26,413 classified references to American scientific literature prepared by this bureau, as follows:

Literature of—	
1906	10
1907	19
1908	192
1909	195
1910	348
1911	1,358
1912	3,511
1913	8,394
1914	12,386
Total	26,413

The object of the catalogue is not only to publish references by authors to current scientific literature, but also to supply practically a digest of the subject contents of each paper by means of minutely classified subject catalogues. The elaborate classification schedules used render it possible to refer to all subjects treated in each paper indexed.

It is the duty of this Bureau of the International Catalogue to analyze and classify the contents of all scientific papers published in the United States. An idea of the extent of the work may be gained from the fact that between 25,000 and 30,000 citations are sent each year to the London central bureau for publication, the subjects classified covering all branches of science. In this day of specialization it is not possible for one or two individuals to have a thorough knowledge of all the sciences, and as economy of administration would not warrant the employment of, say, a dozen specialists, it was the practice for a number of years to refer some of the more technical papers to specialists for classification. These specialists, being employees of the various scientific branches of the Government in Washington, have, while not engaged in their official duties, aided the catalogue by furnishing the classification data required. Payments averaged approximately $600 per year, divided among five or six individuals. It may be said that while the specialists were willing to aid in this important international undertaking for a comparatively nominal compensation, the catalogue was benefited to a very great extent, for each citation furnished was the equivalent of a specialist's decision as to the value and application of the scientific subject of each paper classified. This method of compensating employees of other scientific bureaus of the Government was decided on in 1905 after a conference between the disbursing agent of the Smithsonian Institution and the then Comptroller of the Treasury.

The present Comptroller of the Treasury does not agree on this subject with the former comptroller, and in a letter dated February 4, 1914, referring to a number of similar payments stated:

> I am of the opinion that the payments in question come within the prohibition of sections 1764 and 1765, Revised Statutes, and were not authorized by law. In view of the fact that this office, in letters dated October 24, 1905, and February 15, 1906, sanctioned the payments to employees of other bureaus and departments, which seems to have been construed to sanction the payment for both classes, no disallowance will be made in the present settlement, but payments made subsequent to the date of this decision will not be allowed.

This decision has greatly embarrassed the work of the bureau, and it is hoped that Congress will so change the wording of future appropriations for the maintenance of the bureau as to authorize payments of this character being made.

The general organization of the International Catalogue of Scientific Literature consists of a central bureau in London whose duty it is to assemble, edit, and publish classified references to current scientific literature supplied by the various regional bureaus representing the cooperating countries. The following named countries have established regional bureaus, supported in most cases by direct Government grants: Argentine Republic, Austria, Belgium, Canada, Chile, Cuba, Denmark, Egypt, Finland, France, Germany, Greece, Holland, Hungary, India and Ceylon, Italy, Japan, Mexico, New South Wales, New Zealand, Norway, Poland, Portugal, Queensland, Russia, South Africa, South Australia, Spain, Straits Settlements, Sweden, Switzerland, United States of America, Victoria and Tasmania, and Western Australia.

The present war in Europe has seriously interfered not only with the finances but with the general work of the catalogue. Before hostilities began the receipts and expenditures of the London central bureau just balanced. These receipts are derived from the sale of the catalogue to the various subscribers throughout the world and are used entirely to defray the cost of printing and publishing.

Subscriptions aggregating almost $6,000 a year, due from five of the countries engaged in hostilities, have been either delayed or stopped by the war. The Royal Society of London, realizing that it would be impossible for the central bureau to continue publishing the catalogue in the face of this deficit, has very generously made a grant of a sum almost sufficient to cover the deficit caused by the first year of the war. It may be said that the Royal Society has not only stood sponsor for the catalogue since its inception, but it was through the good offices of this society that the enterprise was begun. It is greatly to be hoped that this action of the Royal Society will stimulate similar institutions in the United States to aid in making up the annual deficit until a readjustment of the affairs of the bureaus affected can be made after peace has been declared.

Very respectfully, yours,

Leonard C. Gunnell,
Assistant in Charge.

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

APPENDIX 8.

REPORT ON THE PUBLICATIONS.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1915:

The Institution proper published during the year 14 papers in the series of "Smithsonian Miscellaneous Collections," two annual reports, pamphlet copies of 68 papers from the general appendices of these reports, and 8 special publications. The Bureau of American Ethnology published 2 bulletins and 3 miscellaneous publications, and the United States National Museum issued 1 annual report, 1 volume of the Proceedings, and 41 separate papers forming parts of this and other volumes, 6 bulletins, and 1 volume pertaining to the National Herbarium.

The total number of copies of publications distributed by the Institution proper during the year was 77,710. This number includes 620 volumes and separate memoirs of Smithsonian Contributions to Knowledge, 30,058 volumes and separate pamphlets of Smithsonian Miscellaneous Collections, 30,909 volumes and separate pamphlets of Smithsonian annual reports, 10,185 publications of the Bureau of American Ethnology, 5,424 special publications, 36 volumes of the Annals of the Astrophysical Observatory, 121 reports of the Harriman Alaska Expedition, 245 reports of the American Historical Association, 5 publications of the United States National Museum, and 108 publications not of the Smithsonian or its branches. There were distributed by the National Museum 54,300 copies of its several series of publications, making a total of 132,010 publications distributed by the Institution and its branches during the year.

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

QUARTO.

No publications of this series were issued during the year.

SMITHSONIAN MISCELLANEOUS COLLECTIONS.

OCTAVO.

Of the Miscellaneous Collections, volume 57, the title-page and table of contents was published; of volume 62, 1 paper; of volume 63,

4 papers and title-page and table of contents; of volume 64, 1 paper; and of volume 65, 8 papers; in all, 14 papers, as follows:

Volume 57.

Title-page and table of contents. July 31, 1914. (Publ. 2270.)

Volume 62.

No. 3. Report on European aeronautical laboratories. By A. F. Zahm. July 27, 1914. 23 pp., 11 pls. (Publ. 2273.)

Volume 63.

No. 6. Smithsonian Physical Tables. Sixth revised edition. By F. E. Fowle. November 10, 1914. xxxvi+355 pp. (Publ. 2269.)

No. 8. Explorations and field-work of the Smithsonian Institution in 1913. November 27, 1914. 88 pp. (Publ. 2275.)

No. 9. The olfactory sense of insects. By N. E. McIndoo. November 21, 1914. 63 pp. (Publ. 2315.)

No. 10. Archeology of the lower Mimbres Valley, N. Mex. By J. Walter Fewkes. December 18, 1914. 53 pp., 8 pls. (Publ. 2316.)

Title-page and table of contents. January 30, 1915. v pp. (Publ. 2320.)

Volume 64.

No. 2. Cambrian geology and paleontology. III. Pre-Cambrian Algonkian algal flora. By Charles D. Walcott. July 22, 1914. Pp. 77–156, pls. 4–23. (Publ. 2271.)

Volume 65.

No. 1. The present distribution of the Onychophora, a group of terrestrial invertebrates. By Austin H. Clark. January 4, 1915. 25 pp. (Publ. 2319.)

No. 2. The development of the lungs of the alligator. By A. M. Reese. March 3, 1915. 11 pp., 9 pls. (Publ. 2356.)

No. 3. A study of the radiation of the atmosphere. By Anders K. Ångström. Hodgkins fund. 159 pp. (Publ. 2354.) In press.

No. 4. New evidence on the intensity of the solar radiation outside the atmosphere. By C. G. Abbot, F. E. Fowle, and L. B. Aldrich. Hodgkins fund. June 19, 1915. 55 pp. (Publ. 2361.)

No. 5. The microspectroscope in mineralogy. By Edgar T. Wherry. April 7, 1915. 16 pp. (Publ. 2362.)

No. 6. Explorations and field-work of the Smithsonian Institution in 1914. June 30, 1915. 95 pp., 1 pl. (Publ. 2363.)

No. 7. Two new sedges from the southwestern United States. By Kenneth K. Mackenzie. April 9, 1915. 3 pp. (Publ. 2364.)

No. 8. Report upon a collection of ferns from western South America. By William R. Maxon. May 3, 1915. 12 pp. (Publ. 2366.)

SMITHSONIAN ANNUAL REPORTS.

Report for 1913.

The Annual Report of the Board of Regents for 1913 was received from the Public Printer in completed form in December, 1914.

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, 1913. xi+804 pp., 169 pls. (Publ. 2277.)

Small editions of the following papers, forming the general appendix of the annual report for 1913, were issued in pamphlet form:

The earth and sun as magnets, by George E. Hale. 14 pp., 8 pls. (Publ. 2278.)
The reaction of the planets upon the sun, by P. Puiseux. 16 pp. (Publ. 2279.)
Recent progress in astrophysics, by C. G. Abbot. 20 pp., 3 pls. (Publ. 2280.)
The earth's magnetism, by L. A. Bauer. 18 pp., 9 pls. (Publ. 2281.)
Modern ideas on the end of the world, by Gustav Jaumann. 9 pp. (Publ. 2282.)
Recent developments in electromagnetism, by Eugene Bloch. 19 pp. (Publ. 2283.)
Wireless transmission of energy, by Elihu Thomson. 18 pp. (Publ. 2284.)
Oil films on water and on mercury, by Henri Devaux. 13 pp., 7 pls. (Publ. 2285.)
Water and volcanic activity, by Arthur L. Day and E. S. Shepherd. 31 pp., 11 pls. (Publ. 2286.)
Ripple marks, by Ch. Epry. 11 pp., 10 pls. (Publ. 2287.)
Notes on the geological history of the walnuts and hickories, by Edward W. Berry. 13 pp. (Publ. 2288.)
The formation of leaf mold, by Frederick V. Coville. 11 pp. (Publ. 2289.)
The development of orchid cultivation and its bearing upon evolutionary theories, by J. Costantin. 14 pp. (Publ. 2290.)
The manufacture of nitrates from the atmosphere, by Ernest Kilburn Scott. 26 pp., 3 pls. (Publ. 2291.)
The geologic history of China and its influence upon the Chinese people, by Eliot Blackwelder. 12 pp., 9 pls. (Publ. 2292.)
The problems of heredity, by E. Apert. 17 pp. (Publ. 2293.)
Habits of fiddler-crabs, by A. S. Pearse. 14 pp. (Publ. 2294.)
The abalones of California, by Charles L. Edwards. 10 pp., 10 pls. (Publ. 2295.)
The value of birds to man, by James Buckland. 20 pp. (Publ. 2296.)
Experiments in feeding hummingbirds during seven summers, by Althea R. Sherman. 10 pp. (Publ. 2297.)
What the American Bird Banding Association has accomplished during 1912, by Howard H. Cleaves. 11 pp., 2 pls. (Publ. 2298.)
The whale fisheries of the world, by Charles Rabot. 9 pp., 3 pls. (Publ. 2299.)
The most ancient skeletal remains of man, by Aleš Hrdlička. 62 pp., 41 pls. (Publ. 2300.)
The redistribution of mankind, by H. N. Dickson. 17 pp. (Publ. 2301.)
The earliest forms of human habitation, and their relation to the general development of civilization, by M. Hoernes. 8 pp. (Publ. 2302.)
Feudalism in Persia; its origin, development, and present condition, by Jacques de Morgan. 28 pp. (Publ. 2303.)
Shintoism and its significance, by K. Kanokogi. 9 pp. (Publ. 2304.)
The Minoan and Mycenaean element in Hellenic life, by A. J. Evans. 21 pp., 3 pls. (Publ. 2305.)
Flameless combustion, by Carleton Ellis. 14 pp., 1 pl. (Publ. 2306.)
Problems in smoke, fume, and dust abatement, by F. G. Cottrell. 33 pp., 37 pls. (Publ. 2307.)
Twenty years' progress in marine construction, by Alexander Gracie. 21 pp. (Publ. 2308.)
Creating a subterranean river and supplying a metropolis with mountain water, by J. Bernard Walker and A. Russell Bond. 14 pp., 11 pls. (Publ. 2309.)

The application of the physiology of color vision in modern art, by Henry G. Keller and J. J. R. Macleod. 17 pp. (Publ. 2310.)

Fundamentals of housing reform, by James Ford. 14 pp. (Publ. 2311.)

The economic and social rôle of fashion, by Pierre Clerget. 11 pp. (Publ. 2312.)

The work of J. van't Hoff, by G. Bruni. 23 pp. (Publ. 2313.)

Report for 1914.

The report of the executive committee and proceedings of the Board of Regents of the Institution, as well as the report of the Secretary, for the fiscal year ending June 30, 1914, both forming part of the Annual Report of the Board of Regents to Congress, were published in pamphlet form in December, 1914, as follows:

Report of the executive committee and proceedings of the Board of Regents for the year ending June 30, 1914. 17 pp. (Publ. 2318.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1914. iii, 117 pp., 4 pls. (Publ. 2317.)

Small editions of the following papers, forming the general appendix of the report, were issued in June, and the complete volume was received from the printer shortly after the close of the fiscal year:

The radiation of the sun. By C. G. Abbot. 16 pp., 4 pls. (Publ. 2322.)

Modern theories of the sun. By Jean Bosler. 8 pp., 2 pls. (Publ. 2323.)

The form and constitution of the earth. By Louis B. Stewart. 14 pp. (Publ. 2324.)

Some remarks on logarithms apropos to their tercentenary. By M. d'Ocagne. 7 pp., 2 pls. (Publ. 2325.)

Modern views on the constitution of the atom. By A. S. Eve. 9 pp. (Publ. 2326.)

Gyrostats and gyrostatic action. By Andrew Gray. 16 pp., 10 pls. (Publ. 2327.)

Stability of aeroplanes. By Orville Wright. 8 pp. (Publ. 2328.)

The first man-carrying aeroplane capable of sustained free flight—Langley's success as a pioneer in aviation. By A. F. Zahm. 6 pp., 8 pls. (Publ. 2329.)

Some aspects of industrial chemistry. By L. H. Baekeland. 25 pp. (Publ. 2330.)

Explosives. By Edward P. O'Hern. 27 pp., 7 pls. (Publ. 2331.)

Climates of geologic time. By Charles Schuchert. 35 pp. (Publ. 2332.)

Pleochroic haloes. By J. Joly. 15 pp., 3 pls. (Publ. 2333.)

The geology of the bottom of the seas. By L. de Launay. 24 pp. (Publ. 2334.)

Recent oceanographic researches. By Ch. Gravier. 10 pp. (Publ. 2335.)

The Klondike and Yukon goldfield in 1913. By H. M. Cadell. 20 pp., 6 pls. (Publ. 2336.)

The history of the discovery of sexuality in plants. By Duncan S. Johnson. 24 pp. (Publ. 2337.)

Problems and progress in plant pathology. By L. R. Jones. 13 pp. (Publ. 2338.)

Plant autographs and their revelations. By Jagadis Chunder Bose. 23 pp. (Publ. 2339.)

The National Zoological Park and its inhabitants. By Frank Baker. 34 pp., 41 pls. (Publ. 2340.)

On the habits and behavior of the herring gull. By R. M. Strong. 31 pp., 10 pls. (Publ. 2341.)

Notes on some effects of extreme drought in Waterberg, South Africa. By Eugéne N. Marais. 12 pp. (Publ. 2342.)

Homœotic regeneration of the antennæ in a Phasmid or walking-stick. By H. O. Schmit-Jensen. 14 pp., 2 pls. (Publ. 2343.)

Latent life: Its nature and its relations to certain theories of contemporary biology. By Paul Becquerel. 15 pp. (Publ. 2344.)

The early inhabitants of western Asia. By Felix V. Luschan. 25 pp., 12 pls. (Publ. 2345.)

Excavations at Abydos. By Edouard Naville. 7 pp., 3 pls. (Publ. 2346.)

An examination of Chinese bronzes. By John C. Ferguson. 6 pp., 14 pls. (Publ. 2347.)

The rôle of depopulation, deforestation, and malaria in the decadence of certain nations. By Felix Regnault. 5 pp. (Publ. 2348.)

The story of the chin. By Louis Robinson. 11 pp., 12 pls. (Publ. 2349.)

Recent developments in the art of illumination. By Preston S. Millar. 18 pp., 3 pls. (Publ. 2350.)

The loom and spindle: Past, present, and future. By Luther Hooper. 49 pp., 11 pls. (Publ. 2351.)

The demonstration play school of 1913. By Clark W. Hetherington. 29 pp. (Publ. 2352.)

Sketch of the life of Eduard Suess (1831–1914). By Pierre Termier. 10 pp. (Publ. 2353.)

SPECIAL PUBLICATIONS.

The following special publications were issued in octavo form:

Publications of the Smithsonian Institution issued between January 1 and June 30, 1914. Published August 8, 1914. 2 pp. (Publ. 2274.)

Publications of the Smithsonian Institution issued between January 1 and September 30, 1914. October 7, 1914. 2 pp. (Publ. 2314.)

Publications of the Smithsonian Institution issued between January 1 and December 31, 1914. January 23, 1915. 3 pp. (Publ. 2355.)

Publications of the Smithsonian Institution issued between January 1 and March 31, 1915. April 17, 1915. 1 p. (Publ. 2365.)

Biographical sketch of James Smithson. October 30, 1914. 17 pp., 4 pls. (Publ. 2276.)

Opinions rendered by the International Commission on Zoological Nomenclature, Opinion 66. March 3, 1915. Pp. 171–176. (Publ. 2359.)

An index to the Museum Boltenianum. By William H. Dall. March 29, 1915. 64 pp. (Publ. 2360.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM.

The publications of the National Museum are: (*a*) The annual report to Congress; (*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 the Museum published an annual report, one volume of the Proceedings and 41 separate papers forming parts of

this and other volumes, 6 bulletins, and one volume of Contributions from the National Herbarium.

The issues of the proceedings were as follows: Volume 47, papers 2052 to 2063, and the complete volume; volume 48, papers 2064 to 2091; volume 49, paper 2093; Annual Report of the United States National Museum for 1914.

The bulletins were as follows:

Bulletin 71, A monograph of the Foraminifera of the North Pacific Ocean, Part V, Rotaliidae. By Joseph Augustine Cushman.

Bulletin 82, A monograph of the existing Crinoids, Vol. 1, The Comatulids, Part 1. By Austin Hobart Clark.

Bulletin 88, Revision of Paleozoic Stelleroidea, with special reference to North American Asteroidea. By Charles Schuchert.

Bulletin 89, Osteology of the Armored Dinosauria in the United States National Museum, with special reference to the genus Stegosaurus. By Charles Whitney Gilmore.

Bulletin 90, A monograph of the molluscan fauna of the Orthaulax Pugnax Zone of the Oligocene of Tampa, Florida. By William Healey Dall.

Special Bulletin, American hydroids, Part III, The Campanularidae and the Bonneviellidae. By Charles Cleveland Nutting.

In the series of Contributions from the National Herbarium there appeared volume 19, Flora of New Mexico, by E. O. Wooten and Paul C. Standley.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

The publications of the bureau are discussed in Appendix 2 of the Secretary's report. The editorial work of the bureau has been continued by Mr. J. G. Gurley, editor, who has been assisted from time to time by Mrs. Frances S. Nichols.

Two bulletins and three miscellaneous publications were issued during the year, as follows:

Bulletin 46. Byington's Choctaw Dictionary. Edited by John R. Swanton and Henry S. Halbert.

Bulletin 58. List of publications of the bureau.

No. 10. Circular of information regarding Indian popular names.

No. 11. Map of linguistic families of American Indians north of Mexico.

No. 12. List of Indian words denoting "man," prepared in placard form for use in the Smithsonian exhibit at the Panama-Pacific Exposition.

Four annual reports and five bulletins were in press at the close of the year.

PUBLICATIONS 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 to Congress under the provisions of the act of incorporation of the association.

The annual report for 1912 was published in August, 1914. In September, 1914, the manuscript of the 1913 report was sent to the printer, but it was not completed at the close of the year.

PUBLICATIONS OF THE SOCIETY OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The manuscript of the Seventeenth Annual Report of the National Society of the Daughters of the American Revolution for the year ending October 11, 1914, was communicated to Congress March 3, 1915.

THE 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 this committee have been referred the manuscripts proposed for publication by the various branches of the Institution, as well as those offered for printing in the Smithsonian series. The committee also considered forms of routine, blanks, and various matters pertaining to printing and publication. Eighteen meetings were held and 109 manuscripts were acted upon.

Respectfully submitted.

A. Howard Clark, *Editor.*

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

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1915.

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 National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, and the International Catalogue of Scientific Literature for the year ending June 30, 1915, together with balances of previous appropriations:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1915.

The permanent fund of the Institution and the sources from which it has been derived are as follows:

DEPOSITED IN THE TREASURY OF THE UNITED STATES.

Bequest of Smithson, 1846		$515,169.00
Residuary legacy of Smithson, 1867		26,210.63
Deposit from savings of income, 1867		108,620.37
Bequest of James Hamilton, 1875	$1,000.00	
Accumulated interest on Hamilton fund, 1895	1,000.00	
		2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposits from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Deposit from savings of income, 1903		25,000.00
Residuary legacy of Thomas G. Hodgkins, 1907		7,918.69
Deposit from savings of income, 1913		636.94
Part of bequest of William Jones Rhees, 1913		251.95
Deposit of proceeds from sale of real estate (gift of Robert Stanton Avery), 1913		9,692.42
Bequest of Addison T. Reid, 1914		4,795.91
Deposit of savings from income of Avery bequest, 1914		204.09
Balance of bequest of William Jones Rhees, 1915		248.05
Deposit of savings from income of Rhees bequest, 1915		28.39

Deposit of savings from income of Avery fund, 1915	$1,862.60
Deposit of savings from income of Reid fund, 1915	426.04
Deposit of first payment Lucy T. and George W. Poore fund, 1915	24,534.92
Total amount of fund in the United States Treasury	987,600.00

OTHER RESOURCES.

Registered and guaranteed bonds of the West Shore Railroad Co., part of legacy of Thomas G. Hodgkins (par value)	42,000.00
Total permanent fund	1,029,600.00

Also three small pieces of real estate located in the District of Columbia and bequeathed by Robert Stanton Avery, of Washington, D. C.

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act of Congress of August 10, 1846, organizing the Institution, and the act approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum. The real estate received from Robert Stanton Avery is exempt from taxation and yields only a nominal revenue from rentals.

Statement of receipts and disbursements from July 1, 1914, to June 30, 1915.

RECEIPTS.

Cash on deposit and in safe July 1, 1914		$30,560.13
Interest on fund deposited in United States Treasury, due July 1, 1914, and Jan. 1, 1915	$57,630.00	
Interest on West Shore Railroad bonds, due July 1, 1914, and Jan. 1, 1915	1,680.00	
Repayments, rentals, publications, etc	14,922.93	
Contributions from various sources for specific purposes	12,000.00	
Lucy T. and George W. Poore fund	24,534.92	
George H. Sanford fund	1,020.00	
William Jones Rhees fund	248.05	
		112,035.90
		142,596.03

DISBURSEMENTS.

Buildings, care and repairs		5,468.44
Furniture and fixtures		1,290.04
General expenses:		
Salaries	18,514.26	
Meetings	148.00	
Stationery	770.91	
Postage, telegraph, and telephone	793.74	
Freight	93.05	
Incidentals, fuel, and lights	1,264.47	
Garage	1,827.36	
		23,411.79

Library		$2,554.13
Publications and their distribution:		
Miscellaneous collections	$5,447.87	
Reports	493.42	
Special publications	553.21	
Publication supplies	181.86	
Salaries	6,892.72	
		13,569.08
Explorations, researches, and collections		6,358.03
Hodgkins specific fund, researches, and publications		2,753.21
International Exchanges		5,022.74
Gallery of Art		19.53
Advances for field expenses, etc		12,464.60
Deposited to credit of permanent fund		27,100.00
Langley Aerodynamical Laboratory		418.58
		100,430.17
Balance, June 30, 1915, deposited with the Treasurer of the United States	$41,965.86	
Cash on hand	200.00	
		42,165.86
		142,596.03

By authority your executive committee again employed Mr. William L. Yaeger (now Capital Audit Co., William L. Yaeger, president), a public accountant of this city, to audit the receipts and disbursements of the Smithsonian Institution during the period covered by this report. The following certificate of examination supports the foregoing statement and is hereby approved:

CAPITAL AUDIT COMPANY,
METROPOLITAN BANK BUILDING,
Washington, D. C., August 6, 1915.

Executive Committee, Board of Regents, Smithsonian Institution.

SIRS: We have examined the accounts and vouchers of the Smithsonian Institution for the fiscal year ending June 30, 1915, and certify the following to be a correct statement:

Total receipts	$112,035.90
Total disbursements	100,430.17
Excess of receipts over disbursements	11,605.73
Amount from July 1, 1914	30,560.13
Balance on hand June 30, 1915	42,165.86
Balance shown by Treasury statement of June 30, 1915	46,423.25
Less outstanding checks	4,457.39
	41,965.86
Cash on hand	200.00
Balance June 30, 1915	42,165.86

The vouchers representing payments from the Smithsonian income during the year, each of which bears the approval of the secretary, or, in his absence, of

the acting secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution, have been examined in connection with the books of the Institution and agree with them.

CAPITAL AUDIT CO.,
By WILLIAM L. YAEGER, *President.*

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise are deposited with the Treasurer of the United States to the credit of the Institution, and all payments are made by checks signed by the secretary.

The expenditures made by the disbursing agent of the Institution and audited by the Auditor for the State and Other Departments are reported in detail to Congress and will be found in the printed document.

Your committee also presents the following summary of appropriations for the fiscal year 1915 intrusted by Congress to the care of the Smithsonian Institution, balances of previous appropriations at the beginning of the fiscal year, and amounts unexpended on June 30, 1915:

	Available after July 1, 1914.	Balance June 30, 1915.
Appropriations committed by Congress to the care of the Institution:		
International Exchanges, 1913	$0.02	[1] $0.02
International Exchanges, 1914	1,622.22	.01
International Exchanges, 1915	32,000.00	3,453.79
American Ethnology, 1913	1,250.74	[1] 400.74
American Ethnology, 1914	2,676.68	185.30
American Ethnology, 1915	42,000.00	3,854.52
Astrophysical Observatory, 1913	142.42	[1] 41.04
Astrophysical Observatory, 1914	779.87	62.36
Astrophysical Observatory, 1915	13,000.00	1,263.57
Bookstacks, Government bureau libraries, 1914	13,559.77	33.61
Bookstacks, Government bureau libraries, 1915	10,000.00	35.36
Tower telescope on Mount Wilson, 1915	2,000.00	1,284.17
Repairs to Smithsonian Building, 1915	16,000.00	452.13
International Catalogue, 1913	291.73	[1] 291.73
International Catalogue, 1914	720.09	21.50
International Catalogue, 1915	7,500.00	864.45
National Museum—		
Furniture and fixtures, 1913	42.58	[1] 42.58
Furniture and fixtures, 1914	10,369.30	56.85
Furniture and fixtures, 1915	25,000.00	1,048.83
Heating and lighting, 1913	151.81	[1] 151.81
Heating and lighting, 1914	5,902.35	242.62
Heating and lighting, 1915	46,000.00	4,473.33
Preservation of collections, 1913	3,659.15	[1] 1,485.78
Preservation of collections, 1914	7,652.72	714.09
Preservation of collections, 1915	300,000.00	8,774.88
Books, 1913	10.67	[1] 3.67
Books, 1914	1,091.35	25.83
Books, 1915	2,000.00	1,389.73
Postage, 1915	500.00	....
Building repairs, 1913	1.14	[1] 1.14
Building repairs, 1914	1,298.78	5.03
Building repairs, 1915	10,000.00	487.15
National Zoological Park, 1913	9.18	[1] .18
National Zoological Park, 1914	6,210.30	3.94
National Zoological Park, 1915	100,000.00	6,261.07
Bridge over Rock Creek, National Zoological Park	3,018.67	1,830.90

[1] Carried to credit of surplus fund.

Statement of estimated income from the Smithsonian fund and from other sources, accrued and prospective, available during the fiscal year ending June 30, 1916.

Balance June 30, 1915		$42,165.86
Interest on fund deposited in United States Treasury due July 1, 1915, and Jan. 1, 1916	$58,000.00	
Interest on West Shore Railroad bonds, due July 1, 1915, and Jan. 1, 1916	1,680.00	
Exchange repayments, sale of publications, refund of advances, etc	11,901.83	
Deposits for specific purposes	12,000.00	
		83,581.83
Total available for year ending June 30, 1916		125,747.69

Respectfully submitted.

GEO. GRAY,
ALEXANDER GRAHAM BELL,
MAURICE CONNOLLY,
Executive Committee.

WASHINGTON, D. C.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDING JUNE 30, 1915.

ANNUAL MEETING, DECEMBER 10, 1914.

Present: The Hon. Edward D. White, Chief Justice of the United States, chancellor, in the chair; the Hon. Thomas R. Marshall, Vice President of the United States; Senator William J. Stone; Senator Henry F. Hollis; Representative Maurice Connolly; Representative Ernest W. Roberts; Dr. Andrew D. White; Dr. A. Graham Bell; the Hon. George Gray; Mr. John B. Henderson, jr.; the Hon. Charles W. Fairbanks; and the secretary, Mr. Charles D. Walcott.

DEATH OF SENATOR BACON.

The secretary announced the death of Senator Bacon, who had been a Regent of the Institution since 1905, and chairman of the executive committee for the last three years.

Senator Stone submitted the following tribute to his memory:

Augustus Octavius Bacon, doctor of laws, United States Senator from Georgia, and Regent of the Smithsonian Institution, died February 14, 1914, in the seventy-fifth year of his age.

His associates on the Board of Regents, assembled in annual meeting, do here record their personal sorrow in the loss of a distinguished citizen, lawyer, and statesman; one whose sound advice will be greatly missed by the Regents in their deliberations on the affairs of the Institution, in whose development and in whose plans for the advancement of science and the general welfare of mankind he at all times exhibited the deepest interest.

He was a most worthy exemplar of a gentleman, a scholar, a legislator, and a councilor.

On motion, the tribute was unanimously adopted, ordered to be spread upon the records of the board, and a copy directed to be sent to the family of Senator Bacon.

APPOINTMENT OF REGENTS.

Senator Henry F. Hollis, of New Hampshire, was appointed by the Vice President on March 10, 1914, to succeed the late Senator Bacon.

Mr. Charles F. Choate, jr., was reappointed for six years by joint resolution of Congress, approved March 20, 1914.

CHAIRMAN OF THE EXECUTIVE COMMITTEE.

The Hon. George Gray was elected chairman of the executive committee to fill the vacancy caused by the death of Senator Bacon.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Judge Gray, 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, 1916, 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.

The annual report of the executive committee, showing the financial condition of the Institution for the fiscal year ending June 30, 1914, was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

Hodgkins fund.—There has been no change in the status of this fund since the last report of the committee.

The sum of $5,000 was allotted from the income of the fund, in accordance with the formal action of the board at the meeting of May 1, 1913, for the purpose of continuing the work of the Langley Aerodynamical Laboratory during the past year.

Two thousand dollars was allotted to Mr. F. G. Cottrell for experiments in the clearing of fog by electrical precipitation.

Avery bequest.—This bequest has remained unchanged during the past year. Three parcels of land are still to be sold.

The Poore bequest.—A recent report states that this property is being closed up as rapidly as possible, and it is expected that within a short time it will be turned over to the Institution. The whole estate is now valued at approximately $35,000 to $40,000, but under the terms of the will the income is to be added to the principal until the latter has reached the sum of $250,000, the income of which will then become available for the Institution's purposes.

On motion, the report was accepted.

THE SECRETARY'S ANNUAL REPORT.

The secretary presented his report for the fiscal year ending June 30, 1914, and stated that since the last annual meeting of the Regents there had been printed a total of 90 publications, aggregating about 6,000 pages of text and 650 plates. Of this aggregate 23 volumes and pamphlets (1,626 pages and 289 plates) pertain to the institution proper; 55 volumes and pamphlets (4,170 pages and 352 plates)

were issued by the National Museum; and 2 volumes and pamphlets (115 pages and 11 plates) by the Bureau of American Ethnology. In addition there are now in page proof 5 annual reports (about 2,000 pages) and 3 pamphlets and 1 special publication (about 1,000 pages); these will probably be ready for distribution within a few months. The total number of copies of all publications distributed during the year was about 169,000. There were also transmitted through the institution to Congress two annual reports of the American Historical Association and the Annual Report of the Daughters of the American Revolution.

Among the Museum publications is the sixth volume of the Descriptive Catalogue of the Birds of North and Middle America, a work in which there has thus far been technically described more than 2,500 species and subspecies of American birds.

A second edition of the Hodgkins fund prize essay by Dr. Hinsdale on atmospheric air in relation to tuberculosis was published to meet the general demand for this work.

The institution also published through the generosity of Mrs. E. H. Harriman two elaborate volumes by Prof. Verrill, on the Starfishes of the Pacific Coast.

On motion the report was accepted.

THE SECRETARY'S STATEMENT.

The secretary made personal statements as follows:

Death of the assistant secretary, Dr. F. W. True.—Dr. True died on the 25th of June, 1914, in the fifty-sixth year of his age. He entered the service of the Institution as the youngest member of the scientific corps brought together by Profs. George Brown Goode and Spencer F. Baird during the primitive stages of the National Museum, his first work being in connection with investigations by the U. S. Fish Commission. Later he had been placed in charge of the mammal collections in the Museum, and upon its reorganization into three principal departments became head curator of biology. For a number of years he had served as executive curator of the Museum and at times had been designated acting secretary of the Institution. June 1, 1911, he had been appointed an assistant secretary, his special duties being in connection with the library and International Exchanges.

The secretary added a tribute to Dr. True's ability and loyalty.

NATIONAL MUSEUM.

Statue of Lafayette.—The Museum was honored during the past summer by receiving as a gift from the sculptor, Mr. Paul Wayland Bartlett, a copy of his equestrian statue of the Marquis de Lafayette

erected in 1900 in the Court of Honor of the Louvre, Paris, France. The statue in Paris is of heroic size and in bronze, and was presented to France by the school children of the United States. The copy given to the Museum is the original plaster model, of natural size, in excellent condition, and has been installed in the rotunda of the new building.

Collection of pianos.—Since the beginning of the present fiscal year the Museum has received a remarkable donation consisting of an historical collection of pianos, the gift of Mr. Hugo Worch, of Washington, by whom they had been assembled. Mr. Worch is a student of the piano, on which he is preparing an extensive memoir, which is now approaching completion, hence he has sought a place where his collection could be permanently preserved. The series consists of over 200 examples, covering the entire period from the invention of the piano, shown in the various changes in construction and the great variety of form and decoration of the case. The collection is very beautiful, instructive, and has involved a very large expenditure on the part of Mr. Worch. It is being installed in the first gallery of the rotunda in the new building, which it will entirely fill. The Museum was already in possession of one of the best collections of musical instruments in any of the museums of the country and the addition of such an important special series will probably give it a very high standing.

Gift of Mr. John B. Henderson, jr.—During a number of years the Museum has been placed under deep obligations to Mr. John B. Henderson, jr., a Regent of the Institution, for valuable collections of marine animals secured in the course of his own explorations, in a number of which members of the Museum staff have participated as guests of Mr. Henderson. Very recently Mr. Henderson has made a most exceptional donation to the Museum, consisting of over 30,000 specimens of land, fresh-water, and marine mollusks, assembled during a long period of years and representing in a broad sense the donor's special lines of study. Notable among its contents are specially fine series from Japan collected by Hirase, and from the Philippines by Quadras; the old and valuable collection of J. H. Redfield in its entirety; and a complete set of the fluviatile and land shells of the Southern States. This is unquestionably one of the most valuable additions to the division of mollusks of the Museum since the bequest of Dr. Isaac Lea.

BUREAU OF AMERICAN ETHNOLOGY.

The Bureau of American Ethnology has been devoting special attention to the study of certain tribes of Indians on the verge of extinction. To this end successful efforts have been made in recording the languages, beliefs, and customs of some of the tribes of

Oregon, Oklahoma, and Texas. In some cases these remnant groups are represented by only one or two survivors who speak their native language, hence the very last opportunity of gaining authentic information regarding them has been embraced. In other directions also the bureau's activities are being vigorously pursued and several volumes will soon be published.

ADDITIONAL LAND FOR NATIONAL ZOOLOGICAL PARK.

Since the statement at the last meeting of the board much delay has been encountered in the steps taken to acquire the land on Connecticut Avenue, for which Congress appropriated $107,200 by the act of June 23, 1913, but it is now understood that the jury of condemnation has completed its work and will shortly present its findings to the court. As previously stated, the land in question has a frontage on Connecticut Avenue of 1,750 feet and covers about 10 acres, and when acquired will bring the park area to 180 acres.

THE LANGLEY AERODYNAMICAL LABORATORY.

The first year's work of the Langley Aerodynamical Laboratory, reopened by authorization of the Board of Regents in May, 1913, was to organize an advisory committee, arrange a comprehensive program of operations, devise ways and means of carrying on investigations and publishing reports, conduct such active experiments as were possible with the means immediately available, and secure and arrange in the library all available aeronautical literature.

The reports of the committee thus far published have appeared as individual papers in the Smithsonian Miscellaneous Collections. The first of these recounts the organization of the advisory committee and the resources of the Langley Laboratory. The first technical publication sets forth the results of experiments made at the model tank at the Washington Navy Yard. Another report describes the organization and equipment of the leading aeronautical laboratories of England, France, and Germany. Some of the reports of the committee are as yet confidential or incomplete, such as Hammond's report on wireless communications to and from air craft.

The members of the various committees of the Langley Laboratory have been active in aerodynamics and allied subjects. Naval Constructor Hunsaker has completed the installation and equipment of the aerotechnical laboratory at the Massachusetts Institute of Technology and has sent the Smithsonian the results of the first researches for publication. Mr. Buckingham has completed and published a masterly paper on the mathematical principle governing the relations of experimental models of all sorts to those of full-scale machines. Dr. Humphreys has published a long paper on the physics of the

atmosphere. Dr. Zahm has helped to design for the United States Army a 200-horsepower biplane and has published a mathematical method of analyzing the stresses sustained by such an aeroplane during flight.

The library has been furnished with the chief aeronautic periodicals and the best books thus far published. The recent additions number 120 publications, of which 71 were purchased and the others received in exchange. The publications were chosen from a list specially prepared by Dr. Zahm and Naval Constructor Hunsaker while visiting the leading aeronautical libraries of Europe.

The rehabilitation and successful launching of the Langley aeroplane, constructed over a decade ago, was accomplished last May. The machine was shipped from the Langley Laboratory to the Curtiss Aeroplane Factory to have the planes recanvassed and hydroaeroplane floats attached before launching on Lake Keuka May 28. With Mr. Curtiss as pilot the machine planed easily over the water, rose on level wing, and flew in steady poise 150 feet. Subsequent short flights were made in order to secure photographs of the craft in the air. Then Mr. Curtiss was authorized, in order to prolong the flights without overtaxing the bearings of the Langley propulsion plant, to install in its place a standard Curtiss motor and propeller.

On October 1, hovering within 30 feet of the water and without material loss of speed, the great craft made in quick succession flights of the following duration and length at an average speed of 50 feet per second: Twenty seconds, 1,000 feet; 20 seconds, 1,000 feet; 65 seconds, 3,250 feet; 20 seconds, 1,000 feet; 40 seconds, 2,000 feet; 45 seconds, 2,250 feet. The total weight of the aeroplane with its hydro floats and the pilot was 1,520 pounds.

The tests thus far made have shown that former Secretary Langley had succeeded in building the first aeroplane capable of sustained free flight with a man. It is hoped that further trials will disclose more fully the advantages of the Langley type of machine. It may be recalled that this aeroplane was begun in 1898 for the War Department, and in the interest of the national defense.

The numerous and comprehensive aerotechnical investigations planned for the Langley Laboratory can be successfully carried out only when increased funds are available. Properly equipped and endowed, the laboratory would serve as a national aeronautical institute suitable for conducting the aerotechnical investigations and tests required by the Government and the aeronautical industries of this country.

The secretary further spoke of the personnel of the advisory committee, and said that its operations were very much hampered by the recent decision of the Comptroller of the Treasury that it was illegal for the members already in the Government service to act as an ad-

visory committee to the laboratory. All of the gentlemen selected have expressed their interest and willingness to serve, but in view of the decision referred to were able to do nothing except in a most informal manner. The secretary expressed the opinion that a committee of the Regents should be appointed to take up matters in this connection.[1]

Dr. Bell said that he was much gratified at the secretary's statements in regard to the successful flights of the Langley aeroplane. He was familiar with its history and had been present at the flights of the models, and now that the large machine, with the addition of floats weighing upward of 400 pounds, had actually flown, he felt that the Institution, and the board also, should be congratulated at the verification of Langley's work. He thought that the Langley type of machine was a correct one, and he hoped that this would be further proved by the additional flights contemplated. He thought that the important work of the laboratory should be facilitated in every way, and he hoped that the committee recommended by the secretary would be appointed.

Dr. Bell then submitted the following resolution, which was adopted:

> *Resolved*, That a committee be appointed by the chancellor, to consist of four members of the board and the secretary, to consider questions relative to the Langley Aerodynamical Laboratory.

The chancellor appointed the following as the committee: Dr. Bell, Senator Stone, Representative Roberts, Mr. Henderson, and the secretary.

RESEARCH CORPORATION.

It will be recalled that when Dr. F. G. Cottrell presented his precipitation patents to the Smithsonian Institution, the Board of Regents decided that it was not practicable for the institution to undertake the commercial development of the patents, but there was no objection to the secretary becoming a member of a distinct organization that would undertake their development.

This independent organization was formed under the laws of the State of New York as the Research Corporation, as reported to the Board of Regents at the meetings in 1912 and 1913. The secretary became one of the directors of the corporation and a member of the executive committee. The board includes a number of prominent men of wide business experience, such as James J. Storrow, of Lee, Higginson & Co., bankers, Boston; Charles A. Stone, of Stone & Webster, Boston; Arthur D. Little, of the Little Chemical Co., Boston; T. Coleman Du Pont, of Wilmington, Del.; Elon H. Hooker,

[1] By act of Congress approved Mar. 3, 1915, the President was authorized to appoint an advisory committee for aeronautics.

president, Hooker Electrochemical Co., Niagara Falls, N. Y.; Benjamin B. Lawrence, mining engineer, of New York; George F. Kunz, of Tiffany & Co., New York; Frederick A. Goetze, dean, engineering department, Columbia University, New York; William Barclay Parsons, engineer, of New York; Hennen Jennings, mining engineer, of Washington.

The development of a patent on a commercial basis is a very difficult proposition, and it was only through the active cooperation of Dr. Goetze, chairman of the executive committee, and other gentlemen on the board, in connection with the engineers of the corporation, that success has been attained.

On a capital of $10,100, subscribed by the directors, and the fees received for engineer services, work was carried on for 18 months. In July last there was but $1,200 in the treasury and many monthly expenses to be met. This was the low-water mark, as payments then began to come in in the form of royalties and payments for the permanent use of the patent, so that on December 1 there was $65,000 in the treasury besides $100,000 in approved notes.

At a recent meeting of the board of directors it was decided that no grants for general research would be made until after the invested funds of the corporation were $100,000 with cash in bank for expenses.

In addition to the Cottrell patents, the corporation is now considering the acceptance of certain rights in connection with a patent for a reinforced concrete railroad tie that is quite promising. There are also several other patents that have been brought to the attention of the engineers, but owing to the necessity of concentrating all effort upon the commercial development of the Cottrell patents, it was not deemed best to undertake other investigations. Now that the financial conditions are improved, some money and energy will be expended in looking up the concrete tie and other promising patents. Owing to the wide experience of the members of the board and their standing in the business community, it has been possible to do work in connection with the Research Corporation that would have required the expenditure of large sums if undertaken by an ordinary business organization or private individual.

CLEARING OF FOG BY ELECTRICAL PRECIPITATION.

Science has established the fact that all dust and fog particles in the open atmosphere are electrified and subject to dispersion or precipitation. It is apparent, therefore, that a source of very high direct voltage with facilities for control and application, may be of inestimable value in certain quarters and seasons for clearing fog from a street, from along a passenger railway, from around the land-

ing stages of a ferry, or possibly about and in advance of a ship under headway at sea.

Sometime ago Mr. Cottrell, who has been referred to in connection with the work of the Research Corporation, expressed to the secretary his desire to take up the investigation of the possibility of clearing away fog by the precipitation method mentioned, and he was asked to communicate again later when his ideas and plans were more fully developed.

He has recently written from San Francisco to say that the idea is now arousing interest in various quarters; for instance, the University of California is actively engaged in the investigation, while the United States Lighthouse Service has placed its boats and facilities at his disposal when needed, while assurances have been received from certain transportation companies that as soon as definite effects in the open were shown they would assist in the further development of the work.

Mr. Cottrell stated that funds were urgently needed to enable the university people to carry through what he termed the academic part of the program. They had already accomplished a great deal with their own funds and the apparatus and supplies contributed by the electric companies, but certain essential equipment was needed that could not be obtained through these channels. Chief among these was a transformer of at least 250,000 volts, which would cost about $1,500; and $500 additional was desired for smaller items of special equipment.

The importance of this work was apparent, and as it came within the scope of researches outlined in the Hodgkins fund, an allotment of $2,000 was made.

In acknowledging this action, Mr. Cottrell stated that the San Francisco section of the American Institute of Electrical Engineers had appointed a committee to cooperate in this great work. Reports will be submitted from time to time on the progress of the investigation.

THE FREER COLLECTION.

The original gift of Mr. Charles L. Freer, of Detroit, Mich., made in 1906, comprised about 2,326 paintings and other objects of art. The additions since that date, recorded in five supplementary inventories, the last submitted in February, 1914, increase the total extent of this wonderful collection to 4,701 pieces, of which 983 are paintings, engravings, lithographs, etc., by American artists; and 3,718 are oriental paintings, pottery, bronzes, stone and wood carvings, lacquered objects, glass, etc. In the eight years which have intervened since the acceptance of Mr. Freer's offer the collection has,

therefore, been doubled in extent, and its value has been increased far beyond all earlier expectations.

The secretary added that Mr. Freer was considering the matter of erecting the building to house his gift, and that the question of a site was now an important one, and he suggested that a committee be appointed to take the matter up.

Dr. White offered the following resolution, which was adopted:

Resolved, That four members of the board and the secretary be appointed by the chancellor as a committee on the securing of a site for the Freer Art Gallery.

The chancellor appointed the following as the committee: Senator Lodge, Senator Hollis, Judge Gray, Representative Connolly, and Secretary Walcott.

WORK UNDER THE HARRIMAN TRUST FUND.

Dr. C. Hart Merriam, research associate under the special fund established by Mrs. E. H. Harriman, has continued his studies of the big bears of America and has practically completed the research work.

In addition to the technical studies, the literature of early exploration and hunting in the western and northern parts of the continent has been searched for records concerning the former ranges and habits of the grizzlies and big brown bears, and it was now possible to determine the relations of most of the species and to arrange them in definite groups. Of the true grizzlies there appear to be about 38 species and subspecies, representing a dozen groups; of the big brown bears, about 10 species, representing five groups.

REPAIRS, SMITHSONIAN BUILDING.

The appropriation of $16,000 for the repairs to the exterior of the Smithsonian Building became available on August 1, 1914. These repairs are now practically completed, well within the limits of the appropriation, the balance remaining being set aside for exterior painting and some further minor repairs which will be undertaken in the spring.

EXPEDITIONS.

Borneo expedition.—For over two years an expedition has been engaged in Borneo through the generosity of Dr. W. L. Abbott, a collaborator of the National Museum, who had at the time of the last meeting contributed $8,000 for this purpose. Dr. Abbott has since added $3,000 to this sum for the completion of the work in Borneo and the further work of collecting in Celebes, the fauna of which is practically unrepresented here. Mr. H. C. Raven, who has been

conducting this expedition, left Borneo in June, 1914, crossing with his native boat and crew to Celebes.

In addition to the gifts already mentioned, Dr. Abbott has supplied Mr. Raven directly with ammunition and supplies and with funds aggregating between $500 and $1,000. Much valuable material has been received from Borneo and the work in Celebes is expected to prove of great interest.

Biological work in north China.—At the last meeting mention was made of the work being carried on in north China by Mr. A. de C. Sowerby through the liberality of a gentleman who desired to remain unknown. There has been no change in this condition. Mr. Sowerby has already sent numerous valuable specimens to the Museum and other collections are understood to be nearly ready for shipment.

British Columbia and Montana.—The Secretary continued the work of exploration among the fossil beds of British Columbia inaugurated some years ago, and extended the work to Montana.

A week was spent in measuring and recording the flow of two glaciers near Glacier, British Columbia, before beginning the measurement of sections and the collecting of fossil remains in the very ancient pre-Paleozoic rocks of central Montana.

In Montana a camp was established in July and field work continued until a heavy snow storm closed the season early in October. A number of great sections of bedded rocks were studied and measured. Large collections were made from the limestones, that include the oldest and most simple forms of life yet recorded in the early history of the earth. They are mainly algal deposits that may be compared with those now being made in fresh-water lakes and streams by the beautiful blue-green algae.

At the secretary's request, Dr. Albert Mann, the distinguished microscopist, began a search for microscopic organisms in thin, translucent sections of the algal deposits. He has discovered the remains of two types of bacteria in great abundance. These, in connection with the microscopic cells of the algae, furnish positive proof of the organic origin of the limestones in a period that heretofore had furnished no evidence of such life.

Solar radiation.—Observations have been continued on Mount Wilson, Cal., for the purpose of observing the variability of the sun, and of confirming the newly discovered relationship between the variation of the total heat of the sun and the variation of the distribution of its light over the solar surface. Computations of the results are now in progress, and it is hoped very soon to make a satisfactory confirmation of this discovery.

Mr. Aldrich, in cooperation with the United States Weather Bureau, sent up several sounding balloons with apparatus attached

for measuring the heat of the sun at high altitudes. In spite of unlooked-for difficulties, an excellent ascension was made to an altitude above 15 miles and very fine records were obtained, the preliminary reduction of which indicate that they will confirm the value of the solar constant of radiation which has resulted from years of observation at the Astrophysical Observatory. Additional flights were made up to altitudes of 20 miles, but no records were obtained at that height owing to the freezing of the mercury in the thermometers.

By invitation of the Australian Government and of the British Association for the Advancement of Science, Dr. C. G. Abbot, director of the Astrophysical Observatory, attended the meetings of the British association in Australia and submitted to the Australian Government a recommendation for the establishment in that country of a solar observatory particularly devoted to the measurement of the radiation of the sun. Owing to the breaking out of the war in Europe, the Australian Government was unable to promise definitely the early establishment of such an observatory, but expressed great interest in the project.

Island of Timor expedition.—The island of Timor in the East Indies has been a rich collecting ground for scientific study, though little or nothing has been done by the paleontologist. An expedition for this sole purpose would be a very expensive undertaking, but an opportunity presented itself for acquiring many of these collections through the courtesy and interest of Mr. W. E. Crane, of Pittsburgh, a retired engineer and an enthusiastic collector, who had planned to visit the East Indies and to aid in making collections on the island of Timor for the National Museum. The expense of the enterprise was estimated to be $2,000, one-half of which was contributed by Mr. Crane, while Mrs. E. H. Harriman and Mr. Frank Springer gave $500 each.

Unfortunately, about the time Mr. Crane was to start, the war broke out in Europe and the expedition had to be abandoned for the present.

Western Siberian expedition.—During the spring of 1914 the secretary received information that an expedition was being fitted out for western Siberia to take in the Kolyma River region, for the purpose of making collections in general ethnology and natural history. The locality was represented as particularly rich in such material, and after consultation with those qualified to advise, the secretary decided that it would be well that the Institution participate in the results of the expedition.

There being no funds of the Institution that could be allotted for this purpose, however, steps were taken to secure the means by private subscription, and it is with pleasure that the secretary an-

nounces that a sum sufficient for the purpose, $3,500, was contributed by the Telluride Association of Provo, Utah, and Ithaca, N. Y.

The expedition is under the direction of Mr. John Koren, an explorer of experience. He is accompanied by Mr. Copley Amory, jr., who made collections for the Institution in 1912 along the Alaskan-Canadian boundary, and by Mr. Benno Alexander, of Tolt, Wash., who is the special representative of the Institution.

The chief object of the expedition, so far as the Institution is concerned, is to secure remains of the Siberian mammoth, the woolly rhinoceros, and the mastodon; it is also desired to secure skulls, tusks, hair, skin, flesh, and anything to indicate the contents of the stomach and the nature of the food. Other much desired remains are those of the bison, musk ox, camel, and bear. In addition to the above, collections will be made of geological, mineralogical, and paleontological material likely to be of interest to the Museum.

The expedition sailed from Seattle on June 26, 1914, and touched at Nome on August 1, since which date no word has been received from the party. It is expected that they will return to Seattle by the end of September, 1915.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1915.

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 this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the secretary, induced in part by the discontinuance of an annual summary of progress which for 30 years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, 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 1915.

REVIEW OF ASTRONOMY FOR THE YEAR 1913.[1]

By P. PUISEUX,

Member of the Institute, Astronomer at the Observatory of Paris.

STUDY OF PLANETS AND COMETS.

The increasing knowledge of the phenomena of the globe that carries us puts us in a position to interpret more surely what we observe in the celestial bodies. The astronomer, who gives to the mariner and the geodecist the means for determining their time and precise position, hopes some day to receive some recompense for these services. He is examining now the facts which come from the scientific stations established at diverse latitudes. One of the least expected among these facts is a small annual variation in geographic latitude. This variation had not been predicted by dynamical theory. It takes place as though the center of gravity of our globe were displaced alternately about 3 meters toward the North, and then toward the South Pole. Several explanations come to mind, but have to be abandoned under closer analysis. For instance, the melting of the ice, taking place alternately each six months in the region of the two poles, acts in the right direction, but in order to correspond with the magnitude of the observed change, would have to affect masses of ice very improbable in size. The most-favored opinion, developed by the recent studies of Kimura, Ross, and Biske, assumes that the isobars (lines of equal pressure) of the air vary with the season, oscillating about a mean configuration. There would result, for a series of stations at the same latitude, a variation in the same manner of the atmospheric refraction, and an annual, purely *apparent* oscillation would be mixed with the one of 430 days, the reality of which we have no reason for doubting.

The movements of the magnetic needle show bizarre caprices which would seem to escape all prediction. However, in a long series of means, each magnetic element is seen to be affected by four superposed fluctuations the periods of which are the day, the year, the synodic rotation of the sun, and the sun-spot-cycle period. From this we conclude that the sun acts upon the earth's magnetism, not only through the unequal heating to which it subjects our globe, but also through a direct action, doubtless the restricted emission of electrified

[1] Translated, by permission, from the Revue générale des Sciences, vol. 25, p. 746, 1914.

particles. According to the calculations of Chapman, the moon also possesses this power in much less degree but nevertheless surely. To it are due several oscillations the most marked of which has a period of half a lunar day.

We are not yet in the position for studying the distribution of magnetism on the moon. But in lunar topography we are making progress. The valuable collection of plates collected at the Observatory of Paris furnished the basis to Le Morvan of a new 48-plate atlas of our satellite. One half of this work had appeared in 1913. This chart, less expensive and more manageable than the great atlas of this observatory, is well conceived, admirably executed, and will be of great value to observers.

The planetoid Eros, which so held the attention of astronomers in 1900, had at that time surprised them by its rapid variations in brightness. Now we find that its orbit is contracting more than we would have predicted. There will result far more favorable conditions for a new determination of the solar parallax. In 1931 the distance of this planetoid from the earth will be decreased to almost one-half of the smallest value reached in 1900.

The system of planets which revolve about the sun, and the two systems of moons which keep company with Jupiter and Saturn, respectively, have always attracted calculators in a search for numerical analogues. The well-known law of Bode serves as the point of departure for such calculations, and its aspect is changed slightly, according as weight is attached to the exactness of the verifications, the absence of discontinuities, or the small number of parameters. Miss Blagg has made a marked advance over her predecessors, including the three series of distances in one formula, analogous to one which connects the reciprocals of the wave-lengths in the spectra of simple bodies. The existence of this relation between such apparently different systems makes us feel that we are dealing with some mysterious physical law imposed in the formation of the planets as well as of the satellites. Such grouping could not be the effect of fortuitous and successive aggregations, as the theory of capture would have. It rather forces us to require in each system a unity of origin, retaining the general idea of the cosmogony of Laplace.

None of the laws derived from that of Bode would have foretold the existence of the distant and retrograde moons which both Jupiter and Saturn possess. In studying these two exceptional cases, which have been considered by certain authors as irreconcilable with the ideas of Laplace, Jackson found that these anomalous moons could be considered as the remains of a nebulous ring, the component parts of which possessed confused movements, and sufficiently vast to have expanded beyond the sphere of effective attraction of the planets. Certain distances from the planets and certain angular velocities are

more favorable to stability and are just such as correspond to the distances and velocities of the retrograde satellites.

An analogous conclusion is drawn by Eddington from the statistics of the elements of the comets. The positions of their aphelia, as a rule, group about two directions which seem to depend in no way upon the general movement of the solar system. These directions rather reveal the direction of the elongation of the one or two primitive rings at the expense of which the comets were formed. The short-period comets form an exception possibly because they are endowed with a shorter longevity. They are to be considered as revolving in their actual orbits through the intervention of the greater planets. Thus the comet Neujmin (1913c), discovered the 6th of September, 1913, was the third member of the cometary family of Saturn. It was remarkable for its almost constant stellar aspect. The Westphal comet (1852, IV), refound September 26, 1913, by Delavan, underwent in October a considerable and unexplained decrease in brightness.

In comparison with the planets and the stars the comets are doubtless ephemeral. What becomes of the matter—tenuous, to be sure, but in time abundant—which is left in their wake? Fessenkoff considers that it must expand in the region of the ecliptic in the form of a vast flattened, lens-shaped mass centered about the sun and decreasing in density with increasing distance from the sun. All the well-known traits of the zodiacal light could thus be explained. Fessenkoff believes that certain unsymmetrical and changeable features which have been noted are due to insufficient allowance for the effects of atmospheric absorption. The total mass of the zodiacal matter is certainly very small compared with that of the principal planets, indeed compared with that of the comets and meteors.

We may suppose that certain meteors are efficacious for troubling the surface of the sun because they are subject to closer approaches to it. Turner was led to adopt the idea, formerly held by J. Herschel, while trying to represent the variable frequency of sun spots by a series of periodical terms. For a course of years certain constant values may be adopted for the coefficients of these terms, and then these values have to be altered. The epochs of all these perturbations, according to Turner, fall close to the time of the perihelion passage of the Leonides. It is true the distance of the Leonides from the sun, even at perihelion passage, is somewhat great and necessitates recourse to a secondary stream derived through the intervention of some planet. This theory finds a certain degree of confirmation in the Chinese Annals, which record ancient increases in the number of sun spots at epochs when the Leonides swarm must have passed close to Saturn.

STUDY OF THE SUN.

Is the periodic increase in the number of sun spots definitely connected with the flux of heat which we receive from the sun? The question has been answered in various senses, and it must still be considered as under litigation. The discordance of the statistics, when they are not coordinated in point of time, may result from a general variation in the transparency of the earth's atmosphere. For instance, the greater or less diffusion of volcanic dust suffices to explain this discordance. And it seems quite certain that the eruption of Mount Katmai (Alaska) in 1912, as well as that of Krakatoa in 1883, have had effects of this nature. At any rate the passage of this atmospheric disturbance does not occur simultaneously in widely separated countries and the parallelism of the solar-constant values found by the methods of Dr. Abbot in California and in Algeria, Africa, prove that very perceptible variations can be imputed to the sun. These variations up to the present appear rather irregular than periodic.

Fabry and Buisson have found that the solar spectrum is cut off at the violet end by an absorption band due to ozone. The presence of a layer of ozone, formed in the upper part of our atmosphere by the action of the ultra-violet light of the sun, is not improbable. It would in that region somewhat alter the laws of absorption and (slightly) alter the value of the solar constant.

The micrometric examination of the numerous plates taken at the Observatory of Zo-Sé (China) under the direction of P. Chevalier, shows that the sun underwent, from 1905 to 1909, a measurable and somewhat variable elongation along the polar diameter. It is not the first time that such a change has been suspected, but it is asserted now, it seems to us, with an imposing train of evidence. The mean photographic diameter surpasses by 0.6″ that which is generally admitted on the authority of Auwers. An indication pointing in the same direction, results from the discussion by Simonin of the plates of the eclipse of April 17, 1912.

The documents resulting from the last solar eclipse still furnish material for interesting publications. Father Cortie gives the description of several limited bundles of rays, each one issuing from a spotted region of the sun and showing marked effects upon terrestrial magnetism. In the American photographs of the flash spectrum taken at Daroca in 1905, Mitchell found the whole counterpart of the Fraunhofer spectrum. The only differences occur in the relative intensities of the lines. Neither Mitchell nor Evershed are disposed to consider the presence of radium as established in the sun's chromosphere.

The powerful spectroscopes continue to give numerous results relative to the velocities which rule at the various levels in the sun. But

their interpretation is complicated and the results change according as we consider some special spectrum line or the diverse parts of the same line. For Evershed the dominant fact is the general expanding out of the metallic vapors as they leave the border of each spot. St. John finds that the centripetal tendency again becomes predominant above a certain elevation. The analogies which have been attempted between sun spots and cyclones or the whirlpools in water currents give little satisfaction.

The ascending movements which the spectroscope records toward the center of the disk of the sun are not as rapid as the horizontal movements, but it is not a rare occurrence for them to be accelerated as if the weight was opposed effectively by a repulsive force. These vertical velocities, in every case, are sufficiently great to make us consider very hazardous the attempt of Schulz to revive the former theory of Kirchhoff concerning the general constitution of the sun. According to that theory the sun is liquid up to the level of the spots and the latter are floating scum. Every difficulty is removed by that theory relative to the existence of a continuous spectrum but not relative to temperature and velocities. Fowler prefers to admit the existence in the sun of some unknown physical agent capable of maintaining certain refractory elements in a pulverulent state at temperatures above 6,000° C., the temperature above which pyrheliometric measures show that the sun must be. We must resign ourselves for a long while yet perhaps to see Nature use in the stars far more powerful sources than those at our disposal in the laboratory.

Deslandres and d'Azambuja continue to devote themselves to the isolation of the light of the central parts of the strongest lines of the solar spectrum and its use in their solar photographs, and that choice is justified by the striking originality of the photographs obtained. The astronomers at Meudon, despite the doubts raised by A. Buss, maintain an essential distinction between "filaments" and "alignements." The latter, fainter but more prolonged, are characteristic of the upper layers. They appear as far as the greatest latitudes and are not dependent upon the Schwabe cycle.

The existence of the Zeeman phenomenon at the border of the spots, shown by Hale, as we know, has furnished him with a means of measuring the local magnetic fields. We see no other probable origin for these magnetic fields except the motion of electrified particles, but one would suppose that electricity would be conducted with great difficulty in as rare a medium as that which surrounds the sun. This objection has been very much weakened, although not nullified, by the recent experiments of Harker, who found that a rarified gas becomes an effective conductor for electricity in the neighborhood of a body at a very high temperature.

STARS AND NEBULÆ.

The observatory at Greenwich has undertaken the task during recent years of the redetermination of the precise positions of all the bright stars of the corona borealis, stars already included by Carrington in a catalogue which is now half a century old. It has thus become possible to study and classify a great number of proper motions. The discussion made by Dyson gives a result favorable to the views held by Schwarzschild that the existence of a single preferential direction for stellar motions is probable. In measure as we consider a direction differing from this, the number of stars having this different direction diminishes regularly. From the relation between the brightness of a star and its apparent motion, it may be deduced that the distribution of stars in space is neither uniform nor fortuitous. The greatest frequency is found in the constellation of Gemini at a distance which is small compared with the dimensions of the Milky Way. When we depart from this central region the frequency of the stars diminishes without limit, so that we may speak of the stars visible in meridian instruments as a limited system of definite structure.

Analogous conclusions were derived by Eddington from the study of the catalogue of Boss, in which are collected the most accurate data concerning the bright stars in all parts of the sky. It is especially in high galactic latitudes that the density is found to decrease most markedly. We must therefore regard the stars connected with the Milky Way—that is, the great majority of the visible stars—as forming a globular cluster with a very marked flattening.

At each point of such a cluster the Newtonian attraction must produce a field of force. A star, obedient to this field of force and sensibly untroubled by neighboring bodies, would complete its revolution about the center in about 300,000,000 years, and we would expect a definite, dominant direction in each region of space.

The researches of L. Boss and of Messrs. Hertzsprung and Plummer have definitely revealed the existence of several groups or families of stars, all the members of which travel with equal and parallel velocities and having a yet further kinship in the character of their spectra. These stars thus preserve a trace of their common origin and move freely or under the action of a common field of force, and resemble very little the final state of bodies intermingling with diverse velocities. It is therefore necessary to abandon the comparison of the Milky Way to a gaseous mass where the velocities of the molecules result from multiple collisions in every direction and with velocities showing definite relationship to the masses, but no regularity as to direction. Jeans, starting with the stellar density calculated as existing in the neighborhood of our sun, has found

that the dispersion of a swarm, once formed, would require billions of years—a time much greater than the probable life of a star as a bright star.

Results well worthy of attention have been obtained lately through the formation of tables having as headings the principal characteristics of the stars, spectrum class, annual parallax, magnitude of motion, intrinsic brightness. Thus, Campbell has shown that the white stars (A and B of the Harvard classification) are more numerous than other stars near the Milky Way, have small velocities, great distances from the sun, and great brightness. The red stars are, on the average, nearer the sun and have greater velocities. There is reason for concluding, according to Stratton, that the stars have their birth close to the plane of the Milky Way and depart from it with time with increasing velocities. H. N. Russell thinks that he can go yet further, laying stress upon the fact that statistics separate the red stars into two classes—one much brighter intrinsically than the sun, and the others decidedly fainter. The former (giant stars) are less advanced in their evolution. Their destiny is to contract, and consequently become warmer and whiter, losing in size and gaining in velocity. They again become red before their final extinction. These correlations are valuable for guiding researches, but it will without doubt be necessary to wait until their degree of generality is better established.

The existence of a particularly close analogy between certain stars and the sun results from the work of the observers at Potsdam. They have found that in the spectra of Arcturus and Aldebaran we can observe the partial reversal of the H and K lines, that is to say, the formation of a brilliant central line in them such as those seen in the troubled regions of the sun.

The category of spectroscopic double stars, enriched continually by the work of the Lick and Allegheny observers, presents on the other hand a phenomenon of which we find no analogy in the sun. We know now several instances of the fact, noted first in δ Orionis, that the calcium lines do not follow the periodic oscillations of those due to hydrogen and helium. Possibly clouds of calcium, unconnected with the stars, are interposed in the line of sight. In the Cepheid variables, compared with one another, Ludendorff has noted the existence of a proportionality between the amplitudes of the variations which the brightness and radial velocities respectively undergo.

It will be useful, in order to interpret these and similar laws, to be able to reach greater precision in the measure of faint magnitudes. All methods, in which the judgment of the eye is utilized, involve a certain inaccuracy of physiological origin. Attempts are being made to substitute for the operator's eye an apparatus of rigorously impersonal measures, indefatigable and of a superior sensitiveness.

Stebbins uses for this purpose the variable resistance which selenium offers to the passage of the electrical current when the selenium is more or less exposed to light. But the results do not appear to be regular except when the selenium is kept at low temperatures. Messrs. Elster, Geitel, and Guthnick have utilized the property which certain alkaline metals, such as sodium and calcium, offer of emitting, under the influence of light, corpuscles capable of acting upon an electrometer. They have thus obtained a sensitiveness of one part in a thousand in estimating the brightness of faint stars.

The photographic study by Prof. Bailey of the cluster Messier 3 has shown the existence in this single group of 137 variable stars, all of the same type and having periods of about a half a day. Stars showing such rapid changes are rarely found outside of clusters. There has, however, meanwhile been found a new example in the star RR Lyræ, investigated by Kiess.

In order to establish a homogeneous system of magnitudes in a photographic catalogue there has been used with success at the Greenwich Observatory a diffraction grating formed of metallic wires stretched across the front of the objective of the telescope. Each star then furnishes a central image with a series of secondary images on either side. The ratio of the brightness of the successive members of each series can be calculated with precision if a micrometrical study is made of the grating and the widths of the wires and spaces are made very uniform. Each bright star thus will give in the field of the telescope a scale of magnitudes to which the fainter stars may be referred. Messrs. Chapman and Melotte have thus been able to make a complete catalogue of the stars down to the fifteenth magnitude and within a radius of 25′ of the pole.

The examination made by Reynolds of the distribution of brightness in the great Andromeda nebula makes it seem as though a great part of that nebula's brightness were due to a central star too enveloped and obscured in the diffused matter for us to see it. In the spectrum of this same nebula, generally held to be continuous with a few absorption lines, Messrs. Fox and Max Wolf have found bright lines, and in the spectrum of the Wolf-Rayet stars, characterized by bright lines, Max Wolf finds also the lines of gaseous nebulæ. We are thus forced to believe that bright lines are a general characteristic of true nebulæ, which do not shine by reflected stellar light, and that the Wolf-Rayet stars show a transition type between such nebulæ and ordinary stars.

How is the evolution from one to the other effected? Nicholson has tried to determine it by a subtle analysis of the numerical values of the wave lengths. The only terrestrial elements known with certainty as existing in the nebulæ, and accordingly in the Wolf-Rayet stars, are hydrogen and helium. The other lines which are in the

spectra, and as yet unreproducible in the laboratory, are distributed in series, and the structure of these series allows us to attribute to them modified forms of these simple elements. The passage takes place by discontinuous steps, corresponding to successive whole numbers of electrons. The transmutation of the nebula into the star results less from a concentration of visible matter than from new intraatomic configurations, the reverse of that which radioactive matter undergoes in our laboratories and which has helium for its final product.

Nicholson, faithful to the traditions of Laplace, considers the nebula as the primal form of matter in preference to the star, which seems to him on the track toward a more complex structure. One is tempted to regard the reverse route as probable if we consider two incontestable facts: The practical irreversibility of the radioactive transformation and the constant evolution of new stars toward the nebulous state. The artificial production of the nebula spectrum, if it ever becomes possible, will of course throw light upon this problem of the utmost importance to cosmogony. May we live long enough to be witnesses of this conquest, the object of so much of our striving!

THE UTILIZATION OF SOLAR ENERGY.[1]

By A. S. E. Ackermann,
B. Sc. (Engineering), A. C. G. I., M. Cons. E., A. M. Inst. C. E.

[With 6 plates.]

As it has been justly said that the play of Hamlet without the Prince of Denmark is somewhat dull, perhaps it will be well to devote a few words to the principal actor in all schemes for the utilization of solar energy, viz, the sun. He is no longer regarded as a monster fire, burning in the manner of fires in our grates. Great as is his mass, it would be comparatively rapidly consumed if such combustion were taking place. Another reason why this old idea was given up is that the temperature of the sun has been determined by several experimenters, and all agree that it is about 6,000° C. This is far too high to permit of the formation of most chemical compounds, and for the production of heat by combustion it is necessary for such compounds to be formed. Briefly, such a temperature decomposes nearly all compounds into their elements and prevents their reuniting and the consequent production of heat.

Scientists are by no means certain how the sun's heat is produced, but one theory is that it is due to radioactivity; and another, due to Helmholtz, that the energy to keep up the radiation could be supplied by a relatively microscopic contraction of the sun's volume, though even this theory is not a complete success, as it implies that the age of the sun is 17,000,000 years. Great as is this lapse of time, geology indicates that our earth is considerably older; but as the earth can not very well be older than the sun, we must conclude that the sun is older than 17,000,000 years.

As to what the structure of the sun is there is also doubt; but the inner portion is spoken of as the nucleus and the outer portion as the atmosphere, and as the outer layers of the atmosphere get relatively cooled they sink to a lower level, and their place is taken by hotter layers. Thus there is a continual circulation of the sun's atmosphere.

The specific gravity of the sun is only about a quarter of that of the earth, whose specific gravity is 5.53. A cubic foot of water weighs

[1] Reprinted, by permission, from the Journal of the Royal Society of Arts, London, April 30, 1915.

62½ pounds, and hence an average cubic foot of the sun weighs 86¼ pounds, while an average cubic foot of the earth weighs 345 pounds. For comparison it may be mentioned that a cubic foot of granite weighs 165 pounds. The density of the sun being so small, it is concluded that it can still go on contracting, and hence that it is probably getting hotter instead of cooler, as is popularly supposed. If this be so, it is a hopeful feature for future workers in the field of solar energy.

The diameter of the sun is 863,600 miles, or about one hundred times the diameter of the earth, and an earthly pound weight at its surface would weigh 27½ pounds. The glowing surface which the sun presents to us, even considering him as a flat disk, has the enormous area of 585,750,000,000 square miles, each square foot of which emits the enormous amount of about 12,500 horsepower, and the radiant energy received at the outer surface of the earth's atmosphere is equivalent to 7,300 horsepower per acre. Of this about 70 per cent (say, 5,000 horsepower per acre) is transmitted to the land surface of the earth at noon on a clear day, and less in the morning and evening, owing to the greater thickness of atmosphere through which the radiation has to pass.

The quantity of solar heat per unit area which arrives in unit time at the outer surface of our atmosphere is called the solar constant, and its value, as determined in 1913 by C. G. Abbot, of the Smithsonian Institution, after making 696 experiments in different parts of the globe, is 1.93 calories per square centimeter per minute (equal to 7.12 B. t. u. per square foot per minute). Its value given by various experimenters between 1881 and 1909 was considerably higher, and this makes it all the more remarkable that John Ericsson, the engineer and inventor, who spent some £20,000 on experiments with solar energy, when writing in 1876 a record of his life's work, gave the value of the solar constant as 7.11 B. t. u. per square foot per minute and said, "In view of the completeness of the means adopted in measuring the energy developed and the ample time which has been devoted to the determination of the maximum intensity, it is not probable that future labors will change the result of our determination," and, as shown above, his confidence was justified.

Perhaps the most remarkable things about solar radiation are that it passes through the 93,000,000 miles (1,000,000 is 2,740 a day for a year) of space between the sun and the earth, the temperature of which is nearly absolute zero (i. e., it is about −263° C.), and that only three-fifths of it produces any impression on the eye. It is not till the radiant energy impinges on some material body that it is converted into heat. The best body for causing such conversion is a dead-black one.

The absorption of solar energy by the atmosphere is about 20 per cent greater in summer than in winter. This may be due to there being a larger total quantity of water vapor in the atmosphere in summer than in winter. It has long been known that the greater the humidity of the atmosphere the greater the amount of heat stopped

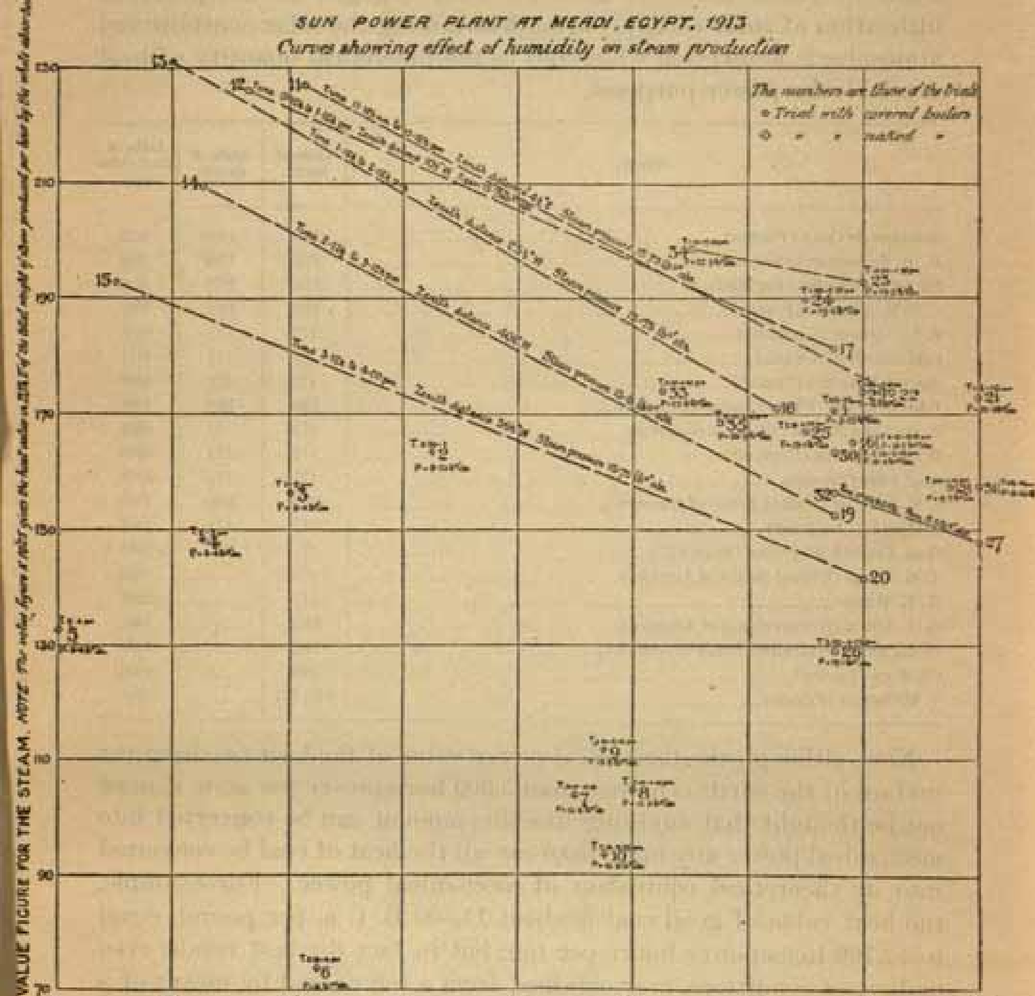


FIG. 1.

by it; but the author believes that his experiments in Egypt in 1913, with the Shuman-Boys sun-power plant, were the first which determined the quantitative effect of humidity, especially on so large a scale. The curves on figure 1 record the results, from which it is seen that when the humidity decreased 20 per cent the quantity of

steam increased about 30 per cent, thus showing the great importance of humidity in connection with this subject.

The great possibilities of this field of work, and the obvious fact that there is a limit to our supplies of coal and oil, have naturally attracted many workers, of whom the following is a chronological list. Some of them, however, have not been engaged in the practical utilization of solar energy, but in determining the solar constant and atmospheric absorption which tell us the theoretical quantity of heat available for power purposes.

Name.	Date of birth.	Date of death.	Date of first solar work.
Solomon de Caux (France)	1576	1626	1615
H. B. de Saussure (Sweden)	1740	1799	1766
Sir John Herschel (England)	1792	1871	1836
C. S. M. Pouillet (France)	1791	1868	1838
C. L. Althans (Germany)	(?)	(?)	1853
Carl Güntner (Austria)	(?)	(?)	1854
August Mouchot (France)	(?)	(?)	1860
John Ericsson (United States of America)	1803	1889	1864
C. H. Pope (United States of America)	(?)	(?)	1875
William Adams (England)	(?)	(?)	1876
Abel Pifre (France)	(?)	(?)	1878
S. P. Langley (United States of America)	1834	1906	1881
J. Harding (England)	(?)	(?)	1883
Chas. Louis Abel Tellier (France)	(?)	1913	c. 1884
A. G. Eneas (United States of America)	(?)	....	1900
H. E. Willsie	(?)	....	1902
C. G. Abbot (United States of America)	1872	....	1905
Frank Shuman (United States of America)	1862	....	1906
Ch. Féry (France)	1865	....	1906
G. Millochau (France)	1871 (?)	....	1906

Now, although the theoretical power value of the heat reaching the surface of the earth is no less than 5,000 horsepower per acre, it must not be thought that anything like this amount can be converted into mechanical power any more than can all the heat of coal be converted into its theoretical equivalent of mechanical power. For example, the heat value of good coal is about 14,500 B. t. u. per pound, equal to 12,760 horsepower hours per ton, but in fact the best result, even under test conditions, ever obtained from a ton of coal by means of a boiler and steam engine is only about 1,470 brake horsepower hours, or 11.5 per cent of the heat value, while in the case of a gas engine the corresponding figure is 25.5 per cent, and of a Diesel oil engine 31 per cent. The chief loss is in converting the steam into mechanical energy, and most of the loss is inevitable for thermodynamic reasons. With this fact in mind, you will not be so surprised to learn that the best overall thermal efficiency obtained from the Shuman-Boys plant in Egypt was only 4.32 per cent, the chief reasons for this being so much less than 11.5 per cent being that the steam pressure was so low, and

that the best efficiency of the sun-heat absorber was only 40.1 per cent, compared with 75 per cent for the best coal-fired boiler. But it has taken boilermakers many years to attain this efficiency, so that 40.1 per cent is not a bad result when the number of sun boilers that have been made is taken into account. Thermal efficiencies of engines are materially affected by the heat fall of the steam, just as the efficiencies of water turbines are affected by the height of the waterfall. The larger the fall in either case the better the efficiency.

It is interesting to realize from the foregoing figures that the value of $2\frac{1}{4}$ acres of bright sunshine for an hour is 1 ton of coal. This fact is more readily realized in Egypt in the summer. With this we may compare what Mr. J. C. Hawkshaw said in his presidential address to the Institution of Civil Engineers in 1902, viz, that the wood fuel produced by an acre of land in Europe is equivalent to at least 1 ton of coal a year.

With so much heat generated at the surface of the earth it might be thought that the temperature of the earth would rise. So it would do were it not for the fact that the earth radiates into space as much heat as it receives, though some of it may be stored on earth for a time in the form of vegetable growth (including coal) or water raised to high levels.

Coal has been called "bottled sunshine," but the cork of the bottle must be a leaky one, for Abbot says (The Sun, p. 360): "It appears from such investigations as have been made that plants may store up as chemical energy in round numbers 1 or 2 per cent of the energy of solar radiation which shines upon their leaves." With regard to the earth's own heat, it has been estimated that the continuous supply coming from the interior to the surface is equivalent to 1,280 horsepower per square mile, or only 2 horsepower per acre.

Having now considered the nature of the source and the quantity of heat available, we will give a brief description of the plants which have been constructed by various experimenters for the purpose of utilizing solar heat. They are given in chronological order as regards their solar work so far as the author has been able to discover the facts.

At one stage the author thought he had discovered the earliest worker at the subject when he came across a record of Sir John Herschel's experiments in 1836, but further research disclosed that Buffon, the celebrated French naturalist, was at work in 1747, and on April 10 of that year he succeeded in setting fire to a plank of tarred wood, at a distance of 150 feet, by solar rays reflected from a combination of flat mirrors. He did this to show the possibility of the legend that Archimedes set fire to the fleet of Marcellus at Syracuse in 212 B. C.

Other early workers were Roger Bacon, an English Franciscan monk, who died in 1294; Solomon de Caux (1576–1626), a French engineer, who, in 1615, invented and described the first machine for raising water by solar heat and the expansion of air; Ducarla; and H. B. de Saussure, the Swiss geologist, physicist, and naturalist, who made (in 1787) the second ascent of Mont Blanc. To de Saussure the credit is due for inventing the "hot box" (i. e., an insulated air-tight wooden box, black inside, and covered with two layers of plain glass with an air space between them), which has since been such a favorite with other workers. It was he, too, who found that a cover of two sheets of glass gave the best results.

Next in the field was Sir John Herschel, F. R. S., who in 1837 took the temperature of the surface soil near Cape Town, and for dry earth recorded temperatures varying from 120° F. to 162° F., the latter having been obtained on December 1, 1837, at 0.36 p. m., in a sand heap sheltered from the wind in a small garden inclosure, the soil being moist 3 inches or 4 inches below the surface.

He also experimented with a "small mahogany box, blackened inside, covered with windowglass fitted to size, but without putty, and simply exposed perpendicularly to the sun's rays." In this box he recorded a temperature of 152° F., but "when sand was heaped around the box to cut off the contact of cold air, the temperature rose on December 3, 1837, to 177° F. And when the same box, with its inclosed thermometer, was established under an external frame of wood well sanded up at the sides, and protected by a sheet of windowglass (in addition to that of the box within), the temperatures attained on December 3, 1837, were—

Time (p. m.).	Temperature.
	° *F.*
1.30	207
1.50	217.5
2.44	218

and that with a steady breeze sweeping over the spot of exposure. Again, on December 5, under a similar form of exposure, temperatures were observed:

Time (p. m.).	Temperature.
	° *F.*
0.19	224
0.29	230
1.15	239
1.57	248
2.57	240.5

As those temperatures far surpass that of boiling water, some amusing experiments were made by exposing eggs, fruit, meat, and in the same manner (Dec.

21, 1837, et seq.), all of which, after a moderate length of exposure, were found perfectly cooked, the eggs being rendered hard and powdery to the center; and on one occasion a very respectable stew of meat and vegetables was prepared, and eaten with no small relish by the entertained bystanders.

Sir John then described his method of determining the solar constant by means of a tinned iron vessel 3¾ inches diameter, and 2.4 inches high filled with inked water, upon which he allowed the nearly vertical rays of the sun to play through a 3.024-inch-diameter hole for 10 minutes and noted the rise in temperature, of course allowing for cooling losses. The mean of six experiments, made between December 23, 1836, and January 9, 1837, inclusive, gave a rise of 0.38° F. per minute, the quantity of water being 4,638 grains. Allowing for the obliquity of the sun's rays, the mean area of the normal cross-section of the beam of sunlight was 7.01 square inches. From these particulars we are able to calculate that Herschel's value of the solar radiation reaching the earth's surface was 1.38 calories per square-centimeter-minute, while if we assume the coefficient of atmospheric transmission to have been 0.70, his value of the solar constant was 1.98, agreeing well with 1.93, the value now accepted as correct.

From these experiments he deduced that a cylindrical rod of ice, 45.3 miles in diameter, and of indefinite length, continually darted into the sun with the velocity of light (186,000 miles per second), would barely suffice to employ the whole radiant heat for its fusion, without at all reducing the temperature of the sun.

For comparison with Herschel's sand temperatures recorded above, the author gives the following similar readings, which he obtained at Meadi, Egypt:

Date.	Time.	Reading of thermometer under loose lamp-black and sand.	Reading of thermometer under ordinary sand.	Thermometer with blacked bulb lying on sand.	Shade temperature.	Humidity per cent.	Wind.	
							Velocity in miles per hour.	Direction.
1913.		°F.	°F.	°F.	°F.			
July 14	4.20 p. m.	....	110	....	93	37	Fair breeze.	
15	2.30 p. m.	....	120	....	90	37	....	
18	9.45 a. m.	....	120	....	92½	45	No wind.	
	11.30 a. m.	....	130	....	92½			
	4.20 p. m.	....	123	....	97	34	Slight wind.	
19	12 noon	....	125	....	94	33	Slight breeze.	
24	11.45 a. m.	107	127	....	89½	40	2.7	N.
26	11 a. m.	122	132	144	89½	33		
	12 noon	127	138	145	91½		2.9	NW.
	3 p. m.	127	125	128	94			
	4 p. m.	120	115	123	91	32		
	5 p. m.	105	103	105	91		2.7	
Aug. 1	11.10 a. m.	116	....	143	99	33	1.9	NE.
	12 noon	122	....	144	102			
	2.45 p. m.	126	....	140½	....			
	4.22 p. m.	115	....	125	....			

Almost contemporaneous with the work of Herschel was that of M. C. S. M. Pouillet, a record of which, on the determination of the solar constant, appears in Comptes Rendus, Vol 7, 1838, pages 24–65. His value of the solar constant was 1.763 calories per square-centimeter-minute.

Carl Güntner was at work experimenting with reflectors in Laibach in 1854, and in 1873 he exhibited one at the Vienna Exposition. Güntner wrote in the Scientific American Supplement of May 26, 1906, pages 25, 409–412:

> This reflector possessed, however, the disadvantages common to all sheet-metal reflectors—that to maintain the surface in proper condition when exposed to all sorts of weather requires careful and costly attention.
>
> Being convinced, however, that the exploitation of solar heat will come more and more into vogue, even in spite of the disadvantageous periodicity of this source of warmth, I have taken the trouble to put aside the evil mentioned above and overcome it by an entirely new method of reflector construction. * * * This plane reflector consists of a large number of long, narrow mirrors placed at suitable distances from one another, and which, when upon level ground, lie parallel with each other horizontally, extending either from north and south or from east to west.
>
> Each one of these mirrors revolves about a horizontal axis, and by means of a simple parallelogram motion may be made to follow the sun in such a manner that all the sun's rays falling upon the plane mirrors may be reflected on the surface of a tube or boiler, the long axis of which lies also in the plane of the mirror axis * * *. By a simple movement of a hand lever, all the mirrors may be simultaneously turned through an arc of 180°, which means that all the mirrors may thus be made to look toward the ground and be in this way protected from the destructive action of sudden falls of hail.

He claimed that the reflector could be made at a cost of 8s. 6d. per square yard of reflecting surface, and that it required "but 200 square feet of surface to generate steam sufficient for 1 horsepower." He proposed to construct the reflectors of thin corrugated steel plates, faced with lead and then coated with tin.

> Hence it is necessary to discover the value of *e* (the amount of useful heat dispensed per unit of surface per minute) which affords the unit of heat that can be made available for effective service from a square foot of catching surface per minute.
>
> Being deprived of the experience of any former experimenter in this direction, I myself made appropriate trials with reflectors * * *. The two opposite sides, each 3 feet long, of a wood right-angular frame, having a width of 1 foot and a length of 3 feet, were hollowed out to correspond with a previously designed parabolic template, and upon the parabolic curve thus established two sheets of white tin were nailed. Four supports, which were fastened to the sides of the frame, carried a 3½-inch tube erected in such a manner that its axis coincided with the burning axis of the reflector * * *. The catching surface presented a superficial area equal to 3 square feet * * *. The boiler was not lagged with glass or anything.

He then gives a table of four tests of one hour each, varying from 9 a. m. to 4 p. m., and goes on to say:

> From these experiments it has been deduced that the amount of heat given off per square foot per minute is about equal to 1.3 (major) calories (equal to 1.4 minor calories per square-centimeter-minute). For our zone [probably Laibach, Austria], then, the mean value of e may be set down as 1.3.

The work of August Mouchot in connection with the utilization of solar energy was certainly of great importance. It is recorded in his book entitled "La Chaleur solaire et les Applications industrielles," second edition, 1879; but, as with other workers in this field, he gives extremely meager information as to results of experiments.

Mouchot started his solar work in 1860 and took out his first patent, No. 48,622, on March 4, 1861. In the first edition of his above-named work (p. 231) he stated that theoretically, on an average, 86 square feet of reflecting surface are required for 1 horsepower. Then, to allow for losses, he doubled the area, thus making it 172 square feet. It is to be noted that he referred to reflecting surface and not the area of radiation collected, which would almost certainly be a smaller quantity.

On page 195 he described one of his boilers as having a capacity of 3½ pints. It consisted of two cylindrical concentric copper vessels with domed tops and the water space between them. The vertical height of the outer vessel was 16 inches. The boiler was covered by a bell glass and placed at the focus of a reflector. The water boiled in one hour from an initial temperature of 50° F.

In August, 1866, Emperor Napoleon III of France saw Mouchot's first solar engine at work in Paris, and in 1872 Mouchot (with the monetary assistance of the French Government) constructed another sun boiler. This was described by M. L. Simonin in the Revue Des Deux Mondes of May 1, 1876, as follows:

> The traveler who visits the library of Tours sees in the courtyard in front a strange-looking apparatus. Imagine an immense truncated cone, a mammoth lamp shade, with its concavity directed skyward. This apparatus is of copper, coated on the inside with very thin silver leaf. On the small base of the truncated cone rests a copper cylinder, blackened on the outside, its vertical axis being identical with that of the cone. This cylinder, surrounded as it were by a great collar, terminates above in a hemispherical cap, so that it looks like an enormous thimble, and is covered with a bell glass of the same shape.
>
> This curious apparatus is nothing else but a solar receiver—or, in other words, a boiler—in which water is made to boil by the heat rays of the sun. This steam generator is designed to raise water to the boiling point and beyond by means of the solar rays, which are thrown upon the cylinder by the silvered inner surface of the conical reflector. The boiler receives water up to two-thirds of its capacity through a feed pipe. A glass tube and a steam gauge communicating with the inside of the generator, and attached to the outside of the reflector, indicate both the level of the water and the pressure of the steam. Finally, there is a safety valve to let off the steam when the pressure is greater

than desired. Thus, the engine offers all desirable safety and may be provided with all the accessories of a steam boiler.

The reflector, which is the main portion of the generator, has a diameter of 2.60 meters at its large and 1 meter at its small base, and is 80 centimeters in height, giving 4 square meters of reflecting surface or of insolation. The interior walls are lined with burnished silver, because that metal is the best reflector of the heat rays; still, brass with a light coating of silver would also serve the purpose. The inclination of the walls of the apparatus to its axis measures 45°. Even the ancients were aware that this is the best form for this kind of metallic mirrors with linear focus, inasmuch as the incident rays parallel to the axis are reflected perpendicularly to the same and thus give a focus of maximum intensity.

The boiler is of copper, which of all the common metals is the best conductor of heat; it is blackened on the outside, because black possesses the property of absorbing all the heat rays, just as white reflects them; and it is inclosed in a glass envelope, glass being the most diathermanous of all bodies; that is to say, the most permeable by the rays of luminous heat. Glass further possesses the property of resisting the exit of these same rays after they have been transformed into dark rays on the blackened surface of the boiler.

The boiler proper of the Tours solar engine consists of two concentric bells of copper, the larger one, which alone is visible, having the same height as the mirror, i. e., 80 centimeters, and the smaller or inner one 50 centimeters. Their respective diameters are 28 and 22 centimeters. The thickness of the metal is only 3 millimeters. The feed water lies between the two envelopes, forming an annular envelope 3 centimeters in thickness. Thus the volume of liquid is 20 liters, and the steam chamber has a capacity of 10 liters. The inner envelope is empty. Into it pass the steam pipe and the feed pipe of the boiler. To the steam pipe are attached the gauge and the safety valve. The bell glass covering the boiler is 85 centimeters high, 40 centimeters in diameter, and 5 millimeters in thickness. There is everywhere a space of 5 centimeters between its walls and those of the boiler, and this space is filled with a layer of very hot air.

Mechanism was provided whereby the reflector was adjusted by hand to follow the movement of the sun.

On May 8, 1875, a fine day, 20 liters of water, at 20° C., introduced into the boiler at 8.30 a. m., produced steam in 40 minutes at 2 atmospheres (30 pounds) of pressure to the square inch, i. e., a temperature of 121°, or 21° above boiling water. The steam was then raised rapidly to a pressure of 5 atmospheres (75 pounds to the square inch), and if this limit was not exceeded it was because the sides of the boiler were only 3 millimeters thick, and the total effort supported by these sides was then 40,000 kilograms. It would have been dangerous to have proceeded further, as the whole apparatus might have been blown to pieces.

Toward the middle of the same day, with 15 liters of water in the boiler, the steam at 100°—that is to say, at a pressure of 1 atmosphere—rose in less than a quarter of an hour to a pressure of 5 atmospheres, equal to a temperature of 153°. Finally, on July 22, toward 1 p. m., an exceptionally hot day, the apparatus vaporized 5 liters of water per hour, which is equal to a consumption of 140 liters of steam per minute, and one-half horsepower. For these experiments the inventor used an engine which made 80 strokes per minute under a continued pressure of 1 atmosphere. Later on it was changed for a rotative engine—that is to say, an engine with a revolving cylinder—which worked admirably, putting in motion a pump to raise water, until the pump, which was too weak, was broken.

In 1878 Mouchot used a boiler made of many tubes placed side by side (pl. 1) and having a capacity of 100 liters (70 for water and 30 for steam).

Mouchot seems to have been the only inventor of a solar plant, with the exception of Shuman, who has had his apparatus tested by independent engineers. The following refers to Mouchot's plant. In Comptes Rendus, Vol. 94, 1882, pages 943–945, M. A. Crova reports that—

The minister of public works appointed two commissions, one at Constantine and the other at Montpellier, to make experiments with two identical mirrors of 5.22 square meters in section normal to the sun's rays and to evaluate their practical utility.

The commission of Montpellier was composed of MM. Duponchel, engineer in chief of Ponts et Chaussées, as president; Col. Fulcrand, R. E.; Guibal, and myself.

The experiments (at Montpellier) lasted from January 1 to December 31, 1881, and were made from hour to hour every day during which the sun was bright and the observations possible.

The solar rays concentrated at the focal line of the mirror were received on a black boiler placed at the axis and which was inclosed by a glass shade.

The number of major calories utilized, divided by those incident, received in one hour upon 1 square meter of surface normal to the rays, gives the efficiency of the apparatus.

Here are the principal results obtained during 176 days which gave 930 observations, during which 2,725 liters of water were distilled.

Moyenne générale des valeurs mesurées pendant l'année 1881 et rapportées à 1^{mq}, et à 1^{h}.

	Calories.	Maximum calories.	Date.
Chaleur reçue directement	616.1	945	25 Avril.
Chaleur utilisée par l'appareil	258.8	547.5	15 Juin.
Moyenne des rendements	.491	.854	14 Juin."

The author has purposely not translated the last five lines for fear of making a mistake. He is unable to interpret the results; but as they represent an important and independent investigation lasting a year, they are given in the hope that some of his audience may be able to throw some light on the matter.

Next came that versatile engineer and successful inventor, John Ericsson, a Swede by birth and an American by adoption. He made an immense number of experiments, extending over 20 years, with costly apparatus, to determine the solar constant, and later on made apparatus for the practical utilization of solar radiation. All these experiments were made at his own expense, and he tells us they cost him £20,000; and having done all this work, the conclusion he arrived at was:

The fact is, however, that although the heat is obtained for nothing, so extensive, costly, and complex is the concentration apparatus that solar steam is

many times more costly than steam produced by burning coal. (Letter dated Sept. 21, 1878, to R. B. Forbes.)

We have already referred to his remarkably accurate determination of the solar constant; but he was not so happy in deducing the temperature of the sun, which he made to be 723,000° C., the present accepted result being only 6,000° C.

He tried hot-air engines, as well as steam engines, for utilizing solar energy, and claimed that the steam engine which he constructed in New York for this purpose in 1870 was the first one driven by the direct agency of solar radiation. The diameter of its cylinder was 4½ inches. He afterwards modified his solar hot-air engine so that it might be used as a small pumping engine, using gas as its heat supply.

The profits upon this chip from his workshop are already estimated at several times the amount of the £20,000 expended by Ericsson upon the solar investigations leading up to this invention. (Vol. II, p. 275 of his "Life," by W. C. Church.) Mouchot claimed, apparently correctly, that his engine was the first, and Ericsson admits that, "Some time previous to 1870, Mouchot made a small model engine, a mere toy, actuated by steam generated on the plan of accumulation by glass bells * * *.

Ericsson gives full details of all his apparatus for determining the solar constant in the record of his life's work, entitled, "Contributions to the Centennial Exhibition," New York, 1876; but unfortunately he did not describe in detail therein the solar boilers, explaining that "experienced professional men will appreciate the motive, viz, that of preventing enterprising persons from procuring patents for modifications." He does, however, give us the following amount of information:

On grounds already fully explained, minute plans of my new system of rendering sun power available for mechanical purposes will not be presented in this work. The occasion, however, demands that I should present an outline of the concentration apparatus before referred to. It consists of a series of polished parabolic troughs, in combination with a system of metallic tubes charged with water under pressure, exposed to the influence of converging solar rays, the augmented molecular action produced by the concentration being transferred to a central receiver, from which the accumulated energy is communicated to a single motor.

Thus the mechanical power developed by concentrated solar heat is imparted to the solar steam engine without the intervention of a multitude of boilers, glass bells, gauges, feeders, etc. Moreover, the concentration apparatus, unlike the instrument of Mouchot, requires no parallactic motion, nor does its management call for any knowledge of the sun's declination from day to day. Its position is regulated by simply turning a handle until a certain index coincides with a certain bright line produced by the reflection of the sun's rays.

His boilers seem to have been exceedingly efficient, for he claims that "the mechanism which I have adopted for concentrating the sun's radiant heat abstracts, on an average, during nine hours a day, for all latitudes between the Equator and 45°, fully 3.5 units of heat per

minute for each square foot of area presented perpendicularly to the sun's rays." Three and five-tenths B. t. u. per square-foot-minute $=0.95$ calories per square-centimeter-minute. The mean transmission of solar radiation by the atmosphere over a zenith distance from 45° E. to 45° W. is 67.5 per cent when the sky is clear. Thus $0.675 \times 1.93 = 1.31$ calories per square-centimeter-minute are available at the earth's surface. Hence the efficiency of Ericsson's boiler was $\frac{0.95}{1.31} \times 100 = 72.5$ per cent, which is remarkably high.

In 1872 Ericsson built his hot-air solar engine, which had a reflector the shape of which was approximately a portion of a sphere and which concentrated the solar radiation onto one end of the cylinder. The power of both these engines was evidently very small. On July 9, 1875, Ericsson wrote that he had up to that time constructed and started seven sun motors.

Ericsson wrote in Nature of January 3, 1884, an illustrated article describing another of his sun motors which he erected in New York in 1883, in spite of his opinion as to the cost of solar steam (previously quoted) expressed in 1878 (pl. 1). His description was as follows:

The leading feature of the sun motor is that of concentrating the radiant heat by means of a rectangular trough having a curved bottom lined on the inside with polished plates so arranged that they reflect the sun's rays toward a cylindrical heater placed longitudinally above the trough. This heater, it is scarcely necessary to state, contains the acting medium, steam or air, employed to transfer the solar energy to the motor, the transfer being effected by means of cylinders provided with pistons and valves resembling those of motive engines of the ordinary type. Practical engineers, as well as scientists, have demonstrated that solar energy can not be rendered available for producing motive power, in consequence of the feebleness of solar radiation. The great cost of large reflectors and the difficulty of producing accurate curvature on a large scale, besides the great amount of labor called for in preventing the polished surface from becoming tarnished, are objections which have been supposed to render direct solar energy practically useless for producing mechanical power.

The device under consideration overcomes the stated objections by very simple means, as will be seen by the following description: The bottom of the rectangular trough consists of straight wooden staves, supported by iron ribs of parabolic curvature secured to the sides of the trough. On these staves the reflecting plates, consisting of flat window glass silvered on the under side, are fastened. It will be readily understood that the method thus adopted for concentrating the radiant heat does not call for a structure of great accuracy, provided the wooden staves are secured to the iron ribs in such a position that the silvered plates attached to the same reflect the solar rays toward the heater.

Referring to the illustration, it will be seen that the trough, 11 feet long and 16 feet broad, including a parallel opening in the bottom, 12 inches wide, is sustained by a light truss attached to each end, the heater being supported by vertical plates secured to the truss. The heater is 6¼ inches in diameter, 11 feet long, exposing $130 \times 9.8 = 1{,}274$ superficial inches to the action of the reflected solar rays. The reflecting plates, each 3 inches wide and 26 inches long, intercept a sunbeam of $130 \times 180 = 23{,}400$ square inches section. The trough is supported by a central pivot, round which it revolves. The change of inclination

is effected by means of a horizontal axle, concealed by the trough, the entire mass being so accurately balanced that a pull of 5 pounds applied at the extremity enables a person to change the inclination or cause the whole to revolve. A single revolution of the motive engine develops more power than needed to turn the trough, and regulates its inclination so as to face the sun during a day's operation.

The motor shown by the illustration is a steam engine, the working cylinder being 6 inches in diameter, with 8-inch stroke. The piston rod, passing through the bottom of the cylinder, operates a force pump of 5 inches diameter. By means of an ordinary crosshead secured to the piston rod below the steam cylinder, and by ordinary connecting rods motion is imparted to a crank shaft and fly wheel, applied at the top of the engine frame, the object of this arrangement being that of showing the capability of the engine to work either pumps or mills. It should be noticed that the flexible steam pipe employed to convey the steam to the engine, as well as to the steam chamber attached to the upper end of the heater, have been excluded in the illustration. The average speed of the engine during the trials last summer was 120 turns per minute, the absolute pressure on the working piston being 35 pounds per square inch. The steam was worked expansively in the ratio of 1 to 3, with a nearly perfect vacuum kept up in the condenser inclosed in the pedestal which supports the engine frame.

In view of the foregoing, experts need not be told that the sun motor can be carried out on a sufficient scale to benefit very materially the sun-burnt regions of our planet.

From the particulars given it is easily calculated that the "concentration" of this absorber was 9.

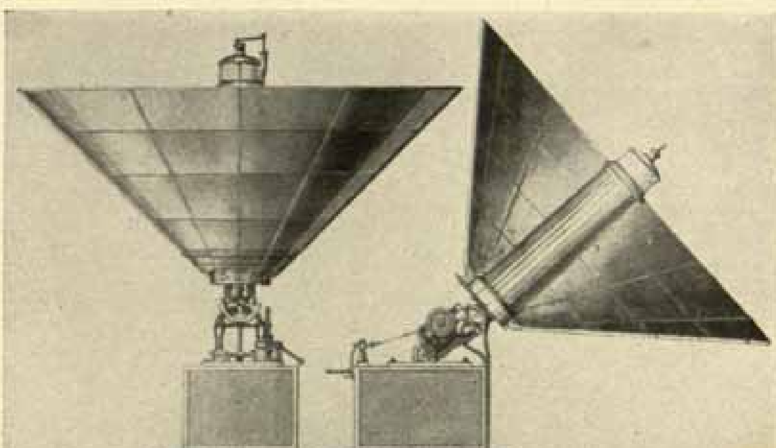
The Rev. C. H. Pope has produced a useful little book entitled "Solar Heat," the second edition of which was published in 1906. In it he tells us he started his experiments (which do not appear to have included the conversion of solar radiation into mechanical energy) in 1875. He used a modification of Mouchot's truncated cone reflector formed of many plane mirrors, the plan adopted about the same time by Adams. Pope has fallen into the same error re the connection between temperature and concentration of radiation as did Adams, for he says (p. 17):

That the degree and amount of heat at the focus will be proportionate to the area of the opening of the lens or mirror, and that thus the only limit to the temperature which may be reached is the size to which such lenses and mirrors may be constructed and revolved.

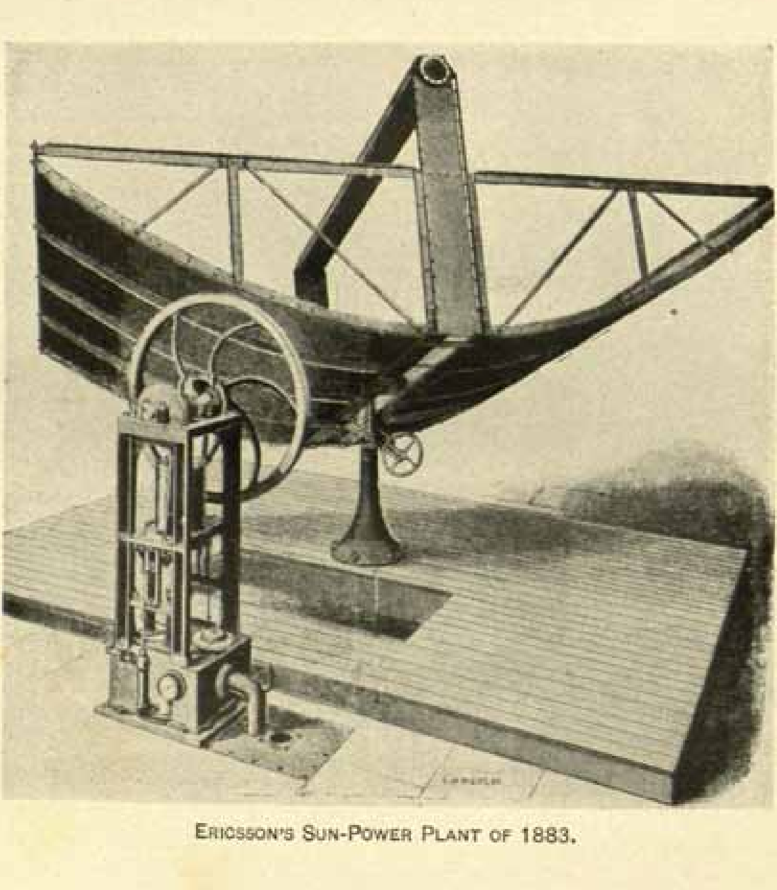
And (p. 93):

These rays may, therefore, be gathered together and made to unite, as if they became one denser, stronger, hotter ray, so that the temperature of the condensed rays will be raised in proportion to the number of rays blended, and we can thus cause the heat to increase to any degree our apparatus can be enlarged.

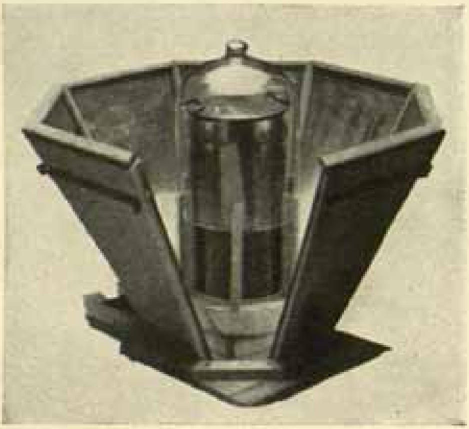
W. Adams, deputy registrar, High Court, Bombay, seems to be the sole Englishman who has worked on the practical side of the problem of the utilization of solar energy. His work was done in India, and is recorded in his interesting book, Solar Heat (Bombay,



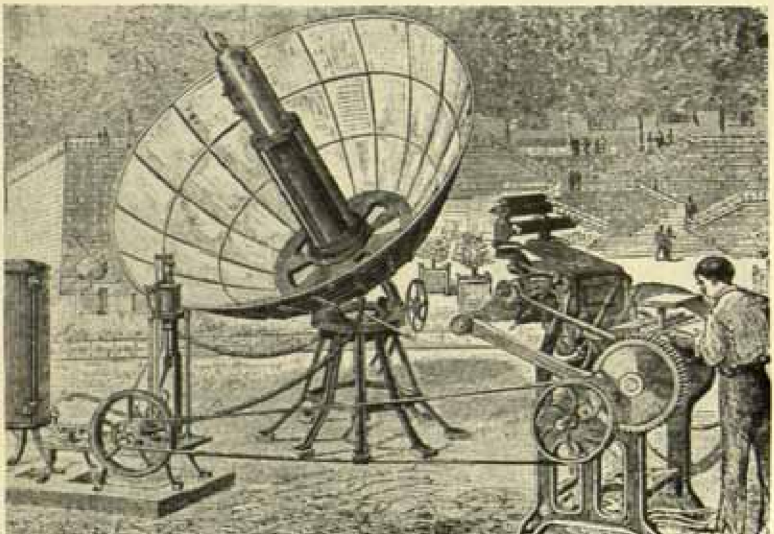
MOUCHOT'S MULTIPLE TUBE SUN-HEAT ABSORBER OF 1878.



ERICSSON'S SUN-POWER PLANT OF 1883.



ADAMS'S SOLAR COOKER, 1876.



PIFRE'S SUN-POWER PLANT OF 1878 DRIVING A PRINTING PRESS.

1878). He started on the work in 1876, and his experiments led him to conclude, as did Buffon, that silvered-glass mirrors were superior to polished-metal ones. This is no doubt true for ordinary use, though for laboratory experiments the polished-metal ones give better results, as there is then no absorption by the glass (pl. 2).

In two particulars Adams was much at fault—(1) in believing that the solar rays which reach the earth are not practically parallel, and this in spite of the opposite opinions of the many physicists whom he quotes, and (2) in believing that the temperature attained at the focus of a lens or mirror is directly proportional to the concentration of the rays. As a consequence, he stated that if a lens 85 feet 4 inches in diameter concentrated the radiation onto a circle one-half inch in diameter the temperature would be 73,400,320° F. This is equal to 40,780,000° C., while the temperature of the sun itself is only 6,000° C., and no amount of such concentration could produce a temperature in excess of this. This error on the part of Adams and Pope seems to be due to a confusion of "temperature" with "quantity of heat."

His experiments were all made with plane or flat glass mirrors, the use of which he strongly advocated in preference to curved metal ones, which Mouchot used. Sometimes he used groups of 18 mirrors, each 17 by 10½ inches, and sometimes of 32, each 9 by 6 inches. The latter he arranged in a concave wooden frame in 4 tiers of 8 in each tier. Such a group of 32 formed 1 unit, of which he had 16, all focused onto one boiler. When placed together the 16 units formed a portion of the surface of a hollow sphere 40 feet in diameter. One of his boilers was of copper one-sixteenth inch thick, 16 inches diameter, 2 feet 7 inches high, and held 9 gallons of water, which boiled in 30 minutes and evaporated 3¾ gallons in an hour.

His next boiler was also of copper one-fourth inch thick, and of the same design and external dimensions as Mouchot's, but with a water space between the inner and outer shells of 3 inches instead of 3 centimeters, and containing 12 gallons of water as compared with Mouchot's 4½ gallons. The 12 gallons of water were boiled and the pressure raised to 10 pounds to the square inch in the half hour from 7.30 a. m. to 8 a. m., and by 8.30 a. m. the pressure was 70 pounds to the square inch, when the safety valve opened, whereupon he goes on to say:

A gentleman present kept the valve down by placing his foot on it, till the steam, escaping from several leaks in the joints of the fittings made the position untenable. The weight on the safety valve was then supplemented by a brick suspended from the lever by a piece of string, when suddenly the packing and red lead at the top of the dome under the socket of the steam pipe (which had been fixed by my butler, who professed to have formerly been a fitter) gave way, and, with a terrific noise, the whole volume of steam rushed out of the

opening. On turning off the solar rays and examining the boiler it was found to be dry. All the water had either been evaporated or blown out.

When this boiler had been properly fitted up by professional fitters, a steam pump was hired, said to be of 2½ horsepower, and it was connected with the steam pipe. At 7.30 a. m. fire was opened on the boiler from the whole battery of 16 mirrors at a range of 20 feet, the boiler containing 12 gallons. At 7.45, i. e., a quarter of an hour there was a pressure of about 2 pounds and at 8.30 a. m. 55 pounds. The steam was then turned into the cylinder of the pump, and the pump was kept working at a uniform pressure of about 30 pounds to the square inch.

This pump, the first steam engine ever worked in India by solar heat, was kept going daily for a fortnight in the compound of my bungalow at Middle Colaba, in Bombay, and the public was invited, by a notification in the daily papers, to witness the experiments.

Adams also made a solar cooker, the reflector of which was formed of eight sheets of plane glass arranged so as to form a hollow truncated octagonal pyramid 2 feet 4 inches in diameter at the larger end. The food was placed in a cylindrical copper vessel, at the axis, covered with an octagonal glass shade. With this he and others cooked many meals, both stews and roasts, and he records that both he and Mouchot found (p. 98) that animal fat—

When exposed to the direct or reflected rays of the sun was converted into butyric acid, a substance having such an offensive odor and taste as to render the roast unpalatable. Mouchot then discovered that a sheet of red, pink, or yellow transparent glass interposed between the roast and the reflector had the effect of preventing this fermentation, as those colors have the curious property of absorbing, neutralizing, or eliminating the rays by which it is caused.

Adams also states (p. 36) that—

When the sacred fire that burned in the Temple of Vesta[1] became extinct, the ancient Romans used to rekindle it by placing a piece of dry wood in the linear focus of the conical reflector * * * To bring fire from heaven, by supernatural aid and a metal reflector was, no doubt, one of the most ancient miracles of priestcraft."

He suggested many uses for solar heat, among others (p. 96), "for the cremation of deceased Hindus and others."

Taking into account the facts that he did not expend much money on his experiments, and that he did the whole of his solar work in 18 months, it will be admitted his was a most creditable piece of work, especially as he was neither an engineer nor a physicist. To make this amply clear, he says:

I have neither the capital, the time, nor the practical knowledge required to conduct any business in which steam machinery is used. I know now that the "governors" of a steam engine are the two iron globes which revolve about it, and not, as I had supposed, the two men who lubricate the machine and feed the boiler with coals. This is nearly the extent of my knowledge of steam machinery.

[1] Vesta, the Goddess of the Hearth.

In concluding this brief account of Adams's work you will be pleased to learn that he was awarded the gold medal of the Sassoon Institute of Bombay for his essay on The Utilization of Solar Heat, which he submitted in March, 1878.

In Comptes Rendus, Volume 91, 1880, pages 388–389, M. Abel Pifre claims an efficiency of 80 per cent for his apparatus when he says he obtained a rate of absorption of 1.21 calories per square-centimeter-minute. If such a rate were obtained we now know it would mean an efficiency of 89.7 per cent, which is improbable. Pifre used a parabolic reflector (instead of a truncated cone), and reduced the surface of the boiler, thus increasing the concentration. The capacity of his boiler was 11 gallons, and he collected 100 square feet of solar radiation so the diameter of his reflector was about 11 feet 4 inches. He used a rotary pump, and raised 99 liters of water 3 meters in 14 minutes, which is equivalent to 0.065 horsepower. He ran a printing press with his sun-power plant, and claimed that if he had collected 216 square feet of radiation he could have produced 1 horsepower, which is quite likely (pl. 2).

Next in order we have Langley's work, which consisted of many experiments to determine the value of the solar constant, the value of which he gave as 3 calories per square-centimeter-minute.

Langley experimented with de Saussure's "hot box," and was the leader of the expedition to Mount Whitney, where some of his best work was done. He gave a preliminary account of this trip in Nature of August 3, 1882, pages 314–317, and a full record of it under the title "Researches on solar heat" in the United States of America War Department, Papers of the Signal Service, 15, 1884. He also referred to it in the New Astronomy (1900).

In Nature (p. 315), he said:

> As we still slowly ascended and the surface temperature of the soil fell to the freezing point, the solar radiation became intenser, and many of the party presented an appearance as of severe burns from an actual fire, while near the summit the temperature in a copper vessel, over which were laid two sheets of plain window glass, rose above the boiling point, and it was certain that we could boil water by the direct solar rays in such a vessel among snow fields.

In Volume 73 of the Proceedings, Inst. C. E., 1883, page 284, is described a plant designed by J. Harding, M. Inst. C. E., for distilling water by solar radiation.

This plant was erected at Salinas, Chile, 4,300 feet above sea level, and had 51,200 square feet of glass arranged in sections 4 feet wide, and in the form of a very flat Λ, forming the roof of a shallow water trough. The sun evaporated the water, and the resulting vapor condensed on the glass, for the temperature in the box was far higher than that of the atmosphere, and hence of the glass. The pure water trickled down the sloping glass and dripped from its lower edge into

a small channel on the top of each side of the box. These channels delivered into larger ones, and thus the distilled water was collected. The plant yielded 5,000 gallons of pure water per day in summer, i. e., 1 pound of water per square foot of glass. Allowing for interest on capital, cost of repairs, etc., the cost of the pure water is said to have been less than one-half penny per gallon. The chief item of expense was the breakage of glass by whirlwinds. Distillation started at 10 a. m. and continued to 10 p. m. The maximum temperature of the water in the troughs was 150° F. The total cost of the plant, including pumps, windmills, and tanks, was $50,000, or 1s. 6d. per square foot of glass.

It is not clear when the solar energy problem first engaged the attention of C. L. A. Tellier, a French refrigerating engineer, but in 1889 he published his book, "Élévation des Eaux par la Chaleur Atmosphérique," in which he gave many drawings and details, and a very full description of his plant. He may have been the first to use the lamellar boiler, but the United States patent No. 230323, of July 20, 1880, of MM. Molera and Cebrian, shows that they proposed this form of boiler. The dimensions of each section of Tellier's boiler were 3.5 by 1.12 meters. They were made of thin plates of iron, so riveted together as to give them a quilted formation. They were filled with ammonium hydrate, which, he says, when heated by the sun produced gaseous ammonia at a pressure of "several atmospheres." The ammonia gas was used in a small vertical engine, and was then liquefied in a condenser and used again. The boilers were fixed in a sloping position so as to "face the sun," and two somewhat fanciful illustrations show them used as roofs of verandas. The boilers were insulated on their lower or shade sides to prevent loss of heat, and were placed in shallow boxes with only one layer of glass to form the cover. He experimented with different colored glass, and found, as might be expected, that colorless glass gave the best results. He also gave complete details of his invention as applied to the manufacture of ice. With so much detail it is disappointing that the author could not find the results of a single experiment with the plant. In fact, he is not sure whether Tellier ever constructed one.

In his work La Conquête Pacifique de l'Afrique Occidentale (1890), Tellier discussed social and economical questions, and showed how improvements might be made by rendering the deserts of Africa productive by means of his sun-power plants.

A. G. Eneas, in the United States, used the popular truncated, cone-shaped reflector, collecting about 700 square feet of solar radiation. The weight of the reflector was 8,300 pounds.

The boiler was formed of two concentric steel tubes, the two together being incased in two glass tubes with an air space between them and another air space between the inner glass one and the outer steel tube.

The water circulated up between the inner and outer steel tubes and down the inner tube. The boiler was placed at the axis of the cone. Its length was 13 feet 6 inches, its water capacity 834 pounds (13.4 cubic feet), and steam space 8 cubic feet. Hence the diameter of the outer tube appears to have been 1 foot 2 inches and the concentration of radiation 13.4; i. e., 13.4 square feet of sunshine were concentrated on each square foot of the external surface of the boiler.

C. G. Abbot (The Sun, p. 369) states that Eneas gave him the following particulars:

February 14, 1901.—Pasadena, Cal., 11.30 a. m.–0.30 p. m.; 642 square feet sunshine. Temperature of air, 61° F. Steam pressure, 145–151 pounds per square inch. Steam condensed, 123 pounds.

October 3, 1903.—Mesa, Ariz., "about midday"; 700 square feet sunshine. Temperature of air 74° F. Average steam pressure, 141 pounds per square inch. Steam condensed, 133 pounds.

October 9, 1904.—Willcox, Ariz., 11 a. m.–12 a. m.; 700 square feet sunshine. Steam pressure, 148–156 pounds per square inch. Steam condensed, 144.5 pounds.

The temperature of the feed water is not given, but, assuming it to be the same as the temperature of the air, we can deduce the rate of absorption per square foot of radiation and the thermal efficiency of the absorber. This being done, we obtain the following table:

Place and date.	Period.	Weight of steam produced in pounds.	Mean pressure of steam in pounds per square inch of absorber.	Rate of absorption per square foot of radiation collected, B. t. u. per hour.	Thermal efficiency of the absorber.
					Per cent.[1]
Pasadena, Feb. 14, 1901	11.30 a. m. to 0.30 p. m.	123	163	223	74.6
Mesa, Oct. 3, 1903	"About midday"	133	156	219	73.3
Willcox, Oct. 9, 1904	11 a. m. to 12 m.	144.5	167	238	79.6

[1] For a maximum transmission of radiation through the atmosphere of 70 per cent.

Eneas refers to his "nine different types of large reflectors," and found that he obtained better results when he concentrated the reflected rays "on two parts of the boiler instead of its entire length, as in the Pasadena machine." The unexposed portions of the boiler then appear to have been lagged.

Eneas said, "I find 3.71 B. t. u. per square foot per minute as the greatest amount of heat obtainable during the trial runs." This gives a maximum efficiency of 74.5 per cent, which agrees with the result given for his Pasadena plant in the foregoing table.

Eneas also stated that "the interposition of a single thin glass plate in a beam of sunlight diminishes the intensity about 15 per cent. This decrease is owing principally to reflection." On page 466 of

Preston's Treatise on Heat, it is stated that "mirror glass 2.6 millimeters thick transmitted 39 per cent of the radiation that fell on it from a Locatelli lamp, while rock salt transmitted 92 per cent." The diathermancy of each substance varies with the nature of the source of heat, so the result just given is not comparable with that given by Eneas.

Abbot found the following percentages of heat were transmitted through sheets of glass, each from 1.5 to 2 millimeters thick. In one set of experiments the glass was normal to the rays and the other at 45°.

Number of sheets of glass.	Percentage transmission.	
	Rays normal to glass.	Rays at 45° to glass.
1	86.5	85
2	74.5	71.8
3	63.5	60
4	53.3	49

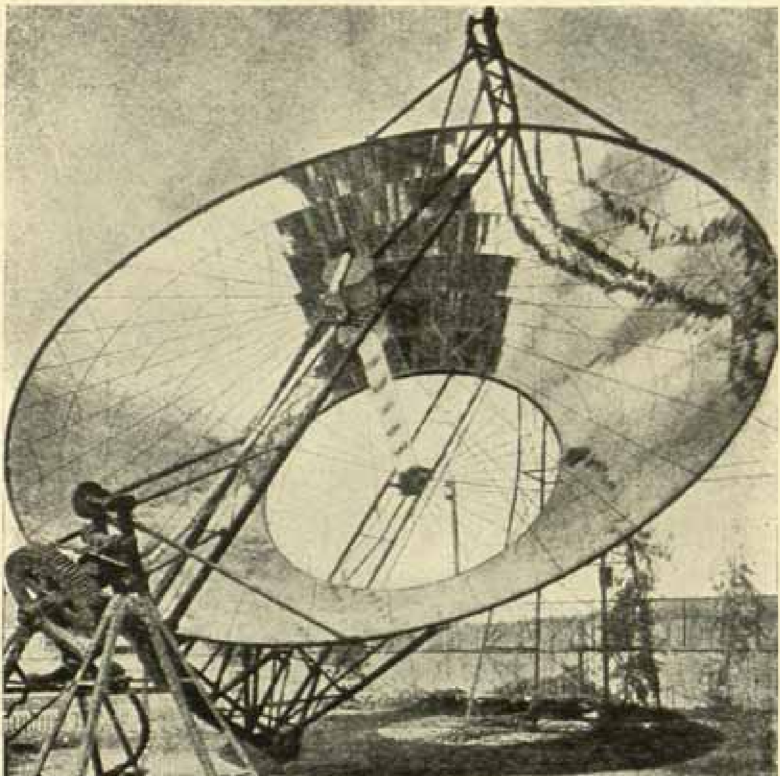
The sun-power plant known as the Pasadena[1] one was described and illustrated in the August, 1901, issue of Cassier's Magazine by Prof. R. H. Thurston, LL. D., D. E., and on page 103 of the Railway and Engineering Review of February 23, 1901. It is stated to have been designed by, and erected at the expense of, "a party of Boston inventors whose names have not been made public." It consisted of a truncated cone reflector, 33 feet 6 inches in diameter at the larger end and 15 feet diameter at the smaller, with a boiler 13 feet 6 inches long, having a capacity of 100 gallons (U. S. A.) plus 8 cubic feet of steam space (pl. 3).

The article in the Railway and Engineering Review states: "According to newspaper accounts, the all-day average work performed by the engine is 1,400 gallons (U. S. A.) of water lifted 12 feet per minute, which is at the rate of 4 horsepower." It is more nearly 4¼ horsepower; thus, this plant required 150 square feet of radiation per horsepower, and the concentration appears to have been 13.4.

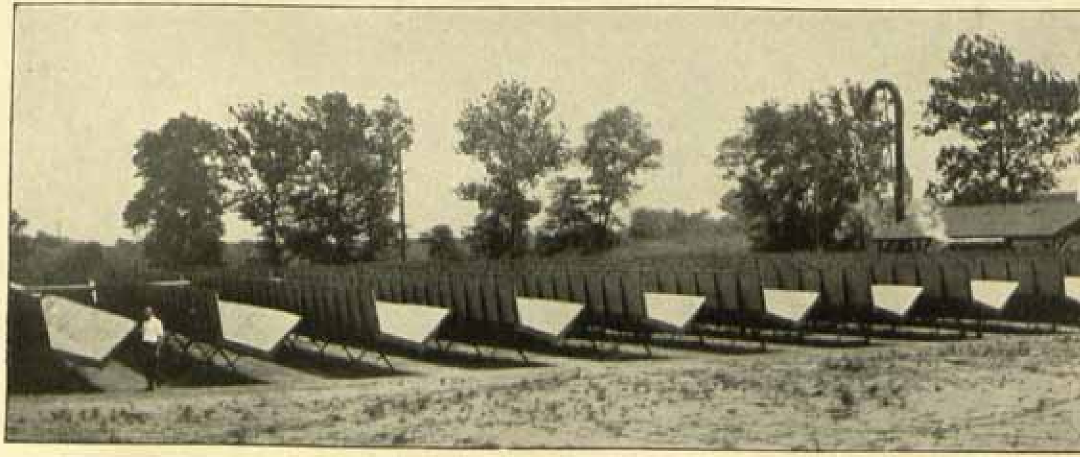
The Pasadena plant is said to have cost £1,000, and Willsie, writing of it in 1909, says it was "the largest and strongest of the mirror type of solar motor ever built."

H. E. Willsie and John Boyle, jr., started their work in America in 1902. The method they adopted was to let the solar radiation pass through glass and heat water, which in turn was used to vaporize

[1] There appear to have been several plants erected at Pasadena by different experimenters. Probably Eneas designed the plant above described.



THE PASADENA SUN-HEAT ABSORBER OF 1901.



GENERAL VIEW FROM THE WEST OF THE SHUMAN ABSORBER, TACONY, 1911.

some volatile fluid such as ammonium hydrate, ether, or sulphur dioxide, the vapor being used to drive an engine.

Willsie thinks he was the first to propose this two-fluid method for the utilization of solar energy, and, so far as the author knows, his claim is correct. Their first sun-heat absorber was built at Olney, Ill., and consisted of:

A shallow wooden tank tightly covered with a double layer of window glass. The sides and bottom were insulated by inclosed air spaces filled with hay. The tank was lined with tar paper, well pitched, to hold water to the depth of 3 inches. Although the weather was cold and raw, even for October, with occasional clouds, the thermometer in the water showed temperatures higher than were needed to operate a sulphur dioxide engine.

The next solar heater was built at Hardyville, Ariz. Sand was used for insulation. Three tests for the amount of heat gave these average results in December:

Test No.	Heat units absorbed per square foot per hour.
1	120
2	122
3	148

An estimate showed that 50 per cent of the heat reaching the glass was absorbed into the water.

In 1903 some further heater tests were made, patent applications filed, and to carry on experiments on a more extensive scale the Willsie Sun Power Co. was incorporated.

In the spring of 1904 a complete sun-power plant was built at St. Louis. In this installation a 6 horsepower engine was operated by ammonia. The heater consisted of a shallow wooden basin coated with asphalt and divided by strips into troughs. It was covered by two layers of window glass and insulated at the sides and bottom by double air spaces. Each trough of the heater formed a compartment. The troughs were inclined so that a thin layer of water flowed from one trough to the next. In this heater was collected and absorbed into the water from the sun's rays 211,500 heat units per hour at noon, or 377 heat units per hour per square foot of glass exposed to the sun. As, according to accepted solar observations, about 440[1] heat units per hour reached a square foot of glass, this heater was showing the surprising efficiency of 85 per cent, and collecting nearly twice as much solar heat per square foot per hour as did the apparatus of Ericsson. Of the lost heat I estimated that 40 heat units were reflected and absorbed by the glass and that 23 heat units were radiated. On cloudy days the water could be heated by burning fuel. A description of this plant appeared in a St. Louis paper and in a New York paper, but, so far as I know, it has not been mentioned in any technical publication.

It was then decided to build a sun-power plant on the desert, and some land about a mile from The Needles, Cal., was purchased for a site.

[1] No; only 290. Note: $0.70 \times 1.93 = 1.352$ calories per square-centimeter-minute = 290 B. t. u. per square-foot-hour.

This Needles plant used sulphur dioxide, and its results decided them to build a larger plant, which Willsie speaks of as their third sun-power plant, and describes as follows:

> A 20-horsepower slide-valve engine was connected to an open-air water-drip condenser and to a fire-tube boiler 22 inches by 19 feet having fifty-two 1-inch tubes. The solar-heated liquid flowed through the tubes giving up its heat to the sulphur dioxide within the boiler. Boiler pressures of over 200 pounds were easily obtained. The engine operated a centrifugal pump, lifting water from a well 43 feet deep (sic), and also a compressor, in addition to two circulating pumps.

Their fourth plant was a rebuilding of the third, and they tried the expedient of covering the heat-absorbing water with a layer of oil, but the results were not so good as when a heat-absorbing liquid (water, or oil, or a solution of chloride of calcium) was rapidly circulated in a thin layer. The sun-heat absorber for this plant was in two sections, one covered with one layer of glass and one with two layers, and both on a slope, the liquid running from the first to the second, and its temperature in the two sections being 150° F. and 180° F., respectively. The liquid at 180° F. was distributed over a "heat exchanger" consisting of horizontal pipes about 3 inches in diameter, arranged in a vertical plane, something like an air condenser. The pipes contained sulphur dioxide, and the heat-absorbing liquid lost about 100° F. in its descent. The cooled liquid was returned to the two sections of the absorber to be reheated. The heat exchanger was inclosed in a glass-covered shed. Willsie says:

> The engine used in this experiment was a vertical automatic cut-off, which at times, with a boiler pressure of 215 pounds, probably developed 15 horsepower. The two-heater sections exposed an area of about 1,000 square feet to the sun, but as the heat was taken from storage and not directly from the heater, it is not fair to assume the above proportion of heater surface to horsepower developed.
>
> The condenser consisted of 6 stacks of horizontal pipes, 12 pipes to the stack. The cooling water, pumped from a well 43 feet deep, had a temperature of 75° F. Only enough water was allowed to drip over the pipes to keep them wet, and so great was the evaporation in the dry desert breeze that the cooling water left the lower pipes at 64°. By using the cooling water over and over, the condenser gave very satisfactory results. A shade of arrow weed, a straight willowlike shrub abundant along the Colorado River, kept the sunshine from the condenser pipes and permitted a good air circulation.

Willsie estimated the cost of his sun-power plant, complete with engine, at £33 12s. per horsepower.

With regard to Willsie's results, it is to be noted that 377 B. t. u. per hour means an efficiency of $\frac{377\times100}{60\times0.70\times7.12}=126$ per cent, for we now know that a maximum of only about 299 B. t. u. per square foot per hour penetrate the atmosphere. The author agrees with the 50 per cent efficiency given a little earlier by Willsie.

Frank Shuman, of America, started on the problem in 1906, and in 1907 he had a plant running which developed about 3½ horsepower; 1,200 square feet of sunshine fell onto a fixed, horizontal water box with a glass top. In the water there were rows of parallel horizontal black pipes containing ether, and exposing 900 square feet of surface to the solar radiation. The water also became heated and conveyed heat to the under sides of the pipes. The ether boiled, and its "steam" drove a small vertical, simple, single-cylinder engine. The exhaust ether vapor passed into an air surface condenser, and the liquid ether from this was pumped back into the tubes of the "boiler" already described.

This plant, Shuman says, ran well even when snow was lying on the ground. This at first seems very remarkable, but though in the winter the number of solar rays falling on a given horizontal area is smaller than in summer, the permeability of the atmosphere is about 20 per cent greater in winter than in summer, which counteracts the other effect; but of course the loss of heat by conduction from the boiler is greater in winter than in summer.

In 1910 Shuman constructed an experimental unit of an absorber measuring 6 by 9 feet. This unit combined the lamellar boiler of Tellier and the "hot box" of de Saussure, for it consisted of a shallow black box with double glass top, with 1 inch of air space between the two layers of glass, another air space of an inch between the lower glass and the boiler, which was 6 feet long (up the slant), 2 feet 6 inches wide, and ¼ inch thick over all. The box was so sloped that at noon the rays of the sun were perpendicular to the glass. The box was not moved to follow the sun, but it was adjusted about every three weeks, so that the condition just named was complied with. The remarkable thing about the absorber was that there was no concentration of any kind of the sunshine by mirrors, lenses, or other means, and yet the author on one occasion recorded a temperature of 250° F. in the box. The best run of an hour's duration produced steam at atmospheric pressure at the rate of 7½ pounds per 100 square feet of sunshine falling on the box. The author's tests of a Shuman 100 horsepower low-pressure engine at Erith showed the steam consumption to be 22 pounds at atmospheric pressure per brake-horsepower-hour. Hence, with an absorber of the type just described, it would be necessary to collect solar radiation to the extent of 300 square feet per brake horsepower, which is a much larger area than any named by other workers. The maximum thermal efficiency of this absorber was 24.1 per cent.

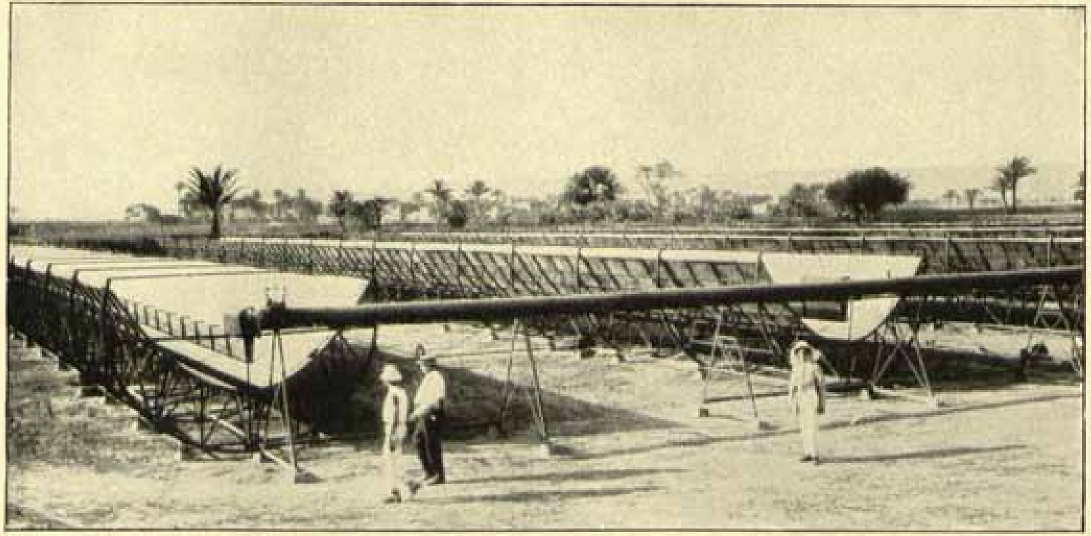
In 1911, with the aid of some English capitalists, Shuman constructed his third absorber at Tacony (a suburb of Philadelphia), which was almost identical with the one just described, except that it had two plane mirrors, one at the upper edge of the "hot box" and

one at the lower, so arranged that 6 square feet of sunshine were concentrated onto 3 square feet of "hot box"; i. e., the concentration was 2 to 1. Its position was adjusted about every three weeks. This time the total quantity of solar radiation collected was many times as large as the largest collected by any previous worker, for the total area was 10,296 square feet. In the best run of one hour this plant produced 816 pounds of steam at atmospheric pressure. This is at the rate of 9 pounds per 100 square feet of sunshine, and therefore equivalent to an allowance of 245 square feet of sunshine per brake horsepower. The maximum thermal efficiency of this absorber was 29.5 per cent (pl. 4).

Toward the end of 1911 the Sun Power Co. (Eastern Hemisphere), (Ltd.), requested their consulting engineers (Messrs A. S. E. Ackermann and C. T. Walrond) to select and invite some distinguished physicist to join them in a consultative capacity. Hence Prof. C. V. Boys, F. R. S., became associated with the work, and he suggested a vital change in the design of the absorber, viz, that the boilers should be placed on edge in a channel-shaped reflector of parabolic cross section, so that solar radiation was received on both their surfaces, instead of one being worse than idle, as it was when the boilers were placed side on to the sun. The design immediately received the hearty approval of the consulting engineers and Shuman, and at the time we all thought the arrangement was novel, but the author has since found and recorded herein that Ericsson used a very similar reflector and boiler.

An absorber of this design was constructed and erected at Meadi on the Nile, 7 miles south of Cairo, in 1912, but the boiler was constructed of thin zinc and failed before the official tests could be made. This boiler was replaced by a cast-iron one in 1913, and the author (accompanied by his old pupil, G. W. Hilditch, A. M. Inst. C. E., as his chief assistant, now Lieut. Hilditch of the Divisional Engineers, Royal Naval Division) spent two most interesting months with the plant in July and August, 1913. He went out in time to tune up the Shuman engine (a 100-horsepower one) taken out from Tacony, and make all the necessary preparations for the trials, of which there were over 35.

In addition to the alteration of the shape of the reflectors, another very important change was made. Their axes were placed north and south, and they were automatically heeled over from an eastern aspect in the morning to a western one in the evening, so as to follow the sun. Thus the same number of solar rays were caught all day long, and the small decrease in steam production in the morning and evening was almost entirely due to the greater thickness of atmosphere through which the rays had to pass. The total area of sunshine collected was 13,269 square feet (pls. 5 and 6).



GENERAL VIEW FROM THE SOUTH OF THE SHUMAN-BOYS ABSORBER, MEADI, 1913.

SHUMAN-BOYS ABSORBER, MEADI, 1913. ONE SECTION OF THE ABSORBER, FROM THE NORTH.

The boilers were placed at the focus of the reflectors and were covered with a single layer of glass inclosing an air space around the boilers. Each channel-shaped reflector and its boiler was 205 feet long, and there were five such sections placed side by side. The concentration was 4½ to 1. The maximum quantity of steam produced was 12 pounds per 100 square feet of sunshine, equivalent to 183 square feet per brake horsepower, and the maximum thermal efficiency was 40.1 per cent. The best hour's run gave 1,442 pounds of steam at atmospheric pressure, hence, allowing the 22 pounds of steam per brake-horsepower-hour, the maximum output for an hour was 55.5 brake horsepower—a result about 10 times as large as anything previously attained, and equal to 63 brake horsepower per acre of land occupied by the plant. A pleasing result was that the output did not fall off much in the morning and evening. Thus on August 22, 1913, the average power for the five hours' run was no less than 59.4 brake horsepower per acre, while the maximum and minimum power on that day were 63 and 52.4 brake horsepower per acre, respectively.

The work of MM. G. Millochau and Ch. Féry was started in 1906 to determine the solar constant and the temperature of the sun. Their work is recorded in Comptes Rendus for 1906 and 1908, and in the Revue Scientifique of September 7, 1907. They give the absolute temperature of the sun as 6,042° C., and the value of the solar constant as 2.38 calories per square-centimeter-minute. This latter value was the result of experiments they made on the summit of Mont Blanc in 1908.

The article in the Revue Scientifique of September 7, 1907, is by Millochau, and in it he gives the following list of experimenters and the results of their determination of the solar constant, after reading which some may consider the word "constant" a misnomer:

Pouillet, 1837	1.793
Forbes, 1842	2.82
O'Hagen, 1863	1.9
Violle, 1875	2.28 to 2.37
Langley, 1884	3.068
Savelief, 1889	3.47
Pertner, 1889	3.05 to 3.28
Ångström, 1890	4
Hansky, 1905	3.29

To these we may add:

Herschel, 1837	1.98
Ericsson, 1876	1.93
Millochau and Féry, 1907	2.38
Abbot, 1913	1.93

In spite of this history of comparative failures, the author is of opinion that the problem of the utilization of solar energy is well worthy of the attention of engineers, for even now it is very nearly

a solved problem where there is plenty of sunshine and coal costs £3 10s. a ton. It is fortunate that where coal is dear sunshine is often plentiful, and it is to be remembered that coal will gradually get dearer while the cost of manufacture of sun-power plants should decrease. Sun-power plants are admirably suitable for pumping in connection with irrigation, for where there is most sunshine there is need for most irrigation, and the slight variation in the quantity of water pumped throughout the day does not matter. Also, when temporarily there is no sunshine (due to clouds), probably little or no irrigation is required.

In conclusion, the author would refer those who are interested in the subject to his paper (8vo, 86 p., 22 illus.), bearing the same title as this one, presented to the Society of Engineers on April 6, 1914. Therein he dealt fully with the whole of Shuman's work from 1910–1913, inclusive, and gave details of the results of the 62 trials of the plant made by the author in England, the United States, and Egypt.

THE CONSTITUTION OF MATTER AND THE EVOLUTION OF THE ELEMENTS.[1]

By Prof. Sir Ernest Rutherford, F. R. S.

[With 5 plates.]

Speculations as to the constitution of matter have occupied an important place in the development of scientific knowledge. The idea that all matter was composed of minute particles called atoms was put forward long ago by the Greek philosophers and was advanced again with varying degrees of confidence by philosophic men at the dawn of the scientific age. For example, Newton suggested that matter was composed of atoms which were likened to "hard massy balls," while Robert Boyle regarded a gas to consist of atoms which were in brisk motion. The first definite formulation of the atomic theory as a scientific hypothesis was given by Dalton, of Manchester, in 1803 in order to explain the combination of atoms in multiple proportion. The necessity of distinguishing between the chemical atom and the chemical molecule was soon recognized, while the famous hypothesis of Avogadro that equal volumes of all gases at the same temperature and pressure contain equal numbers of molecules still further extended the usefulness of the theory. The whole superstructure of modern chemistry has been largely reared on the foundations of the atomic theory. The labors of the chemist have revealed to us the presence of more than 80 distinct types of elements, each of which has a characteristic atomic weight, and in most cases sufficiently distinct physical and chemical properties to allow of its separation from any other element by the application of suitable methods.

It has been generally assumed that all the atoms of one element are identical in shape and weight, and until a few years ago were supposed to be permanent and indestructible. The close study of the variation of chemical properties of the elements with atomic weight led Frankland and Mendelief to put forward the famous "periodic law," in which it was shown that there was a periodic

[1] The William Ellery Hale Lecture, delivered at the annual meeting of the National Academy of Sciences, Washington, D. C., 1914. Reprinted by permission.

variation in the chemical properties of elements when arranged in order of increasing atomic weight. This empirical generalization has exercised a wide influence on the development of chemistry, and the periodic law has been considered by many to indicate that all the atoms are composed of some elementary substance or protyle. It is only within the last few years that our knowledge of atoms has reached a stage to offer a reasonable explanation of this remarkable periodicity.

Time does not allow me to more than refer in passing to the important contributions of Le Bel and van 't Hoff to the structure of complex molecules and the arrangements of the atoms in space, which has exercised such a wide and important influence on the development of organic chemistry.

While the chemist was busy disentangling the elements, determining their relative atomic weights and studying their possible combinations, the physicist had not been idle. The idea that a gas consisted of a large number of molecules in swift but irregular movement had been tentatively advanced at various times to explain some of the properties of gases. These conceptions were independently revived and developed in great detail by the genius of Clausius and Clerk Maxwell about the middle of the last century. On their theory, now known as the kinetic or dynamical theory of gases, the molecules of a gas are supposed to be in continuous agitation colliding with each other and with the walls of the containing vessel. Their velocity of agitation is supposed to increase with temperature, and the pressure is due to the impact of the molecules of the gas on the walls of the inclosure. This theory was found to explain in a simple and obvious way the fundamental properties of gases, and has proved of great importance in molecular theory. The idea that atoms must be in brisk and turbulent motion is strongly supported by the well-known property of the interdiffusion of gases and also of liquids, and in recent years has received practically a direct and concrete proof from the study of a very interesting phenomenon included under the name "Brownian motion." The English botanist, Brown, in 1827 discovered that small vegetable spores immersed in a liquid appeared to be in continuous motion when viewed with a high-power microscope. This motion of small particles in liquids was at first supposed to be a result of temperature disturbances, but at the close of the last century the Brownian movement was shown to be a fundamental property of small particles in liquids. The whole question has been investigated in recent years with great ability and skill by Perrin. He examined in detail the state of equilibrium and of motion of minute particles in suspension in liquids. The excursions due to the Brownian movements depend mainly on the size of the particles, although influenced to some extent by the nature of the liquid. Small

spheres of the size required can be produced by a variety of methods. One of the simplest used by Perrin is to allow a solution of pure water to pour slowly out of a funnel under an alcoholic solution of gamboge or mastic. An emulsion is formed where the layers meet which consists of a great number of minute spheres. When these particles are viewed in a strong light with a high-power microscope, they all exhibit the characteristic Brownian movement; i. e., the particles dart to and fro in irregular and tumultuous fashion and never appear to be at rest for more than a moment. The motions of these small particles under a microscope irresistibly convey the impression that they are hurled to and fro by the action of mysterious forces resident in the solution. Such a result is to be anticipated if the molecules of the liquid are themselves in rapid though invisible tumultuous motion of the kind outlined on the kinetic theory. The particle is very large compared with the molecule, and it is bombarded on all sides by great numbers of molecules. Occasionally the pressure due to the bombardment is for a moment greater on one side of the particle than on the other, and the particle is urged forward, until a new distribution of impacts hurls it in another direction. In fact, the movement of these particles has been found to conform exactly with that predicted by the molecular theory.

It would take too long to discuss the remarkable conclusions that Perrin has reached from a study of the distribution and motion of small particles. The particle which may be an agglomeration of many millions of molecules behaves in many respects like the much smaller molecule. A great number of particles in a liquid do not distribute themselves uniformly under gravity, but the numbers decrease with height according to the same law as the gases in our atmosphere.

On the kinetic theory we thus have strong evidence for believing that the atoms of matter, whether in the solid, liquid, or gaseous form, are in continuous agitation and irregular motion. The velocity of agitation decreases with lowering of temperature, and at the lowest attainable temperature the motion has either ceased or become very small.

It is well known that under suitable conditions the same type of matter can exist in three distinct forms—solid, liquid, and gas. If we take the ordinary air of the room, it can be turned into a clear liquid under certain conditions of temperature and pressure, and this liquid can be frozen solid by still further lowering of the temperature. The most refractory gas of all, helium, has only recently been shown to conform with the behavior of all other gases and to pass into a liquid at a temperature only a few degrees removed from absolute zero. The remarkable changes in appearance

and physical qualities of an element in passing from one state to another is a matter of common knowledge, but it is not for that reason very easy of explanation. These changes are believed to be connected with the average distance which separates one atom or molecule from the other and their rapidity of motion. In the gas or vapor form the molecules are, on an average, so far apart that their mutual attractions are relatively unimportant. With lowering of temperature, the distance and rapidity of motion of the molecules diminish until, under certain conditions, the attraction of the molecules for one another predominates, resulting in a much closer packing and the appearance of the liquid form. The molecules, however, still retain a certain freedom of motion, but this is diminished with lowering of the temperature until at a certain stage the molecules form a tighter grouping, corresponding to the solid state, where the freedom of motion of the individual molecules is much restricted. In order to account for the resistance of solids to compression or extension, it has been supposed that the force between molecules is attractive at large distances, but repulsive at small distances. While we are able to offer a general explanation of the passage of an element from one state to another, a complete explanation of such phenomena will only be possible when we know the detailed structure of the atoms and the nature and magnitude of the forces between them.

While the kinetic theory of gases has proved very successful in explaining the fundamental properties of gases, its strength, and at the same time its weakness, lies in the fact that in most cases it is unnecessary for the explanation to know anything of the structure of the atom or molecule or of the forces between them. In some investigations, in order to explain some of the more recondite properties of gases, assumptions have been made of definite laws of force between the molecules, but no very definite or certain results have so far been achieved in this direction. It should, however, be pointed out that the kinetic theory afforded us for the first time a satisfactory method of estimating approximately the dimensions of molecules and the actual number in a given weight of matter. As the recent development of science has provided us with more certain methods of estimation of these important quantities, we shall not enter further into the question at present.

CRYSTALS.

There is another very striking form that matter sometimes assumes which has always attracted much attention, and which has recently emerged into much prominence. It is well known that the majority of substances under suitable conditions form crystals of

definite geometrical form, which is characteristic of the particular atoms or groups of atoms. The great variety of crystal forms that are known have all been classified as belonging to one or more of the 230 forms of point symmetry which are theoretically possible. While considerations of symmetry are a sufficient guide to the classification of crystals, they offer no explanation of the definite architecture of the crystal nor of the nature of the forces that cause the atoms or molecules to arrange themselves in such definite geometric patterns. We are inevitably led to the conclusion that the atoms of the crystal are arranged according to a definite system, which is characteristic of the particular crystalline form, and the unit of structure is repeated indefinitely with continued growth of the crystal. In fact, if we had no other evidence, the crystalline form of matter would itself point to the necessity of an atomic structure of matter.

While many attempts have been made to explain the grouping of the atoms in a crystal, there has been on the whole little success, with the exception possibly of Pope and Barlow's theory that the atoms take up the positions of closest packing, the dimensions assigned to the atom depending on a quantity connected with its chemical valency. It is only within the last year that a new and powerful method of attack of this problem has been developed, largely through the experiments of Prof. Bragg and his son, W. L. Bragg. On account of the definite ordering of the atoms in a crystal, it acts like an almost perfect optical grating, only in three dimensions, where the grating space is exceedingly small—in most cases about one one-hundred-millionth of a centimeter. Laue showed that when Röntgen rays passed through a crystal definite interference patterns were observed. This result was of great importance, as it showed that Röntgen rays must consist of very short transverse waves akin to those of light. Bragg showed that the reflection, or rather diffraction, of Röntgen rays incident on the face of a crystal afforded a very simple method of determining the wave length of the bright lines generally present in an X-ray spectrum. By a study of the position and intensity of the spectra in different orders thrown by the crystal it was possible to examine in detail the structure of the crystal, and to deduce the grating space, i. e., the distance between successive planes of atoms. The subject is so large and the discovery of this method so recent that so far only a few of the typical crystals have been examined, but in these cases we are able to obtain most positive evidence of the grouping of the atoms in the crystal. The results indicate that the atom and not the molecule is the unit of the crystal structure. Consider the structure of the simple cubic crystal of rock salt (sodium chloride). The structure of the crystal deduced by Bragg is shown in figure 1. The sodium atoms are marked by black spheres, the

chlorine atoms by white spheres. The simplicity of the crystal architecture is obvious, for all the atoms are equidistant. The structure of the diamond is more complicated, but it is one of great interest, for all the atoms in these cases are of one kind, carbon. The structure found by Bragg in seen in plate 1, figure 2. The atoms are all equidistant, but the general arrangement differs markedly from that of rock salt. It is seen that each carbon atom is linked with four neighbors in a perfectly symmetrical way, while the linking of six carbon atoms in a ring is also obvious from the figure. The distance between the plates containing atoms is seen to alternate in the ratio 1:3. This variation of the grating space is brought out clearly from the study of the spectra, and is an essential feature of the structure of the diamond. The cubical arrangement is shown by turning the model so that the lines joining the atoms are vertical and horizontal (pl. 1, fig. 1).

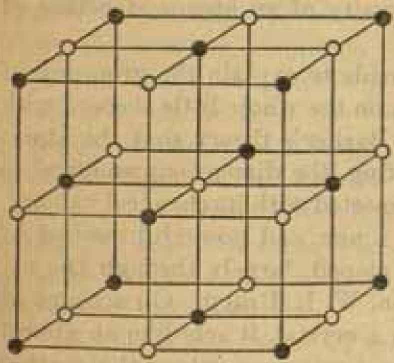
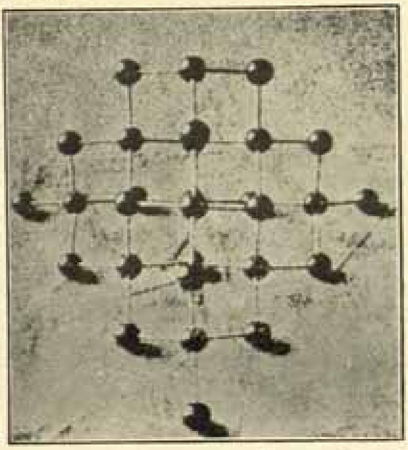


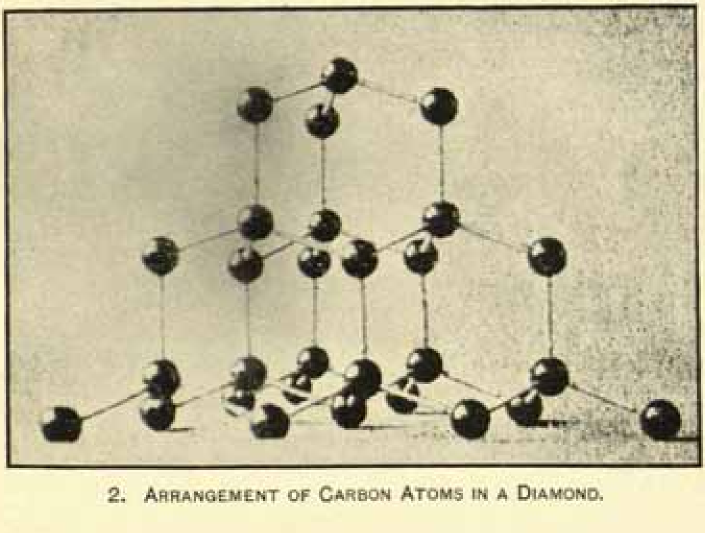
FIG. 1.—Arrangement of atoms in a rock salt (NaCl) crystal. White circles represent sodium atoms; black, chlorine.

Now that we have a method of determining the arrangement and distances apart of the atoms in a crystal, the next step will be to examine the intensity and type of forces which are brought into play to keep the atoms in equilibrium and relatively fixed in their places. It is to be expected that the atoms are able to move to and fro about their position of equilibrium, and this is indicated by the effect of lowering the temperature of the crystal, for the intensity of the diffraction spectra increases as the amplitude of motion of the atom diminishes. The sharpness of the diffraction spectra suggests that the atoms are not only arranged at definite distances from one another, but that each atom is orientated in a definite position with regard to its neighbor.

While varieties of crystals are known of all degrees of hardness, the work of Lehmann has brought to light the unexpected existence of crystalline arrangement in some liquids. These liquid crystals are best shown in certain complex organic substances at a temperature slightly above their melting point, and they are only observable in the liquid by the patterns and colors developed when polarized light passes through them. These crystals are mobile, like a drop of oil in a solution, and can be squeezed into a variety of patterns. Such results would indicate that the molecules of the liquid have a tendency to arrange themselves in ordered patterns, although it is difficult to understand how the freedom of relative motion that



1. CUBICAL ARRANGEMENT OF CARBON ATOMS IN A DIAMOND.



2. ARRANGEMENT OF CARBON ATOMS IN A DIAMOND.

is supposed to characterize a liquid can contemporaneously exist with an ordered arrangement of some of the constituent molecules.

LIGHT SPECTRA.

We will now direct our attention to another type of phenomenon which ultimately promises to throw much light on the detailed structure of the atom. When the light from an incandescent vapor or gas is passed through a prism or reflected from a grating it is resolved and gives a characteristic spectrum consisting of a number of bright lines. By suitable methods, the wave length of these radiations can be determined with great accuracy. Each of these lines represents a definite and characteristic mode of vibration of the atom, and from the exceeding complexity of the spectra of many of the heavy elements we are forced to conclude that an atom can vibrate in a great variety of ways. When the meaning of the dark lines in the solar spectrum was correctly interpreted we were enabled at one stride to extend our methods of observation to the sun and the farthest fixed stars. It was soon recognized that atoms of the same element always vibrated the same way under all conditions. It was found, for example, that hydrogen atoms in the earth vibrated in exactly the same way as the same atoms in a distant star. The important bearing of this result on the structure of atoms was pointed out by Clerk Maxwell, in his well-known address on Atoms and Molecules, before the British Association, at Bradford, in 1873, from which it is interesting to quote the following:

> In the heavens we discover by their light, and by their light alone, stars so distant from each other that no material thing can ever have passed from one to another; and yet this light, which is to us, the sole evidence of the existence of these distant worlds, tells us also that each of them is built up of molecules of the same kinds as those which we find on earth. A molecule of hydrogen, for example, whether in Sirius or in Arcturus, executes its vibrations in precisely the same time. Each molecule,[1] therefore, throughout the universe bears impressed upon it the stamp of a metric system as distinctly as does the meter of the archives at Paris, or the double royal cubit of the temple of Karnac.
>
> No theory of evolution can be formed to account for the similarity of molecules, for evolution necessarily implies continuous change, and the molecule is incapable of growth or decay, of generation or destruction.
>
> None of the processes of nature, since the time when nature began, have produced the slightest difference in the properties of any molecule. We are therefore unable to ascribe either the existence of the molecules or the identity of their properties to any of the causes which we call natural.
>
> On the other hand, the exact equality of each molecule to all others of the same kind gives it, as Sir John Herschel has well said, the essential character of a manufactured article, and precludes the idea of its being eternal and self-existent.

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[1] Maxwell used the term "molecule" where we now use the term "atom."

While there is no doubt that an atom of an element in the earth or in a star vibrates in identical fashion under the same physical conditions, it is now known that the frequency of vibration of an element is not the exact constant that was at first supposed. It is altered to a slight extent by motion of the source, by change of pressure, and by the application of magnetic and electric fields. The apparent change of frequency of vibration with the motion of the source relative to the observer has proved an invaluable method for studying the motion of stars in the line of sight, while the displacement of the lines of hydrogen in the sun has, in the hands of Prof. Hale and his assistants proved of great power in throwing light on some of the physical conditions that exist in that distant body. It has been found that there is order and system in the great complex of modes of vibration of an atom, and that many of the lines can be arranged in definite series whose rates of vibration are connected by simple and definite laws. It is only within the last year or two that we have been able to form some idea of the origin of these spectra and the meaning of a spectral series. The fact that the lightest and presumably the simplest atom known, viz, hydrogen, gives a very complicated light spectrum was at first, and quite naturally, believed to indicate that the hydrogen atom must be a very complex structure. We shall see later, however, that the hydrogen atom is believed to have an exceedingly simple structure, and that the complexity of the spectrum is to be ascribed rather to a complexity in the laws of radiation.

We have seen that the study of the spectrum led Maxwell to conclude not only that the atoms were identical in weight and form but that they were the only permanent and indestructible units in this changing world. The apparent identity of the spectrum under all conditions certainly strongly supported such a view at that time. It was believed that if some of the atoms were changing, it would be shown by a *gradual* alteration of their modes of vibration, i. e., of the spectrum. It was left to the beginning of this century to show the fallacy in this deduction, and to bring undoubted evidence that some elements at least are undergoing spontaneous transformation with the appearance of new types of matter giving a new and characteristic spectrum. This question will be discussed later in some detail.

ELECTRONS.

Before, however, considering the bearing of radioactive phenomena on the structure of the atom I must refer to a discovery which has exercised a most profound influence on the development of physics in general and on our ideas of the structure of atoms. Sir William Crookes long ago found that when an electric discharge was passed

through a vacuum tube at very low pressures a peculiar type of radiation appeared, known as the cathode rays. This radiation appeared to be projected from the cathode in straight lines and, unlike light, was deflected by a magnet. These rays excited strong phosphorescence in many substances in which they fell and also produced marked heating effects. Crookes concluded that the cathode rays consisted of a stream of negatively charged particles moving at high speed. The general properties of this radiation appeared so remarkable that Crookes concluded that the material constituting the cathode stream corresponded to a "new or fourth state of matter." After a controversy extending over 20 years the true nature of these rays was finally independently shown in 1897 by the experiments of Weichert and Sir J. J. Thomson. They proved, as Crookes had surmised, that the rays consisted of a stream of negatively charged particles traveling with enormous velocities from 10,000 to 100,000 miles a second, depending on the potential applied to the vacuum tube. In addition, it was found that the mass of the particle was exceedingly small, about one eighteen-hundredth of the mass of the hydrogen atom, the lightest atom known to science. These results were soon confirmed and widely extended. These corpuscles, or electrons, as they are now termed, were found to be liberated from matter not only in an electric discharge but by a variety of other agencies: For example, from a metal on which ultra-violet light falls and also in enormous numbers from an incandescent body. Radium and other radioactive substances were found to emit them spontaneously at much greater speeds than those observed in a vacuum tube. It thus appeared that the electrons must be a constituent of the atoms of matter and could be released from the atom by a variety of agencies. This idea was much widened and strengthened by the investigations of Zeeman and Lorentz, who showed that the radiation of light must be mainly ascribed to the movements of electrons of the same small mass within the atom.

It does not fall within the scope of my address to outline the very important consequences that followed in many directions from this fundamental discovery of the independent existence of the electron and its connection with matter. It was found by Kaufmann that the mass of the electron was not a constant, but increased with its speed, and from this result it was deduced that the electron was an atom of disembodied or condensed electricity occupying an exceedingly small volume whose mass was entirely electrical in origin.

UNIT OF ELECTRICITY.

I should mention here one important consequence that has followed from these discoveries. From the laws which control the passage of electricity in conducting solutions, Faraday recognized

that there must be a close connection between the atom of matter and its electrical charge. Maxwell and Helmholtz suggested that the results were simply explained by supposing that electricity was atomic in nature. This conclusion is now definitely established, and the positive charge carried by the hydrogen atoms in the electrolysis of water is believed to be the fundamental unit of electrical charge. This charge is equal to and opposite to the charge carried by the electron. Any charge of electricity, however small or large, must be expressed by an integral multiple of this fundamental unit of electricity. The actual value of this unit charge has been measured by a great variety of methods and concordant results. One of the most detailed and accurate investigations of this important constant has been made by Prof. Millikan, of the University of Chicago.

OBJECTIONS TO ATOMIC THEORY.

We have so far implicitly assumed that the great majority of scientific men now regard the atomic theory not only as a working hypothesis of great value but as affording a correct description of one stage of the subdivision of matter. While this is undoubtedly the case to-day, it is of interest to recall that less than 20 years ago there was a revolt by a limited number of scientific men against the domination of the atomic theory in chemistry. The followers of this school considered that the atomic theory should be regarded as a mere hypothesis, which was of necessity unverifiable by direct experiment, and should, therefore, not be employed as a basis of explanation of chemistry. This point of view was much strengthened by the recognition of the power of thermodynamics in affording a quantitative explanation of the changes of energy in chemical reactions without the assumption of any definite theory of the constitution of matter. This tendency advanced so far that textbooks of chemistry were written in which the word atom or molecule was taboo, and chemistry was based instead on the law of combination in multiple proportion. At that time it did undoubtedly appear that there was little if any hope of finding a concrete proof of the validity of the atomic hypothesis or of detecting by its effects a single atom of matter or a single electron, for it was known that the smallest fragment of matter visible under a high-power microscope must still contain many millions, or even billions, of atoms.

The march of science has, however, been so rapid in this direction that we have been able in recent years to show in a definite and concrete way the independent existence of atoms and also of electrons in rapid motion.

COUNTING ATOMS AND ELECTRONS.

We shall, first of all, consider the method devised by Rutherford and Geiger for detecting and recording the effects of single alpha particles from radium. At this stage it is unnecessary to enter into details of the nature of the transformations occurring in radioactive matter. It suffices to say here that the atoms of a radioactive substance are unstable and occasionally break up with explosive violence. In many cases the explosion is accompanied by the ejection of a charged body, called the alpha particle, with a velocity of about 10,000 miles a second. These alpha particles are known, from other investigations, to consist of charged atoms of the rare gas, helium. The presence of these rays is simply shown by the marked phosphorescence they set up in certain substances. I have here a fine glass tube, which was filled about a week ago in Manchester with purified emanation released from about one-fifth of a gram of pure radium. In the interval of its journey across the Atlantic the activity of the emanation has decayed to about one-quarter of its original value. The glass walls of the tube are made so thin (about one one-hundredth millimeter) that the alpha rays are able to escape freely into the surrounding air. They produce a small phosphorescence in the walls of the glass tube, which is just visible in the darkened room. On bringing near, however, a screen covered with zinc sulphide, a brilliant phosphorescence is observed, which increases in intensity as we approach the tube. Similar effects are seen to be produced in this crystal of willemite, while the crystal of kunzite is seen to be translucent and emit a ruddy light. This phosphorescence of zinc sulphide and willemite is due mainly to the alpha rays, and from the present emanation tube about 5,000,000,000 of these particles are projected each second.

In their passage through air or other gas the alpha particles produce from the neutral molecules a large number of negatively charged particles called ions. The ionization due to the alpha particles can be readily measured by electrical methods, and it can be shown that the effect to be expected from a single alpha particle is much too small to detect except by very refined methods. In order to overcome this difficulty Rutherford and Geiger employed a method of magnifying automatically several thousand times the electric effect due to an alpha particle. The general arrangement of the original apparatus is seen in figure 2.

A few of the alpha rays from a radioactive substance passed along an exhausted tube E through an opening D covered with thin mica into the detecting tube A B. The latter contained a central insulated electrode B connected with an electrometer, and the pres-

sure of the gas inside was adjusted to a few centimeters of mercury. The tube B was connected with the negative pole of a battery of about 1,500 volts, the other pole being earthed. The potential was adjusted so that a spark was on the point of passing between A and B. Under such conditions the ionization due to an alpha particle passing along the detecting vessel is magnified several thousand times by collision of the negative and positive ions with the neutral molecules.

The entrance of an alpha particle into the detecting vessel is then signified by a sudden *ballistic* throw of the electrometer needle, and the number of particles entering the vessel in a given time can

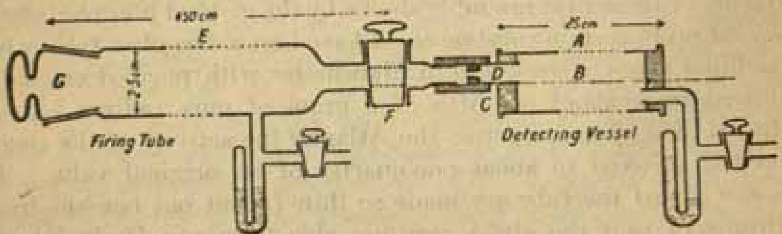


FIG. 2.—Apparatus for counting alpha particles.

be counted by observing the throws. The amount of active matter and its distance from the opening were adjusted so that 3 to 5 alpha particles entered the opening per minute. The following table illustrates the results obtained:

	Number of throws.	Magnitude of successive throws, scale divisions.
First minute	4	11, 12, 10, 11.
Second minute	3	10, 11, 8.
Third minute	5	10, 9, 13, 8, 12.
Fourth minute	4	18*, 8, 12.
Fifth minute	3	10, 6, 10.
Sixth minute	4	9, 10, 12, 11.
Seventh minute	2	10, 11.
Eighth minute	3	11, 13, 8.
Ninth minute	3	8, 20*.
Tenth minute	4	8, 12, 14, 6.
Average per minute	3.5	
Average throw (divisions)		10.

It will be seen that the number of throws varies from minute to minute. This is to be expected, since the chance of an alpha particle entering the opening is governed by the ordinary laws of probability. It will be seen that two throws, marked by asterisks, are much larger than the others. These were due to the passage of two

alpha particles through the opening within a short interval. This was readily seen from the motion of the spot of light reflected from the electrometer needle. As the needle was moving slowly near the end of its swing, caused by one alpha particle, a second impulse due to the entrance of another was communicated to it.

By this method the number of alpha particles expelled from one gram of radium per second was determined. Of course only a minute fraction of the alpha particles was actually counted, but the total number was deduced on the assumption, verified by experiment, that the alpha particles on an average were expelled equally in all directions. In this way, 1 gram of radium in equilibrium was found to expel the enormous number of 1.36×10^{11} alpha particles each second.

Another interesting result followed from these experiments. It has long been known that the alpha particles produce a marked phosphorescence in crystalline zinc sulphide. When examined by a lens, the light is found not to be uniform, but exhibits a very beautiful scintillating effect. By counting the number of scintillations due to the alpha particles it was found that each scintillation was produced by the impact of a single alpha particle. It is thus seen that two distinct methods, one electrical and the other optical, are available for detecting and counting single alpha particles, i. e., single atoms of matter. This is only possible because the atoms are in swift motion and expend their great energy of motion in ionizing the gas or in producing luminosity in zinc sulphide.

Still another simple method was devised later. Kinoshita first showed that a single alpha particle produced a detectable effect on a photographic plate which was observable under a microscope. A number of experiments have been made by Reinganum, Makower, and Kinoshita to examine the effect of single alpha particles on a photographic plate. If a fine needle point coated with a trace of radioactive matter rests on the surface of the film, the plate on development shows a number of distinct trails radiating from the active point. Each of these trails results from the action of a single alpha particle. A beautiful photograph of this kind (magnification about 300) obtained by Kinoshita is shown in plate 2, figure 1. It appears that each alpha particle makes a certain number of the grains, through which it passes, capable of development.

The use of an ordinary electrometer is not very suitable for counting alpha particles by the electric method, since the time of swing of the electrometer needle is fairly long, and accurate counting can be made when only a few alpha particles enter the detecting vessel per minute. This difficulty can be got over by the use of a string electrometer in which the moving system consists of a fine silvered quartz fiber suspended between two charged parallel plates and

viewed with a high-power microscope. The entrance of an alpha particle is shown by a sudden movement of the fiber, and if the current is allowed to leak away through a suitable resistance, the fiber returns to the position of rest in a small fraction of a second. The movement of the fiber can be recorded photographically on a moving film, and it is possible in this way to count accurately the number of particles, even if several thousand enter the detecting vessel per minute.

Examples of such photographic records, obtained by Rutherford and Geiger, are shown in plate 2, figure 2. The vertical movements of the fiber from the horizontal line are due to the entrance of alpha particles, and it is seen how clearly the detailed movements of the fiber are registered. In some cases one alpha particle follows another so rapidly that the fiber has not time to come to rest in between, and this is shown by the sawlike appearance of some of the peaks in the photograph. It will be noticed also that while the heights of most

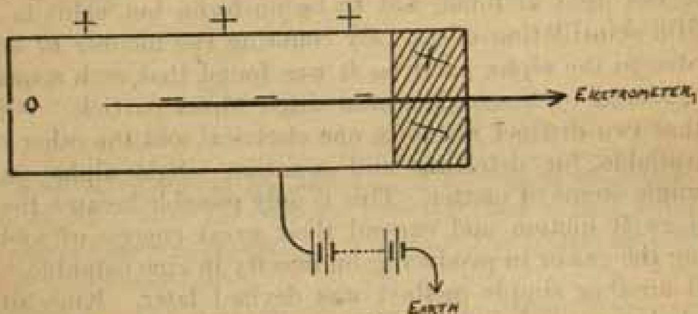


FIG. 3.—Geiger's detector of individual alpha and beta particles.

of the deflections are nearly the same, in a few cases the deflections are nearly twice as great as the normal. This is due to the nearly simultaneous entrance of two alpha particles into the vessel. Although the photographic film moved at a constant rate, it is seen that the throws due to the alpha particles are distributed very irregularly along it. A close examination of such records shows that variations of this kind are in accord with the ordinary laws of probability.

During this year, Dr. Geiger has found a still more sensitive detector for counting alpha particles. The arrangement, which is very simple, is shown in figure 3. A fine sharply pointed needle ends about 1 centimeter from the opening O, where the alpha particles enter. If the outer brass tube be charged positively to about 1,000 volts, and the needle connected with a string electrometer, it is found that the entrance of an alpha particle produces a very great deflection of the fiber. So sensitive is this method that Geiger has found that individual beta particles can easily be detected and counted by

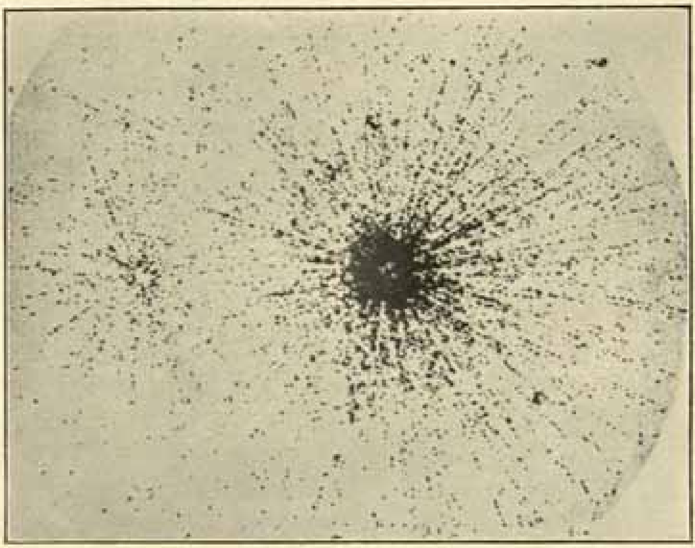
its aid. This is very remarkable when it is remembered that the ionization effect due to a beta particle is on the average not more than one one-hundredth of that due to an alpha particle.

A photographic record of the entrance of beta particles into the detecting vessel is shown in plate 2, figure 3. The upper record is for beta particles and the lower for alpha particles. I am indebted to Dr. Geiger for this photograph. It is seen that the effect of a beta particle is just as marked and as definite as for an alpha particle with the old form of detector. We are thus in a position not only to count single atoms of matter, but also to detect the presence of a single electron in swift motion, although the mass of the latter is exceedingly small compared with that of the lightest atom.

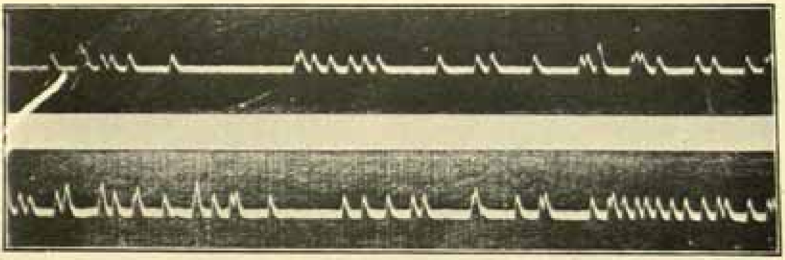
I would now very briefly direct your attention to some results which to my mind not only completely prove the hypothesis of the atomic structure of matter, but allow us at once to calculate the number of atoms in a given weight of matter with the minimum amount of assumption. We have seen that by direct counting it has been found that 1.36×10^{11} alpha particles are expelled per second from 1 gram of radium in equilibrium with its rapidly changing products. Now, it has been definitely shown by methods I need not discuss here that each alpha particle consists of a helium atom carrying two unit positive charges. Since the alpha particle, when it has lost its charge, becomes a neutral helium atom we should expect to find that helium would be produced by radium at a definite rate. This is found to be the case, and it is not difficult to determine by actual measurement the volume of helium formed by a known quantity of radium in a given time. It has been found that one gram of radium in equilibrium produces each year 156 cubic millimeters of helium at standard pressure and temperature. Now, the number of alpha particles expelled per year per gram is 4.29×10^{18}, giving rise to 156 cubic millimeters of helium, each of these alpha particles is an atom of helium, and consequently the number of atoms of helium in 1 cubic centimeter of that gas at normal pressure and temperature is 2.75×10^{19}.

It appears to me that no more direct and convincing proof could be obtained of the atomic structure of matter or of the number of atoms forming a given weight or volume of helium, for the number of separate constituents are counted and the volume of the resulting gas is measured. The value so obtained is in good accord with measurements based on entirely different data of various kinds.

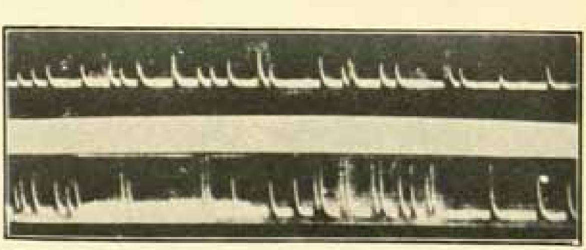
It is somewhat remarkable that while the study of radioactive phenomena has clearly indicated that the atom is not always permanent and indestructible, it has at the same time supplied the most convincing proof of the actual reality of atoms and has pro-



1. PHOTOGRAPHIC EFFECT DUE TO ALPHA PARTICLES FROM A CENTRAL POINT.



2. PHOTOGRAPHIC RECORD ON STRING ELECTROMETER OF ENTRANCE OF ALPHA PARTICLES INTO THE DETECTING VESSEL.



3. RECORD WITH STRING ELECTROMETER; UPPER RECORD FOR BETA PARTICLES, LOWER FOR ALPHA PARTICLES.

vided some of the most direct methods of determining the values of atomic magnitudes.

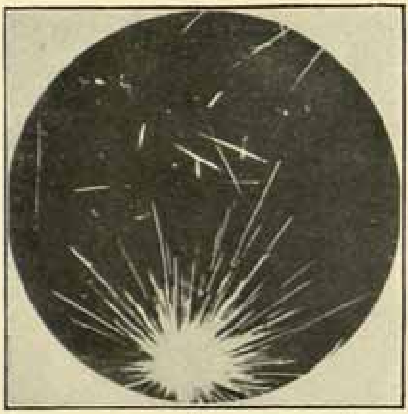
TRACKS OF SWIFT ATOMS AND ELECTRONS.

We have seen how it is possible to detect single alpha and beta particles and to count their number. We will next consider a most remarkable experimental method, not only for detecting such particles but of following in detail the effects produced by them in their passage through a gas. C. T. R. Wilson showed many years ago that the positively and negatively charged ions produced in a gas by the passage of alpha and beta and X rays possessed a remarkable property. When air, for example, saturated with water vapor is suddenly expanded the air is rapidly cooled and the water tends to deposit on any nuclei present. C. T. R. Wilson showed that in dust-free air the ions produced by external radiation become nuclei for the condensation of water upon them when the cooling by expansion was sufficiently great. Under such conditions each ion becomes the center of a visible globule of water, and the number of drops formed is equal to the number of ions present.

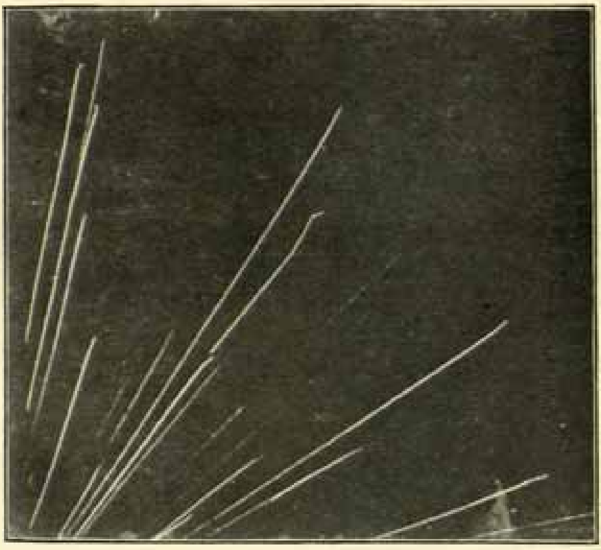
C. T. R. Wilson later perfected this method to show the trail of a single alpha or beta particle in passing through the gas; for each of the ions produced by the flying particle becomes a visible drop of water by the sudden expansion. By suitable arrangements the trails of the individual particle can be photographed, and the pictures obtained show with remarkable fidelity and detail the ionizing effects produced in the passage of alpha and beta particles or X rays through gases.

Plate 3, figure 1, shows the tracks of the alpha particles shot out from a small fragment of radium. The number of ions produced per centimeter in the gas by the alpha particle is so great that the trail of drops shows as a continuous line. The alpha particles are seen to radiate in straight lines from the active point and have a definite range in air—a characteristic property discovered by Bragg many years ago. The next photograph (pl. 3, fig. 2) shows a magnified image of these trails. It is seen that the tracks are generally quite straight, but in a few cases there is a sudden bend near the end. The significance and causes of these sudden deviations in the rectilinear paths of the alpha particles will be discussed later.

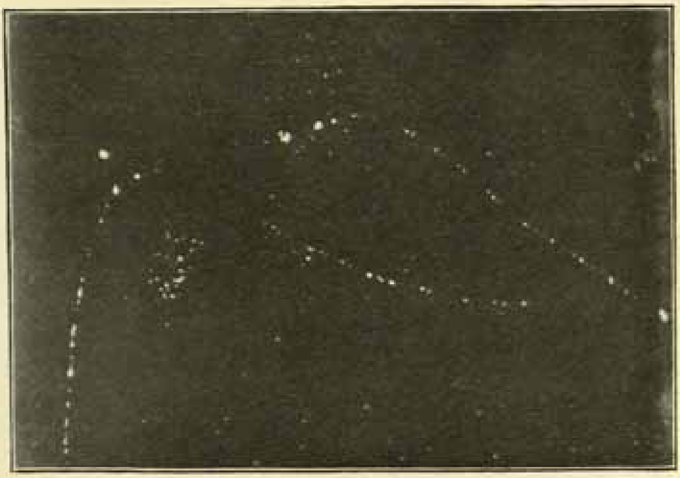
A radioactive substance like radium emits not only alpha particles but beta particles which are electrons in very swift motion. These beta particles are generally far more penetrating than the alpha rays, but produce a much smaller number of ions per centimeter of their path through a gas. In plate 4, figure 1, is seen the track of a swift beta particle crossing the expansion chamber. It will be observed that the path is not straight but tortuous, due to the marked



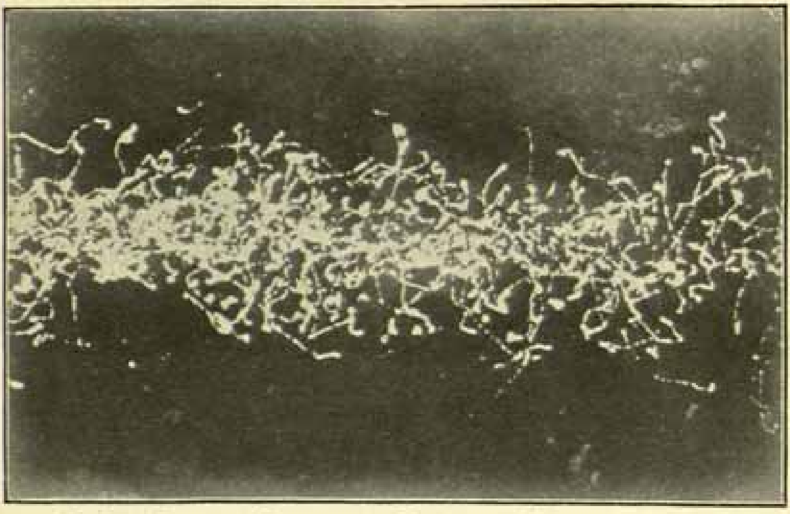
1. TRACKS OF ALPHA PARTICLES FROM CENTRAL POINTS (C. T. R. WILSON'S METHOD).



2. MAGNIFIED TRACK OF ALPHA PARTICLES (WILSON).



1. TRACKS OF BETA PARTICLES.



2. BETA PARTICLES PRODUCED BY PASSAGE OF X RAYS THROUGH AIR (WILSON).

scattering of the particle by collisions with the atoms of matter in its path. Although the trail is clearly defined, the density corresponding to the number of drops per centimeter is much smaller than for the alpha particle. In fact, by magnifying still further small portions of the track the individual ions, or rather the drop formed around each ion produced by the beta particle, are clearly visible. In this way it is obviously possible to count directly the number of ions produced in any length of the path.

These beautiful photographs thus not only bring out clearly that alpha and beta particles are definite entities but show with great perfection the actual path of the particles in traversing matter. The next photograph (pl. 4, fig. 2) shows the effect of passing a pencil of Röntgen rays through the expansion chamber. It is believed that these rays do not ionize the gas directly, but indirectly, through the slow speed electrons which are liberated by some of the atoms acted on by the radiation. These electrons are not nearly so swift as some of those emitted by radium, for they are only able to traverse a few millimeters of air before being stopped. The photograph brings out clearly these effects and shows the tortuous path of a beta particle resulting from collisions with the atoms. Such scattering effects become more marked the slower the velocity of ejection of the beta particle.

TRANSFORMATION OF MATTER.

While the discovery of the independent existence of the electron as a constituent of the structure of atoms gave a great impetus to the study of atomic structure, it was soon found that the removal or addition of an electron from an atom did not appear to cause a permanent transformation of the atom, for no evidence has yet been obtained that the passage of an electric current through a gas or metal is accompanied by a permanent alteration of the atoms of matter through which the current passes, although there is little doubt the current is carried in part at least by the electrons liberated from the atoms.

The first definite evidence of the transformation of matter was obtained from a study of the processes occurring in radioactive substances. The writer and Mr. Soddy in 1903 put forward the theory that the radiations from active matter accompanied a veritable transformation of the atoms themselves. The correctness of this theory as an explanation of radioactive phenomena is now generally accepted. As an illustration of these processes, consider the transformation of the radioactive element uranium. The series of substances which arise from the transformation of uranium are shown clearly in the diagram (fig. 4). The best known of these elements is radium, which will be taken as a typical example of a

radioactive substance. Radium differs from an ordinary element in its power of spontaneously expelling alpha particles with very great speed. This property is ascribed to an inherent instability which is not manifest in the atoms of ordinary elements. A small fraction of the radium atoms—about 1 in 100,000,000,000—break up each second with explosive violence, expelling a fragment of the atom (the alpha particle) with very great speed. The residue of the atom is lighter than before and becomes the atom of an entirely new substance, which is called the radium emanation. The atoms of the latter are far more unstable than those of radium, for half of them break up in 3.85 days, while half of the radium atoms break up in about 2,000 years. After the loss of an alpha particle an atom of the emanation changes into an atom of a new substance (radium A), which behaves as a solid.

Radium A is very unstable, half of it breaking up in 3 minutes with the emission of an alpha particle, and gives rise to radium B. The latter differs from the substances already mentioned in the nature of its radiation, for it emits beta rays but no alpha rays. Notwithstanding this fact, it is transformed according to the same law as an alpha ray's substance, and gives rise to an entirely distinct element, radium C. In the transformation of the latter, not only are swift alpha rays emitted but also beta rays of great speed. There is some evidence, however, that the substance called radium C is complex, and that the alpha and beta rays arise from two distinct substances.

The successive substances arising from radium C are radium D, radium E, and radium F. The two former, like radium B, emit only beta rays; the latter, known generally as polonium, emits only alpha rays. It is believed that the sequence of changes ends with the transformation of radium F, which is supposed to change into the well known nonradioactive element lead.

According to the transformation theory, radium, like all other radioactive products, must be regarded as a changing element, but one whose rate of transformation is very slow compared with its successive products. Boltwood showed experimentally that radium is half transformed in about 2,000 years, and a quantity of radium would practically have disappeared as such in 100,000 years. In order to account for the continued existence of radium in the earth, it is necessary to suppose that it is steadily produced from some other element. Boltwood showed that the parent substance is a radioactive element called ionium, which is itself derived from the transformation of uranium. A quantity of ionium, entirely freed from radium, will grow radium at a slow but constant rate. The primary element of the ionium-radium series is uranium, which we can calculate should be half transformed in 5,000,000,000 years—a

period probably long compared with the age of many of the minerals in which uranium is found.

The complete sequence of changes in the uranium-radium series is shown in the diagram (fig. 4). The nature of the radiation and the half period of transformation is added for each element. In addition to uranium, there are two other radioactive elements, thorium and actinium, which are transformed with the appearance of a number of new substances. The time at my disposal, however, is too short to discuss these changes in detail. Thorium is known to be a primary element whose radioactive life is even longer than uranium, but actinium is believed to be a branch descendant from some point of the uranium series, and is thus to be regarded as a product of that element. In all, 34 of these radioactive substances have been

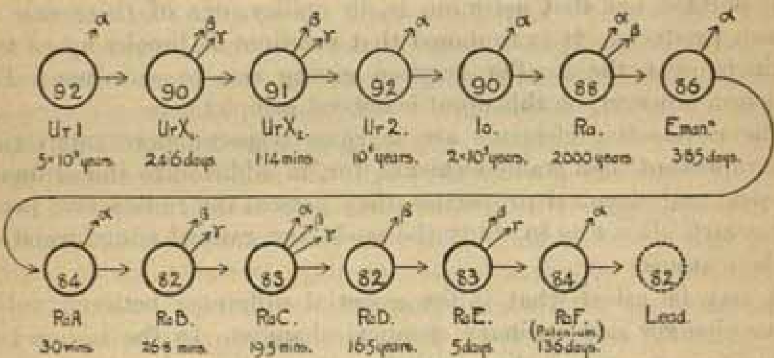


FIG. 4.—Successive substances produced by the transformation of the uranium atom.

discovered, and the position of each in the three main radioactive series has been determined.

Each of these new substances is to be regarded as a distinct chemical element in the ordinary sense, but differs from ordinary stable elements in the spontaneous emission of special radiations which accompanies the disintegration of the atoms. The radioactive substances are thus transition elements which have a limited life and which carry within themselves the seeds of their own destruction. Not only are these transition elements distinguished by their types of radiation but also by their distinct physical and chemical properties. The extraordinary differences in properties which sometimes exist between a product and its parent substance is well illustrated by the comparison of radium and its product, the emanation. Radium is a solid element of atomic weight, 226, which has chemical properties allied to barium, but is capable of separation from it. The emanation is a heavy monatomic gas of atomic weight, 222, which, by its absence of chemical properties, is allied to the well-known group of rare gases—helium, argon, neon, xenon, and krypton. In some cases the elements show almost identical physical and chemical prop-

erties with those of known elements, although they differ from them in their atomic weight and radioactivity. For example, radium B appears to be identical in ordinary chemical and physical properties with lead, although its atomic weight, 214, is quite distinct from lead, 207. The probable explanation of this, at first sight, remarkable identity will be discussed later.

It is of interest to note that in the majority of cases a radioactive element breaks up in only one way, which is characteristic for all the atoms of that element and gives rise to only one new product. The work of Fajans and Marsden, however, has clearly shown that in the case of radium C and the corresponding products in the thorium and actinium series, the atoms break up in two distinct ways and give rise to two distinct radioactive elements. It has already been pointed out that actinium is, in reality, one of these side or branch products. It is supposed that uranium X breaks up in two distinct ways, the smaller fraction giving rise to actinium. The evidence, however, on this point is not yet complete.

The radioactive elements are in some respects more interesting and important than stable elements, for, in addition to the ordinary physical and chemical properties, they possess the radioactive property which allows us to study the mode and rate of transformation of their atoms.

It may be asked what is the essential difference between radioactive changes and ordinary chemical changes. In the radioactive changes we are not dealing with the dissociation of molecules into atoms, but an actual disruption of the chemical atom. The disintegration of any given element appears to be a spontaneous and uncontrollable process which, unlike ordinary chemical changes, is quite unaffected by the most drastic changes in temperature or by any other known physical or chemical agency.

The radioactive changes differ entirely from chemical changes not only in the peculiar character of the emitted radiations, but also in the enormous emission of energy. It can be simply shown that the energy emitted from a radioactive substance which expels alpha particles is several million times greater than the energy emitted from an equal weight of matter in any known chemical reaction. This emission of energy is mainly to be ascribed to the conversion of the energy of motion of the swift alpha and beta particles into heat, and is thus in a sense a secondary effect of the radiations. The enormous emission of energy is most simply illustrated by considering the case of the radium emanation, together with its swiftly changing products radium A, radium B, and radium C. The heating effect of a given volume or weight of this gas has been accurately determined. From the data it can be calculated that 1 pound weight of the emanation would emit heat energy initially at the

rate of 23,000 horsepower. The rate of emission decreases with the time, falling successively to half value after intervals of 3.85 days. During the life of the emanation the total energy emitted corresponds to an engine working at 128,000 horsepower for one day. Such a quantity of emanation would be an enormously concentrated source of power, for the total energy emitted is many million times greater than for an equal weight of the most powerful known explosive.

The emission of energy from radioactive substances does not controvert the law of the conservation of energy, for the energy is derived from the atom itself where it exists in kinetic or potential form. We shall see later that the atom is believed to consist of a large number of positively and negatively charged particles which are collected in a very small volume and held together by intense electrical forces. Such an idea of atomic structure involves the necessity of a large store of energy resident in the individual atom. The great emission of energy from a radioactive substance like the emanation illustrates in a striking way the enormous reservoir of energy that must exist in the atoms themselves, for there is every reason to believe that an equivalent amount of energy is present in the atoms of the common heavy elements. This store of energy ordinarily does not manifest itself and is not available for use. It is only when there is a drastic rearrangement of the atom resulting from an atomic explosion that part of this store of energy is liberated.

It must be borne in mind that the processes occurring in radioactive matter are spontaneous and uncontrollable. There is at present no evidence to indicate that we shall be able in any way to influence radioactive changes. We are at present only able to watch and investigate this remarkable phenomenon of nature, without any power of controlling it. In a recent book H. G. Wells has discussed in an interesting way some of the future possibilities if this great reservoir of energy resident in the atoms were made available for the use of man. This will only be possible on a large scale if we are able in some way to alter the rate of radioactive change and to cause a substance like uranium or thorium to give out its energy in the course of a few hours or days instead of over a period of many thousands of millions of years. The possibility, however, of altering the rate of transformation of radioactive matter or of inducing similar effects in ordinary matter does not at present seem at all promising.

STRUCTURE OF THE ATOM.

We have seen that in recent years a number of methods have been devised for determining with precision the actual weight of any atom of matter. If it be assumed that in the solid state the atoms,

or molecules, of matter are in close contact, it is a simple matter to deduce the diameter of the atom. This varies slightly for different atoms, but on an average comes out to be about one one-hundred-millionth of a centimeter. It is necessary, however, to be cautious in speaking of the diameter of the atom. The term "diameter of the sphere of action" of the atom is preferable, for it is not at all certain that the actual atomic structure is nearly so extensive as the region through which the atomic forces are appreciable.

Even before the discovery of the electron the general idea had been suggested that the atom was an electrical structure composed of negatively and positively charged particles held in equilibrium by electrical forces. Such ideas had been proposed and developed by Larmor and Lorentz in order to explain the electrical and optical properties of the atom. The proof that the negative electron was an independent unit of the structure of the atom gave a great impetus to the formation of more concrete ideas on atomic structure. There was one important difficulty, however, that arose at the outset. While negative electricity had been shown to exist in independent units of very small apparent mass, the corresponding unit of positive electricity was never found associated with a mass less than the atom of hydrogen. All attempts to show the existence of a positive electron of small mass, which is a counterpart of the negative electron, have resulted in failure, and it seems doubtful whether such a positive electron exists. The rôle played by positive electricity in the atom was thus a matter of conjecture. In a paper called Aepinus Atomized the late Lord Kelvin considered an atom to consist of a uniform sphere of positive electrification, throughout which negative electricity was distributed in the form of discrete electrons. In order to make such an atom electrically neutral it is, of course, necessary that the positive charge should be equal and opposite to the charge carried by the electrons. This idea of the structure of the atom was taken up and developed with great mathematical skill by Sir J. J. Thomson. He investigated the constitution of atoms containing different numbers of electrons and showed that such model atoms possessed properties very similar to those shown by the actual atoms. The Thomson atom proved for many years very useful in giving a concrete idea of the possible structure of the atom and had the great advantage of being amenable to calculation.

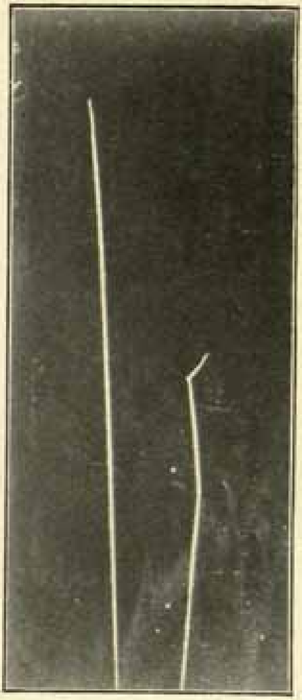
The rapid advance of science in the last decade has provided us with new and powerful methods of attack on this problem, and has allowed us to distinguish to some extent between various theories of atomic structure. One of these methods depends on the study of the deflection of swiftly moving bodies like alpha and beta particles in their passage through matter. It is found that these rays are always scattered in their passage through matter; i. e., a narrow pencil of

rays opens out into a diffuse or scattered beam. The alpha and beta particles move so swiftly that they are actually able to pass through the structure of the atom and are deflected by the intense forces within the atom. Geiger first drew attention to a very unexpected effect with alpha particles. When a pencil of alpha rays falls on a thin film of gold, for example, the great majority of the particles pass through with little absorption. A few, however, are found to be so scattered that they are turned back through an angle of more than a right angle. Taking into consideration the great energy of motion of the alpha particle, such a result is as surprising as it would be to a gunner if an occasional shot at a light target was deflected back toward the gun. It was found that these large deflections must result from an encounter with a single atom. The occasional sudden deflection of an alpha particle is well illustrated in one of the later photographs of the trail of an alpha particle obtained by Mr. C. T. R. Wilson, and shown in plate 5, figure 1. It is seen that the rectilinear path of the particle suffers two sharp bends, no doubt resulting in each case from a single close encounter with an atom. In the sharp bend near the end a slight spur is seen, indicating that the atom was set in such swift motion by the encounter with the alpha particle that it was able to ionize gas at a short distance. If the forces causing the deflection were electrical, it was at once evident that the electric field within the atom must be exceedingly intense. The distribution of positive electricity assumed in the Thomson atom was much too diffuse to produce the intense fields required. To overcome this difficulty the writer inverted the rôle of positive electricity. Instead of being distributed through a sphere comparable in size with the sphere of action of the atom, the positive electricity is supposed to be concentrated in a very minute volume or nucleus, and the greater part of the mass of the atom is supposed to be resident in this nucleus. The latter is supposed to be surrounded by a distribution of negative electrons extending over a distance comparable with the diameter of the atom as ordinarily understood. On this point of view the alpha particle is the minute nucleus of the helium atom, which has lost its two external electrons. In this type of atom the large deviations of the alpha particle take place when it passes through the intense electric field close to the nucleus of the colliding atom. The nearer it passes to the nucleus, the greater the deflection of the particle. Assuming that the forces between the alpha particle and the nucleus of the colliding atom are mainly electrical and vary according to an inverse square law, the alpha particle describes a hyperbolic orbit around the nucleus, and the relative number of alpha particles deflected through different angles can be simply calculated.

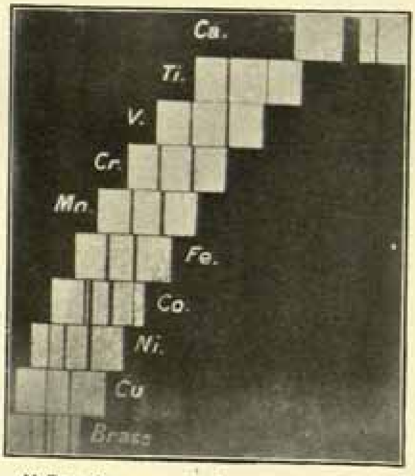
It was thus possible to test this theory of atomic structure by actual experiment. This was undertaken by Geiger and Marsden in

a very important but difficult investigation. They examined the relative number of alpha particles scattered through various angles by their passage through thin films of matter—e. g., aluminum, silver, and gold—by actually counting the alpha particles by means of the scintillations on a zinc sulphide screen. The experimental results were found to be in very good accord with the theory, while Darwin, in addition, showed that any other law of force except the inverse square was incompatible with the observations.

From these results it is a simple matter to show that the radius of the nucleus of the gold atom can not be greater than 3×10^{-12} cm.—an exceedingly small distance and only about one ten-thousandth part of the diameter of the atom. While the results thus indicated that the nucleus of a heavy atom was of minute dimensions, it was of interest to see whether a still lower limit could be obtained for lighter atoms. On this theory, the helium atom has a nucleus of two unit positive charges, and the lighter atom, hydrogen, should have a nucleus of only one unit. When an alpha particle passes through hydrogen gas there should be occasional very close encounters between the particle and nucleus of the hydrogen atom. Since the mass of the hydrogen atom is only one-quarter of that of helium, it is to be anticipated that the former should be set in very swift motion by a close collision with an alpha particle, and in special cases should be given a velocity 1.6 times greater than that of the colliding alpha particle, and should travel four times as far. Such swiftly moving hydrogen nuclei were actually observed by Marsden with the scintillation method when a pencil of alpha rays passed through hydrogen, and they were found to travel, as the theory predicted, about four times farther than the alpha particle itself. Since the energy gained by the hydrogen nucleus depends on the closeness of its approach to the alpha particle, it can be simply calculated that the centers of the nuclei must have passed within 10^{-13} cm. of each other. This is an extraordinarily small distance, even smaller than the diameter of the electron itself. It is thus clear that the nuclei of hydrogen and of helium must be exceedingly minute. It should be borne in mind that such observations only give a maximum limit to the size of the nucleus, and there is no experimental evidence against the view that the nucleus of the hydrogen atom may not actually prove to be minute in volume compared even with the negative electron. If this be the case, it appears probable that the hydrogen nucleus is the *positive electron* and that its great mass, compared with the negative electron, is due to the greater concentration of its charge. According to modern theory the electrical mass of a charged particle varies inversely as its radius. The greater mass of the positive than of the negative electron would thus be explained if its



1. TRACK OF ALPHA PARTICLES SHOWING SHARP DEVIATIONS (WILSON).



2. X-RAY SPECTRA OF SUCCESSIVE ELEMENTS (MOSELEY). THE ADDITIONAL LINES IN SPECTRUM OF CO AND NI ARE DUE TO IMPURITY. BRASS SHOWS THE COMBINED SPECTRA OF COPPER AND ZINC.

radius were only one eighteen-hundredth of that of the negative electron, viz, about 10^{-16} cm.

There is no evidence to contradict this point of view, and its simplicity has much to commend it. In viewing the essential differences exhibited by positive and negative electricity in connection with matter and the obvious asymmetry of the distribution of the two electricities in the atom, one is driven to the conclusion that there is a fundamental distinction between positive and negative electricity. Since the unit of positive charge is identical in magnitude with the unit of negative charge, the only possible difference is the mass of the two units, and this on modern views is mainly dependent on the dimensions or degree of concentration of the electricity in these fundamental entities.

If we take the view that the hydrogen nucleus is the positive electron, it is to be anticipated that the nuclei of all atoms are built up of positive and negative electrons, the positive electricity being always in excess, so that the nucleus shows a resultant positive charge. The mass of the atom will depend mainly on the number of the massive positive electrons in the nucleus, although it will be affected to a slight extent by the number of the lighter negative electrons involved in the structure of the whole atom. The mass of the atom will no doubt be influenced also by the distribution of the positive and negative electrons in the nucleus, for these must be packed so closely together that their field must interact. As Lorentz has shown, the mass of a number of closely packed electrons is not necessarily the same as the sum of individual masses of the component electrons. Taking such factors into account, we should not necessarily expect the mass of all atoms to be nearly an integral multiple of the mass of the hydrogen atom, although it is known that in a number of cases such a relation appears to hold fairly closely.

The appearance of a helium atom in such a fundamental process as the transformation of radioactive atoms indicates that helium is one of the units, possibly secondary, of which the nuclei of the heavy atoms are built up. In course of its successive transformations a uranium atom loses eight helium atoms, a thorium atom six, and an atom of actinium five. The probability that helium is one of the units of atomic structure not only in the case of radioactive atoms but for ordinary atoms is strengthened by the fact that the atomic weights of a number of elements differ by about four units.

The fact that the helium nucleus survives the intense disturbance resulting in its violent ejection from a radioactive atom suggests that it is a very stable configuration. On the views discussed it is natural to suppose that the helium nucleus, of atomic weight about four, is made up of four positive electrons united with two negative electrons. No doubt it is difficult to understand why such a system

should hold together, but it must be remembered that we have no information as to the nature or magnitude of the forces existing at such minute distances as are involved in the structure of the nucleus.

We have so far assumed without proof that while the nucleus of an atom carries a resultant positive charge, negative electrons are also present. The main evidence on this point comes from a study of the radioactive elements. A substance which breaks up with the emission of swift electrons (beta rays), but no alpha particles, suffers disintegration according to the same laws and gives rise to a new element in the same way as when an alpha particle is lost. It seems necessary to suppose from a number of lines of evidence that a transformation which is accompanied by the emission of primary beta particles must have its origin in the ejection of a negative electron from the nucleus itself or from a point very close to the nucleus.

There are no means at present of deciding definitely the relative number of positive and negative units composing the nucleus, except possibly from a consideration of the atomic weight of the atom in terms of hydrogen. It is, however, premature to discuss such questions until more information is obtained as to the structure of the nucleus and the effect of concentration and distribution of the component electrical charges on its apparent mass.

CHARGE CARRIED BY THE NUCLEUS.

We are now in a position to consider a very important question, viz, the magnitude of the positive charge carried by the atomic nucleus. Since an atom is electrically neutral, the negative charge carried by the exterior distribution of electrons in the structure of the atom must be equal and opposite to the resultant positive charge carried by the nucleus. The electrical charge is most conveniently expressed in terms of the number of the fundamental units of charge in the nucleus. Since the charge carried by the electron is one unit, the charge on the nucleus of the atom may be expressed numerically by the number of electrons exterior to the nucleus. Several methods of attack on this problem have been suggested. Sir J. J. Thomson showed that the scattering of Röntgen rays in passing through the atoms of matter must depend on the number of electrons composing the atom. By assuming that each electron scattered is an independent unit, an expression for the scattering was found in terms of the number of electrons in the atom. By comparison of the theory with experiment, Barkla deduced that for many elements the number of electrons in an atom was approximately proportional to its atomic weight and numerically equal to about one-half of the atomic weight in terms of hydrogen.

The charge in the nucleus can also be directly determined from the experiments on scattering of alpha rays, to which attention has previously been drawn. Geiger and Marsden found that the large-angle scattering of alpha rays in passing through different substances was proportional per atom to the square of its atomic weight. This showed that the positive charge on the nucleus was approximately proportional to the atomic weight at any rate for elements of atomic weight varying between aluminium and gold. By measuring the fraction of the total number of alpha particles which were deflected through a definite angle in passing through a known thickness of matter, the charge on the nucleus was deduced directly. The number of positive units of charge on the nucleus, which is equal to the number of external negative electrons, was found to be expressed by about one-half of the atomic weight in terms of hydrogen. The results obtained by two entirely distinct methods of attack are thus in good accord and give approximately the magnitude of this important atomic constant.

It is obvious, however, that the deduction that the number of units of charge on the nucleus is half the atomic weight must be only a first approximation to the truth, even in the case of the heavier atoms. It has already been pointed out that the nucleus of the helium atom of atomic mass four must carry two unit charges, for it is difficult to believe that any of the exterior electrons of helium can remain attached after its violent expulsion from the atom and its subsequent passage through matter. If this be the case, the nucleus of the hydrogen atom of atomic mass one must carry one unit charge. Van den Broek and Bohr have suggested that the charge on the nucleus might be equal to the actual number of the element when all the known elements are arranged in order of increasing atomic weight. This is in excellent accord with the experiments of scattering, and removes a difficulty in regard to the lighter atoms. Taking this view, the nucleus charge is for hydrogen 1, helium 2, lithium 3, carbon 6, oxygen 8, etc. The simplicity of this conception has much to commend it.

During the last year a new and powerful method of attack on this fundamental problem has been developed by Moseley by the study of X-ray spectra. In 1912 Laue found that X rays showed obvious interference or diffraction effects in their passage through crystals, thus proving definitely that the X rays consist of very short waves analogous to those of light. W. H. Bragg and W. L. Bragg and Moseley and Darwin found that the reflection of the X rays from crystals provided a very simple method of measuring the wave length of the X rays when the spacing of the atoms in the crystal is known. If the X rays give a spectrum containing some bright lines,

the wave lengths of the latter can be simply determined. The work of Barkla has shown us that an X radiation, characteristic of each element, is excited under certain conditions when X rays fall upon it. The penetrating power of this characteristic radiation increases rapidly with the atomic weight of the radiator. In heavy elements, another type of characteristic radiation makes its appearance. These two types of characteristic radiation have been called by Barkla the K and L radiations, respectively. These radiations can be excited either by X rays of suitable penetrating power or by direct bombardment of the element by cathode rays in a vacuum tube. Moseley made a systematic examination of the X-ray spectra of a great majority of the elements. For this purpose the elements examined were bombarded by cathode rays, and the spectrum of the radiation examined by reflection from a suitable crystal. He found that the spectra of the K radiation from elements varying in atomic weight from aluminium to silver were all similar in type, consisting mainly of two strong lines.[1] An example of the spectrum obtained for a number of successive elements is shown in plate 5, figure 2. It is seen that with increasing atomic weight the wave length of the corresponding lines diminishes, not irregularly but by definite and well-marked steps. Moseley found that for the K radiation the frequency of the radiation was proportional to $(N-a)^2$, where N was a whole number which varied by unity in passing from one element to the next of higher atomic weight and a was a constant about unity. From silver to gold the spectra given by the L radiations of elements were compared. These spectra consist of about five lines, of which two are relatively very strong. It was found again that the spectra were similar in type and that the frequency of a given line diminished by definite steps in passing from one element to another. The frequency of the radiation in this case was proportional to $(N-b)^2$, where b was a constant and N a whole number. Moseley concluded that the value of N in these expressions was the *atomic number*, i. e., the number of the element arranged in order of increasing atomic weight. Taking aluminium as the thirteenth element, he found that succeeding elements were expressed by the value of N 14, 15, 16, 17, etc., up to 77 for gold.

There appears to be little doubt that the X-ray spectrum of an element arises from the vibrations of the rings of electrons deep in the atomic structure outside the nucleus. Quite apart from the very interesting question of the mode of origin of these very high frequency spectra, it is seen that the fundamental modes of vibration of the distribution of electrons are simply connected with the square of a number, which varies by unity in passing from one element to the next.

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[1] In later work Rawlinson and Bragg have found that each of these lines is in reality a very close double.

There appears to be no doubt that the atomic number represents the number of units of positive charge carried by the nucleus, which, on account of the atomic nature of electricity, can only vary by whole numbers and not by fractions.

It is obvious that the study of X-ray spectra reveals at once whether any atomic number is missing, and also affords a remarkably simple method of settling the number of elements possible in the rare earth group about which there has been so much difference of opinion. Moseley concluded that from aluminium to gold only three possible elements were missing which should have atomic numbers 43, 61, 75, and only one element of number 61 appears to be missing in the rare earth group. The frequencies of the X-ray spectra of these missing elements can be calculated with certainty, and these data should prove an invaluable aid in a search for these missing elements. It has long been known that nickel and cobalt occupy an anomalous position in the periodic table when arranged according to atomic weights. This difficulty is now removed, for Moseley found that when arranged in order of nucleus charge both elements fall into the position to be expected from their chemical properties.

NUCLEUS CHARGE AND CHEMICAL PROPERTIES.

It is established by the work of Moseley that the elements can be defined by their nucleus charge, and that probably elements exist which have all the nucleus charges from 1 for hydrogen to 92 for lead. There is, however, another very important consequence that follows from this conception of the atom. Disregarding for a moment the atomic weight which depends mainly on the structure of the nucleus, the main physical and chemical properties of the atom are determined by the nucleus charge and not by the atomic mass. This must obviously be the case, for the number and distribution of electrons around the nucleus is determined by the electric forces between the electrons and the nucleus, and this is dependent on the magnitude of the nucleus charge, which may be regarded as a point charge. Without entering into the difficult question of the actual distribution of the exterior electrons in any atom, it is obvious that the number and position of the outlying electrons of the atomic structure, which probably mainly influence the chemical and physical properties of the atom, are determined by the charge on the nucleus. No doubt if the electrons are in motion, their positions relative to the nucleus and possibly also their rates of vibration will be slightly influenced by the mass of the nucleus as well as its charge, but the general evidence indicates that this effect must be very small.

We thus see that there is in the structure of every atom a quantity which is more fundamental and important than its atomic weight,

viz, its nuclear charge. It is known that the variation of the atomic weights of the elements with atomic number, while showing certain well-marked relationships, shows no definite regularity. From the point of view of the nucleus theory, the atomic weight of an element, while in some cases approximately proportional to its atomic number, is in reality a complicated function of the actual structure of the nucleus. The question why the atomic mass should not necessarily be proportional to the atomic number has already been discussed on page 193. While the main properties of an atom are controlled by its nuclear charge, the property of gravitation and also of radioactivity are to be ascribed mainly, if not entirely, to the nucleus.

RADIOACTIVE ELEMENTS AND THE PERIODIC SERIES.

Since the nucleus charge of an atom determines the main physical and chemical properties of an atom, it is possible that elements may exist of equal nuclear charges but different atomic weights. For example, if it were possible to add a helium nucleus to the nucleus of another atom, it would increase the nuclear charge by two and the mass by about four; if instead of the helium nucleus two hydrogen nuclei were added, the charge would be the same, but the mass of the resulting atom two units less than with helium. In such a case two atoms would be possible of identical nuclear charge but different atomic weights. In a similar way it may be possible for elements to exist of the same atomic mass but *different* nuclear charges. This would be brought about by the loss or gain of one or more negative electrons in the nucleus.

The study of radioactive elements has in the last year thrown a flood of light not only on this problem but on the underlying meaning of the periodic law of the elements. Russell, Fajans, and Soddy independently put forward a remarkable and important generalization in regard to the change of chemical properties of the successive products of transformation of the primary radioactive elements. This generalization can be very simply expressed in terms of the usual arrangement of the elements in groups according to the periodic law. It is found that after a transformation in which alpha particles are expelled the resulting element has chemical properties which shifts its place two groups lower in the direction of diminishing mass. On the other hand, the element resulting from a beta ray transformation shifts one place in the opposite direction. For example, radium, which is in Group II, changes after loss of an alpha particle into the emanation into group O, which included all the inert gases of the helium-argon type. The emanation after loss of another particle becomes radium A, which belongs to Group VI, and this in turn becomes radium B belonging to Group IV. Since

radium B is transformed by the loss of a beta particle, the resulting element, radium C, takes up a position in Group V. By this simple rule it has been found possible to define the essential chemical properties of all known radioactive elements. It was found that on this theory one element was missing in the general scheme. This element was discovered a few weeks later by Fajans and Göhring and found to have the general chemical properties predicted for it.

This generalization is capable of a very simple explanation on the nucleus theory. The loss of an alpha particle of charge 2 *lowers* the nuclear charge of the resulting elements two units; the loss of a beta particle, which carries a unit negative charge, *raises* the nuclear charge by one unit. In other words, the atomic number of an element shifts two units lower after loss of an alpha particle and shifts one unit higher after loss of a beta particle.

The atomic numbers of the elements in the uranium-radium series can be simply deduced from this rule if the atomic number of one element is known. We shall see later that the atomic number of radium B is 82 and identical with that of lead. The actual atomic numbers of the various elements are given in the circles representing the atoms in figure 4. It is seen that uranium, the heaviest known element, has an atomic number, 92, while the elements radium B, radium D, and the end product, which is believed to be lead, have the same atomic number, viz, 82. The evidence of the correctness of this striking conclusion will now be discussed.

As a result of a careful examination of the radioactive substances it has been found that in a number of cases elements which are of different atomic weights and exhibit different radioactive properties yet show identical general physical and chemical behavior. For example, the elements radium B, radium D, and lead, of atomic weights 214, 210, and 207, respectively, are so closely allied in chemical and physical properties that all attempts to separate a mixture of any two of them have failed completely. This would be explained if the nuclear charges were identical for those elements, as the generalization, already referred to, indicates. If this be the case they should give identical spectra under similar conditions. Unfortunately, the elements radium B and radium D are in too small quantity to determine their ordinary light spectra, but we can compare the X-ray spectrum of lead with that given by radium B under the excitation of its own beta rays. Experiments of this kind were recently made by Dr. Andrade and the writer, and the two spectra were found to be identical within the limits of experimental error. It is to be anticipated that their light spectra would also prove to be identical, or nearly so, for, as previously pointed out, the effect of the mass of the nucleus on the spectrum is probably very small.

The fact that the atoms of these three elements are not identical as regards mass or radioactive properties shows that the structure of the nucleus is different in each case.

There is another important deduction that should be mentioned. The end product of the uranium-radium series is an inactive element which has long been considered to be lead, but it has been difficult to verify this conclusion by direct experiment. We have seen that the end product has the same atomic number as lead, but should have an atomic weight about 206 instead of 207, as found for ordinary lead. In a similar way it has been concluded by Soddy and Fajans that the end product of thorium has the same atomic number as lead, but should have an atomic weight about 208.5. In order to test these remarkable conclusions experiments are now in progress by a number of investigators in different countries to examine whether the lead always found in radioactive minerals, and which presumably has partly, if not wholly, a radioactive origin, shows the same atomic weight as ordinary lead. Soddy has already found evidence that there is a distinct difference in the atomic weights in the direction predicted by the theory.[1]

The question naturally arises whether some of the ordinary elements may not prove to be a mixture of two or even more of these isotopes, as they have been termed. Unless the component isotopes are present in different proportion in different natural sources of the element, it will be difficult to settle this problem by ordinary chemical methods. There is one element, however, besides lead, from which some interesting evidence has been obtained on this point. Sir J. J. Thomson found by examining the deflection of the positively charged particles produced by an electric discharge through the rare gas neon that two elements were present of atomic weights about 20 (neon) and 22. Aston was able by diffusion experiments to separate partially the two components of neon and to show that they differed in density, but failed in attempts to separate them by fractional distillation in charcoal cooled by liquid air. Such results are to be anticipated if neon is a mixture of two isotopes; i. e., elements of identical nuclear charges but different atomic weights.

It is obvious that this new point of view will result in a systematic examination of the elements to test for the possible presence of isotopes, and thus give an additional reason for the accurate determination of atomic weights for elements obtained from widely different sources.

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[1] Since the delivery of this lecture similar conclusions have been reached by the experiments of Richards and Lembert in Cambridge and Hönigschmid in Vienna. There still, however, remains some doubt as to the actual difference in atomic weight of uranium lead, thorium lead, and ordinary lead. A very promising beginning has thus been made on the attack of this most important and fundamental problem.

DISTRIBUTION OF ELECTRONS IN THE ATOM.

It is seen that the nucleus theory of the atom offers a simple explanation of many important facts which have been brought to light in recent years, and for this purpose it has not been necessary to make any special assumptions as to the actual structure of the nucleus, or of the way in which the external electrons are distributed. The investigation of the latter problem is beset with many difficulties; for an electron is attracted toward the nucleus, and even if it is in orbital motion, it must, on the electromagnetic theory, lose energy by radiation and ultimately fall into the nucleus. It appears likely that this difficulty is in reality due to our ignorance of the conditions under which an electron radiates energy. According to the views outlined in this lecture, the hydrogen atom has the simplest possible structure, for it consists of a nucleus of one unit charge and one negative electron. The question naturally arises how such a simple structure can give rise to the complex spectrum observed for hydrogen. This problem has been attacked in a series of remarkable papers by Bohr, who concludes that the complexity of the spectrum is not due to the complexity of the atomic structure but to the variety of modes in which an electron can emit radiation. Suppose, for example, that a hydrogen atom has lost its negative electron. Bohr supposes that an electron falling toward the positively charged nucleus may occupy temporarily any one of a number of stationary positions fixed relatively to the nucleus. In falling from one stationary state to another, radiation is emitted of a definite frequency ν which is connected with the difference of potential energy E of the electron in the two stationary states by $E=h\nu$ where h is Planck's fundamental constant. On this hypothesis, he has been able to account for the series spectra of hydrogen and to deduce directly from the theory the value of Balmer's constant which plays such an important part in the spectra of all atoms. In a similar way, the helium atom is supposed to consist of a nucleus of two unit charges surrounded by two electrons. On this theory, the spectrum of helium is connected in a very simple way with that of hydrogen. Bohr also pointed out that the Pickering series of spectral lines observed in certain stars which were originally attributed to hydrogen must be ascribed to helium. This conclusion has since been strongly supported by the direct experiments of Fowler and Evans. In a similar way, Bohr described the possible distribution of electrons in several of the lighter atoms and also discussed the structure of the hydrogen molecule, which is composed of two hydrogen nuclei and two electrons. The heat of combination deduced for the theoretical molecule is in fair accord with experiment. He found that two helium atoms

were unable to unite to form a molecule—in agreement with a well-known property of this gas.

While there is room for much difference of opinion as to the interpretation of the rather revolutionary assumptions made by Bohr to explain the structure of the simple atoms and molecules, there can be no doubt of the great interest and importance of this first attempt to deduce the structure of the simple atoms and to explain the origin of their spectra. The agreement of the properties of such theoretical structures with the actual atoms is in several cases so remarkable that it is difficult to believe that the theory is not in some way an expression of the actual facts. While much work will be necessary before we can hope to understand the structure of any but the simplest atoms, a promising beginning has been made in the attack on this most difficult and fundamental of problems.

There seems to be little doubt that the more marked physical and chemical properties of an atom are to be attributed to a few outlying electrons in the atomic structure. The position and number of these valency electrons, as they have been termed by Stark, are defined by the magnitude of the nucleus charge. It has previously been pointed out that the loss of an alpha particle from a radioactive atom changes the position of the element two groups lower in the periodic table, while the loss of a beta particle raises it one group higher. Consequently it follows that the loss or gain of a unit charge from the nucleus of an atom causes it to change its position from one group to the next. If, for example, we follow the chemical properties of successive elements when the nucleus charge increases by unity, we soon reach an element which belongs to the same group as the first, although of much higher atomic weight. We must consequently conclude that the number and position of the outlying electrons in the structure of the atom passes through successive changes which are regularly repeated with increasing atomic weight. Quite apart from any detailed knowledge of the electronic distribution of atoms, the regular recurrence of elements of similar chemical properties with increasing atomic weight is to be anticipated on the general theory that an atom is an electrical structure.

EVOLUTION OF THE ELEMENTS.

It has long been thought probable that the elements are all built up of some fundamental substances, and Prout's well-known hypothesis that all atoms are composed of hydrogen is one of the best-known examples of this idea. The evidence of radioactivity certainly indicates that the heavy radioactive elements are in part composed of helium, for an atom of the latter appears as a result of many of the radioactive transformations. No definite evidence, however, has been

obtained that hydrogen appears as a result of such transformations; but as previously pointed out on page 191, helium may prove to be an important secondary unit in the structure of heavy atoms. While we have thus undoubted evidence of the breaking up of heavy atoms, no indication has yet been observed that the radioactive processes are reversible under ordinary conditions. Many investigations have been made to test whether new elements appear in strong electric discharges in vacuum tubes. While some of the results obtained are difficult of interpretation, no reliable evidence has yet been adduced that one element can be transformed into another under such conditions.

The question of the evolution of the elements has been attacked from another side. Sir Norman Lockyer and others have suggested that the elements composing the star are in a state of inorganic evolution. In the hottest stars the spectra of hydrogen and helium predominate, but with decreasing temperature the spectra becomes more complicated and the lines of heavier elements appear. On this view it is supposed that the light elements combine with decreasing temperature to form the heavier elements.

There is no doubt that it will prove a very difficult task to bring about the transmutation of matter under ordinary terrestrial conditions. The enormous evolution of energy which accompanies the transformation of radioactive matter affords some indication of the great intensity of the forces that will be required to build up lighter into heavier atoms. On the point of view outlined in these lectures the building up of a new atom will require the addition to the atomic nucleus of either the nucleus of hydrogen or of helium, or a combination of these nuclei. On present data this is only possible if the hydrogen or helium atom is shot into the atom with such great speed that it passes close to the nucleus. In any case it presumes there are forces close to the nucleus which are equivalent to forces of attraction for positively charged masses. It is possible that the nucleus of an atom may be altered, either by direct collision of the nucleus with very swift electrons or atoms of helium, such as are ejected from radioactive matter. There is no doubt that under favorable conditions these particles must pass very close to the nucleus, and may either lead to a disruption of the nucleus or to a combination with it. Unfortunately, the chance of such a disruption or combination is so small under experimental conditions that the amount of new matter which is possible of formation within a reasonable time would be exceedingly small and so very difficult of detection by direct methods. Very penetrating X rays or gamma rays may for similar reasons prove to be possible agencies for changing atoms. Although it is difficult to obtain direct evidence, I personally am inclined to believe that all atoms are built up of positive

electrons (hydrogen nuclei) and negative electrons, and that atoms are purely electrical structures.

There can be little doubt that conditions have existed in the past in which these electrons have combined to form the atoms of the elements, and it may be quite possible under the very intense electrical disturbances which may exist in hot stars that the process of combination and dissociation of atoms still continues.

In these lectures I have tried to give an idea of some modern views of the structure of the atoms and of the great variety of new and powerful methods which have been applied to the attack of this problem in recent years. We have seen that a heavy atom is undoubtedly a complex electrical system consisting of positively and negatively charged particles in rapid motion. The general evidence indicates that each atom contains at its center a massive charged nucleus or core of very small dimensions surrounded by a cluster of electrons, probably in rapid motion, which extend for distances from the center very great compared with the diameter of the nucleus. Such a view affords a reasonable and simple explanation of many important facts obtained in recent years, but so far only a beginning has been made in the attack on the detailed structure of atoms—that fundamental problem which lies at the basis of physics and chemistry.

SUBMARINE SIGNALING—THE PROTECTION OF SHIPPING BY A WALL OF SOUND AND OTHER USES OF THE SUBMARINE TELEGRAPH OSCILLATOR.[1]

By R. F. Blake.

Compared with other forms of transportation, the amount of energy necessary to transport water-borne freight is very small, and its cost would be cheap indeed if it were not for the dangers of the sea. We have fogs and rocky coasts, shoals and icebergs, currents and storms to guard against, and these add immensely to the expense. Of this we have had a very recent instance, for, as the result of the loss of the *Titanic*, vessels carrying passengers are now constructed with a complete double bottom extending above the water line; in other words, instead of a single ship we must now have two complete ships, one entirely inclosed by the other. And the loss of the *Empress of Ireland* indicates that even this may not be adequate.

Bit by bit the dangers which beset the early navigators have been overcome. The chart told him the best course to take from one point to another. The mariner's compass enabled him to maintain his course when the stars were blotted out by clouds. With sextant and chronometer he located his position, with log and soundings he guarded himself when a sight could not be obtained. More recently wireless telegraphy has enabled him to call assistance in time of danger. But with all this, many dangers remain. The more important of these are due to fog.

The North Sea, the English Channel, and the Grand Banks, the New England coast, the western coast of the United States, British Columbia, and Alaska, and other points are all of them subject to fogs, sometimes lasting for weeks at a time, and it is therefore not surprising that thousands of lives are still lost at sea each year.

And there is not only loss of life; the pecuniary loss is also very great. It is no unusual occurrence for a score of steamers to be tied up at one time, unable to enter harbor on account of fog or of the combination of fog and rough weather.

[1] Reprinted by permission from the Proceedings of the American Institute of Electrical Engineers, October, 1914.

In such a case the loss to the steamship companies in interest and depreciation on ships and cargoes and in wages may easily amount to more than $50,000 per day, and this loss occurs not once but frequently during a year, and on many routes.

In addition to this, the danger of collision in fog adds very considerably to the cost of insurance, and some of our worst disasters have occurred in this way.

Aside from those dangers peculiar to fog there remains a number of others. A continuance of cloudy weather or abnormal ocean currents, or both, may throw the navigator out of his reckoning and place him on a rocky shore a score of miles away from the safe route he assumes himself to be following.

Icebergs still remain a menace in spite of all the efforts which have been made to guard against them. From time to time statements have been made that apparatus has been devised which is capable of locating their presence, but in every instance in which such apparatus has been tested it has proved a failure.

The history of systematic marine protection by means of lighthouses and beacons does not go back very far. It is true that there were a few lighthouses, such as the Pharos of Alexandria, centuries ago, but even in quite recent years a European Government received a petition for compensation from the inhabitants of a seacoast district on the ground that the erection of a lighthouse had deprived them of one of their principal sources of income, to wit, luring vessels on near-by shoals by means of false lights.

The systematic employment of sound signals for marine protection is of still more recent date and has never been carried out fully, in spite of the fact that many of our greatest scientists, for example, Tyndall and Rayleigh, have devoted special attention to this matter.

One reason for this is that sound signals produced in air are very erratic in their range and intensity, so much so as to be on many occasions absolutely misleading. This is due to the fact that when a fog horn is blown the sound may be carried by the wind or may be reflected or refracted by layers of air of different densities, with the result that the sound may be audible many miles away, while there may be a zone of complete silence extending from a few hundred yards in front of the signal to a distance of 4 or 5 miles.

As this phenomenon is by no means infrequent, the result has been to discredit more or less this type of signal, and it will be evident that the knowledge that a siren had been installed at a certain dangerous point might prove a source of danger instead of a protection.

As already stated, many eminent men have worked upon this problem, but it was not until Arthur J. Mundy, of Boston, suggested the use of water instead of air as the medium for transmitting signals and proved its value by practical demonstration that any great

advance was made. Water has many advantages over air for this purpose.

1. In the first place, it is free from the dangerous zones of silence which occur when the signals are produced in air.

2. In the second place, the absorption of the sound is much less in water, and consequently the signal is not only absolutely reliable but is transmitted to a distance many times greater than when it is transmitted through air.

3. The sound is not carried away by the wind in stormy weather, as is the case with the siren.

4. It is not affected by atmospheric disturbances, as is the case of wireless.

5. It permits of the accurate determination of the direction from which the sound is proceeding, which is not the case with either the air siren or wireless telegraphy.

Some recent instances where ships have signaled by wireless that they were in distress but have had to remain without assistance for many hours, and in one instance for more than a day, because their location could not be determined by the vessels coming to their aid, will be familiar to everyone.

All these advantages indicated clearly years ago the advisability of developing apparatus for signaling by means of sound waves transmitted through the water itself.

But it is one thing to conceive the idea and another thing to develop a practical system; and it may be of interest to know that up to the present time the sum of a million dollars has been invested in developing submarine signaling, so far without monetary return.

The first method which was employed for producing the sound was through the striking of a bell, and the method of receipt of the signals was by means of a microphone attached to the skin of the ship. Neither the original bell nor the original microphone attachment was satisfactory.

It would be impossible in the space permitted to discuss even briefly the innumerable experiments made with different sizes of bell, with different materials for the bell, with different methods of producing the blow, the precautions taken to eliminate electrolytic action, with different types of microphone, with different methods of mounting the microphone on the side of the ship, with the experiments made to minimize water and other noises. It will be sufficient to say that finally the work of Mundy, Wood, Fay, Williams, and others resulted in a completely practical system.

The submarine bell in use on the lightships is actuated by compressed air stored in a reservoir. The actuating wheel has projections mounted on it so that when the wheel revolves a number of strokes

follow each other, the different intervals being peculiar to the different signal stations, so that the captain of a ship by counting the strokes of the bell can determine what lightship is producing the sound.

In order to receive the sound it has been found absolutely necessary to suspend the microphone in a tank of water, for this is the only method of cutting out the water noises and the noises due to machinery, etc., on board the ship which otherwise drown out the sound of the bell.

One of these small water tanks, containing a microphone of a special type, is attached to each side of the bow inside of the ship. From each tank wires are run to a device which is called the indicator box, so arranged that by throwing the handle to one side the starboard microphone is connected to the telephone, and by throwing the handle to the other side the port microphone is connected.

It will be obvious that once the bell is picked up the captain has only to turn his vessel until the sound is heard with equal intensity on each side, to know that his ship is then pointing in the direction from which the sound is coming, and in this way he can take compass bearings of the lightship on which the bell is situated.

The importance of this method will be at once perceived. No matter how stormy or how foggy the weather may be, it enables the captain of a ship, on making land, to obtain at once the compass bearings of the nearest lightship or lighthouse fitted with a bell.

How many vessels and how many lives this device has saved even in the few years during which it has been in use it would be impossible to tell. Less sensational than the wireless telegraph, it may be questioned whether its actual practical utility to the merchant marine has not been greater.

Compressed air, or an electromagnetic mechanism, may swing the hammer, or the bell may be operated by the waves themselves. A type much used is a bell buoy which may be anchored off a shoal, and will give submarine warning day and night without further attention. A large vane extends from one side of the mechanism. As the buoy swings up and down in the water, the vane by means of a ratchet compresses a spring which automatically releases and operates the bell hammer.

It will be evident that even if no further development had been made the system would be and is a complete and practical one. Its universal adoption would greatly minimize, if not entirely prevent, disasters due to errors of ship position.

But, with the very success of this system it became evident to those in charge of its development that still further advances might be conceived as possible, especially in three directions.

1. Suppose the sound-producing apparatus could be so constructed as to be operated from moving ships by a telegraph key. If this were achieved, it would be possible for one ship to signal to another in fog, to communicate its position, its direction and its speed, and eliminate all dangers of collision. It would also be possible to signal between submarines or between battleships and submarines, and to communicate between battleships in action without interference from the enemy, and though all masts were shot away.

2. Suppose the range of the sound-producing apparatus could be extended so as to cover a radius of 25 or 50 miles. Then it would be within our power so to encircle the coast of every nation with what has been felicitously termed "a wall of sound," that no vessel, under whatsoever circumstances of loss of reckoning, of variable currents, of fogs, and storms, could approach the coast without being warned of that fact and notified of its exact position on that coast and of the direction of the nearest lightship.

3. If the sound-producing apparatus could be constructed so as to be actuated by telephonic currents, it would be possible to transmit speech through the water.

It will be of interest to consider some of the difficulties which had to be overcome before the desired results could be obtained.

The most serious of these obstacles was the fact that water is almost incompressible.

Now, since sound is a compressional wave in the medium through which it is transmitted, it is evident that any apparatus which is to transmit sound through water must be capable of exerting very great force. In the bell this is accomplished by the hammer blow of the clapper, and any electric or other apparatus which is to be used for submarine signaling must have a force comparable with that produced by the impact of a hammer on an anvil.

A second and very grave difficulty arises from the fact that if the water is to be compressed, some material object must be set in motion to compress it, and that object, which must have sufficient mechanical strength to stand the stress, and must therefore be of considerable size, must start from rest, reach its highest velocity, and come to rest in one one-thousandth part of a second, if a musical note having a pitch of 500 per second is to be produced. The forces of acceleration thus necessitated are very large.

A third difficulty arises from the fact that in order to telegraph at a speed of 20 words per minute the time allowable for a single dot is very small. As the average word consists of 5 letters, and the average letter has a length equivalent to 7 dots, an apparatus capable of telegraphing at the rate of 20 words per minute must be capable of making 700 dots per minute, or a single dot in something less than one-tenth of a second.

If the signal is to have individual quality, so as to be readily distinguishable from other noises, and so as to be separable by resonance from other notes, each dot must consist of at least 10 impulses.

Thus we arrive at the conclusion that whatever device is used it must be capable of producing at least 100 compressional waves in a single second in order to telegraph satisfactorily at the rate of 20 words per minute.

If this same apparatus is to transmit speech through the water, it must be still more rapid in its action and must be capable of producing several thousand compressional waves per second.

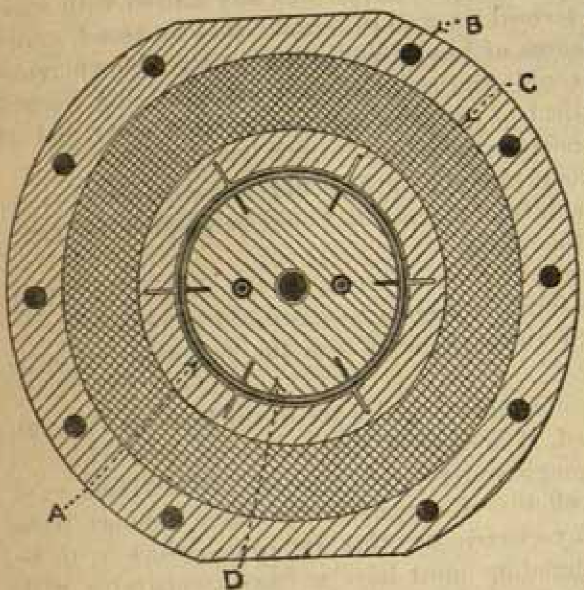

FIG. 1.

The above were the three main difficulties in the way. Of course there were many others; for example, the apparatus must not weigh too much; it must not be affected by water or change of temperature; it must be simple in construction; it must be easily applied to the ship; positive in its action; must not require adjustment after being once set up; and must be able to stand all kinds of ill treatment at the hands of unskilled operators. It will be unnecessary to go over the ground taken by the development, and we will therefore proceed at once to describe the apparatus as finally developed by Prof. R. A. Fessenden.

The device used is termed an "oscillator," and its construction is shown in cross section in the drawing, figure 1.

In the drawing the iron of the magnetic circuit and the copper tube are shaded. The magnetizing coil is crosshatched. The moving part is the copper tube A. This lies in the air gap of a magnetic field formed by a ring magnet B, built up in two parts, as shown in longitudinal section in figure 2.

The ring magnet is energized by the coil C, and produces an intense magnetic flux which flows from one pole of the ring magnet across the air gap containing the upper part of the copper tube,

thence through the central stationary armature D, thence across the other air gap to the lower pole face of the ring magnet, and thence through the yoke of the ring magnet back to the upper pole face.

This field is very much stronger than that in the ordinary dynamo, there being more than 15,000 lines for each square centimeter of cross-section.

Around the armature is wound a fixed winding, which we will call the armature winding and which is reversed in direction so that one-half of the winding is clockwise and the other counterclockwise.

When an alternating current is passed through this armature winding it induces another alternating current in the copper tube.

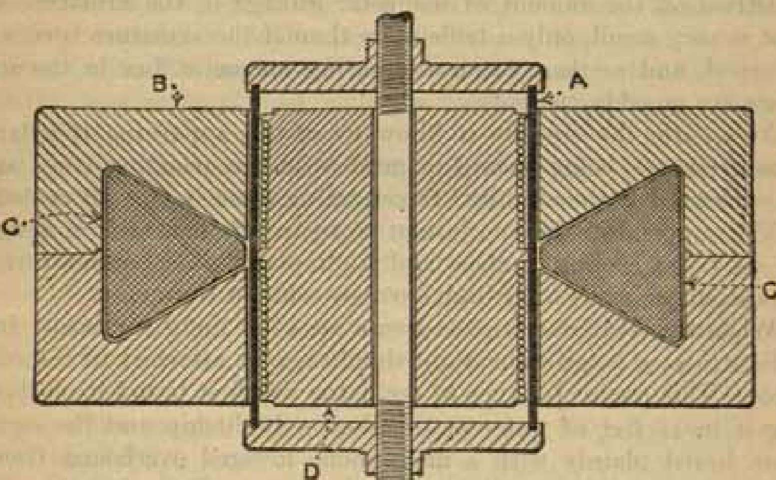

FIG. 2.

Only by this construction has it been found possible to obtain the enormous force and rapidity necessary to compress the water and to overcome the inertia of the moving parts of the mechanism.

In order to apply this force to the work of compression, the copper tube is attached to solid disks of steel, which in turn are attached to a steel diaphragm 1 inch thick, which may be made part of the side of the ship. In practice the tube is provided with lugs, and is held between two disks drawn together on the tube by a 1-inch vanadium-steel rod and a right-and-left-handed screw thread.

Telegraphing is accomplished by means of an ordinary telegraph key placed in the main armature circuit.

Although an ordinary telegraph key is used, there is no sparking at the contacts. This may surprise electrical engineers familiar with the sluggish action and vicious arcing commonly found associated with the operation of electromagnetic apparatus of this size and power, more especially in view of the fact that a very high

frequency is used, 500 per second, and that there is no laminated iron used in the construction of the apparatus.

The secret of this lies in the fact that the armature has substantially no self-induction, and no eddy currents are generated in the apparatus. This is because the copper tube forms, as will be seen, the short-circuiting secondary of a transformer, of which the armature winding is the primary.

This eliminates the self-induction of the armature winding. In addition the upper and lower portions of the winding are wound in opposite directions, and therefore there is no mutual induction between the field coil circuit and the armature circuit. With this construction the amount of magnetic leakage in the armature circuit is very small, only a trifle more than if the armature core were of wood, and as there is no alternating magnetic flux in the iron, there are no eddy currents.

As regards the capacity in kilowatts of this apparatus, it is large. The armature, being wound in grooves in the armature core, so as to withstand the mechanical forces acting upon it, is well cooled.

The copper tube has no insulation to be affected, and on account of its large cooling surface and high permissible temperature of operation can carry very high currents without injury.

When the oscillator is placed on a vessel or hung overboard from a lightship, a large water-tight diaphragm is attached to the oscillator. This particular type of oscillator was first tested by suspending it in 12 feet of water at the Boston Lightship and the signals were heard plainly with a microphone lowered overboard from a tug at Peaked Hill Bar Buoy, 31 miles away. Since that time tests have been made with oscillators installed in the fore-peak tank of the *Devereux*, a collier of the Metropolitan Coal Co., and also with an oscillator mounted on a diaphragm made part of the hull of the vessel. The signals have been heard upward of 20 miles from the *Devereux* running at her regular speed of 8 knots. Full power has not been employed on any of the tests, and it is more than probable that much longer distances can be obtained in the future.

In addition to the tests already described the oscillator has been temporarily installed on submarine boats and proved itself of immense value, and demonstrated that a flotilla of submarines equipped with oscillators will be able to make a combined attack on an enemy, only one needing to show its periscope in order to direct the others, or all of them can be directed by the mother ship. It therefore makes possible a whole field of submarine maneuvers heretofore out of the question, and perhaps, most important, it removes the principal danger these boats have had to face, the risk of being run into.

So much for the apparatus when in use as a sound generator. The signals produced by the oscillator can, of course, be received by

water-immersed microphones of the usual type, but one would perhaps not anticipate the possibility of using the oscillator as a receiver in view of the fact that the diaphragm is of solid steel and weighs, with the copper tube and its attachments, considerably over 100 pounds; but the oscillator, like the ordinary electric motor, is also capable of acting as a generator, and on account of its high efficiency as a motor is a very efficient one.

The same oscillator is therefore used for sending and for receiving, a switch being thrown in one direction when it is desired to telegraph under water and thrown the other way when it is desired to listen in.

In addition to telegraphing and receiving messages, the oscillator can also be used for telephoning under water. Sentences have been transmitted at 800 yards and conversation at more than 400 yards, and this was accomplished with the use of an ordinary telephone transmitter and six dry cells.

It seems evident, therefore, that with more power much greater distances can be reached. Long distances are not, however, necessary, as, even with a distance of 1 mile, it will be readily understood that this method of underwater telephoning will be of great use as a means of communicating between submarines while submerged and between ships in fog, as the captains of the vessels can talk directly to each other instead of transmitting and receiving through a telegraph operator.

Some other uses to which the oscillator may be put may be mentioned briefly.

One which will at once suggest itself is the steering of torpedoes by sound under water. The idea of so operating torpedoes is not a new one, and has occurred to a number of inventors, but until the present time no method of accomplishing it has been developed. With this new source of sound, however, the method should be practicable.

Another use is as a means for obtaining soundings. If we take a commutator wheel, with one live segment and two brushes, one connected to the alternating-current generator and the other to the telephone receiver, it will be evident that when the commutator segment makes contact with the brush connected to the generator a sound will be produced by the oscillator. When the live contact passes away from the brush the sound will cease. This sound wave will travel outward, and on reaching the bottom will be reflected and travel back again to the ship. Meantime no sound will be heard in the telephone receiver, but if the brush connected to the telephone receiver be shifted in the direction of rotation of the commutator until it makes contact with the live segment of the commutator at precisely the instant at which the reflected sound wave has come back and impinged on the oscillator diaphragm then a sound will be

heard. Since sound travels in water at a velocity of approximately 4,400 feet per second, if the distance be 100 feet, the time taken by the sound in traveling from ship to bottom and from bottom to ship will be approximately one-twentieth of a second.

In April, 1914, some tests were made on the U. S. revenue cutter *Miami* to see whether soundings could be taken in the manner above indicated. As the commutator had not been completed, a temporary apparatus with a stop watch was used. The echo from the bottom was plainly heard not only on the oscillator but in the wardroom and in the hold of the ship without any instruments whatever. The elapsed time corresponded to the depth shown on the chart, and the proposed method was proved to be feasible.

The chief object of the tests on the *Miami* was, however, to determine whether a reflection from icebergs could be obtained, and this was proved beyond question. The apparatus used was the same as for taking soundings.

A signal was sent on the oscillator, the echo from the bottom heard, and then the echo from the iceberg came in. To make sure that the second echo was not also from the bottom, the distance from the *Miami* to the iceberg was varied from about 100 yards to 2½ miles. The elapsed time between the signal and the echo from bottom remained the same, but the elapsed time of echo from the iceberg varied with the distance and corresponded very closely to the position of the iceberg determined by the range finder. Moreover, it was found that it made no difference whether the face of the iceberg was normal to the path of the sound or not, thus showing that the echo was due not to specular reflection but to diffraction fringes.

When the *Miami* had gone 2½ miles from the iceberg a heavy storm made it necessary to postpone further tests, and continued rough weather made further tests impossible, as the oscillator was not permanently installed but had to be lowered overboard. The echoes at 2½ miles were, however, loud, and there can be no doubt that they would have been heard at greater distances. (See appended report of Capt. Quinan.)

To sum up: The oscillator represents an important step forward in the science of navigation. It makes it possible to surround the coasts with a wall of sound so that no ship can get into dangerous waters without warning, to make collisions between ships possible only through negligence. Although no sufficient tests have been made to warrant the statement that icebergs can be detected under all circumstances or that soundings can be taken at full speed, what evidence there is points that way. For naval purposes it provides an auxiliary means of short-distance signaling that is available at all times and that can not be shot away, and it widens the possibilities of submarine boats to an extent we can not yet fully grasp.

REPORT OF CAPT. J. H. QUINAN, OF THE U. S. REVENUE CUTTER "MIAMI," ON THE ECHO FRINGE METHOD OF DETECTING ICEBERGS AND TAKING CONTINUOUS SOUNDINGS.[1]

"We stopped near the largest berg and by range finder and sextant computed it to be 450 feet long and 130 feet high. Although we had gotten within 150 yards of the perpendicular face of this berg and obtained no echo from the steam whistle, Prof. Fessenden and Mr. Blake, representatives of the Submarine Signal Co., obtained satisfactory results with the submarine electric oscillator placed 10 feet below surface, getting distinct echoes from the berg at various distances, from one-half mile to 2½ miles. These echoes were not only heard through the receivers of the oscillator in the wireless room but were plainly heard by the officers in the wardroom and engine room storeroom below the water line. Sound is said to travel at the rate of 4,400 feet per second under water. The distance of the ship, as shown by the echoes with stop watch, corresponded with the distance of the ship as determined by range finder. On account of the great velocity of sound through water, it was our intention to try the oscillator at a greater distance for even better results, but a thick snowstorm drove us into shelter on the Banks again.

* * * * * * *

"On the morning of April 27 anchored in 31 fathoms of water with 75 fathoms of chain in order to make current observations. * * * Prof. Fessenden also took advantage of the smooth sea to further experiment with his oscillator in determining by echo the depth of water, the result giving 36 fathoms, which seemed to me very close."

[1] From the Hydrographic Office Bulletin of May 13, 1914.

THE EARTHQUAKE IN THE MARSICA, CENTRAL ITALY.[1]

By Ernesto Mancini,

Secretary of the Royal Academy of the Lincei.

[With 1 plate.]

On the 13th of January, 1915, at 53 minutes past 7 in the morning, a terrible earthquake devastated the Marsica, a rich and flourishing region of Italy, in the southern part of the Aquilian Abruzzi and the neighboring localities, the Valleys of the Salto, of the Latium, and of the Liri. The disaster had terrible consequences; it caused the destruction of a number of small cities, market towns, and villages, and the death of a great number of people. The extent of the cataclysm and unfavorable weather conditions with heavy rain and snow, rendered aid laborious and difficult.

FIG. 1.—Zone of maximum intensity of the earthquake of Jan. 13, 1915.

For some weeks the scientific observations made concerning the details of the terrible phenomenon have been collected, coordinated, and discussed. As a result of the preliminary observations of several scientists of the Meteorological and Geodynamical Bureau of Rome, of which Prof. Palazzo is the director, the following notice was prepared:

[1] Translated by permission from the Revue générale des Sciences, Mar. 15, 1915.

If an attempt is made to trace the isoseismic curves of the principal shock, it will be seen that the area most affected (fig. 1) contains alluvial strata of the dried-up Lake of Fucino, and embraces a zone to a high degree sedimentary and of Karstic origin. This precludes any volcanic cause for the earthquake; it is likely, on the contrary, that it was due to a sudden modification of the deep stratifications of the earth's crust. The region of Marsica which was the epicenter of

FIG. 2.—Distribution of the Italian earthquakes along a fixed line, according to Prof. Omori.

the earthquake, although having a seismic character, had not until that time been the scene of any great catastrophes.

The present phenomenon, adds Dr. Martinelli, was in a way predicted by science. In fact, Prof. Omori, in a study of the great Italian earthquakes from 1638 to 1908, in Sicily, Calabria, and in central Italy, came to the conclusion by an examination of the stricken area that earthquakes follow a determined line and that an area in which an earthquake takes place never coincides with that of a previous quake. In a chart of southern Italy (fig. 2) traced by the learned Japanese seismologist it will be noticed that the destructive area of

the earthquake of January 13 is on this line and does not coincide with any other seismic locality. However, Dr. Martinelli, who has gone over with great care the seismic history of the regions traversed by the axial line of Prof. Omori, thinks that it is merely a curious coincidence; in fact, in tracing this line Prof. Omori has not considered other important earthquakes, which would have altered the direction of it.

The seismogram recorded by Agamennone's seismograph with horizontal pendulums is remarkable for its amplitude. The registering apparatus of the Bureau at Rome, except for the presence of lateral stop screws, would have been put out of action by the shock, as happened to the seismograph of the Observatory of Rocca di Papa. The great seismograph of Strassburg was dismounted by the violence of the shock, and the passage of the seismic waves was recorded by all the sensitive seismographic instruments in the world, even to Japan, Australia, and Canada. The seismogram shown here (fig. 3) is that traced by a bifilar pendulum at the Seismologic Observatory of Cartuja, in Granada; at P and S are shown the beginnings of the preliminary quakes.

The shock commenced at exactly 7h. 52m. 55s. in the direction E. 6° N., the direction from Rome to the region affected by the disaster. During that day and in the days following several small repetitions of the phenomenon were noticed. Concerning these repetitions, Prof. Agamennone observed on the instruments of the Geodynamic Observatory of Rocca di Papa, up to the 6th of February, 750 shocks, occurring sometimes at intervals of less than a minute apart, revealing the state of continual convulsions of the earth in the epicentral area.

The position of the epicenter of the earthquake has not yet been exactly established. This uncertainty and the enormity of the devastation wrought in the Valley of the Liri have led Agamennone to believe in the existence not of a single center but of two separate seismic centers which came into action either at the same instant or one immediately following the other, as occurs in earthquakes spoken of as "in relays." It might even be that the epicenter had a linear form of considerable length and for reasons of a geologic nature the devastation was manifested in two widely separated localities.

From the preliminary researches carried on by Prof. Oddone on the sites of the disaster, relating to the details of the seismic waves, to their transmission, speed, height, etc., it would seem that it can already be deduced that the complete period of the waves was 0.7 second, the length of the waves from summit to summit about 20 meters, with a height of 20 centimeters. The mean speed of transmission, according to Agamennone, appeared to be about 7.69 meters per second. The bulging movement of the ground caused the destruction of the walls

of buildings, a ruin which became even more serious because of other eddying motions due to the combination of longitudinal and transversal vibrations coming from the depths of the hypocenter to the epicenter at the surface of the ground.

The number of victims of the earthquake is estimated at more than 25,000. The greater part of the cities, market towns, and villages in the region affected were entirely destroyed, being reduced to vast heaps of ruins, among which rescuers went in, braving the great dangers and with a fine disregard of self, to the aid of those caught in the ruins. One of the cities where the shocks were most destruc-

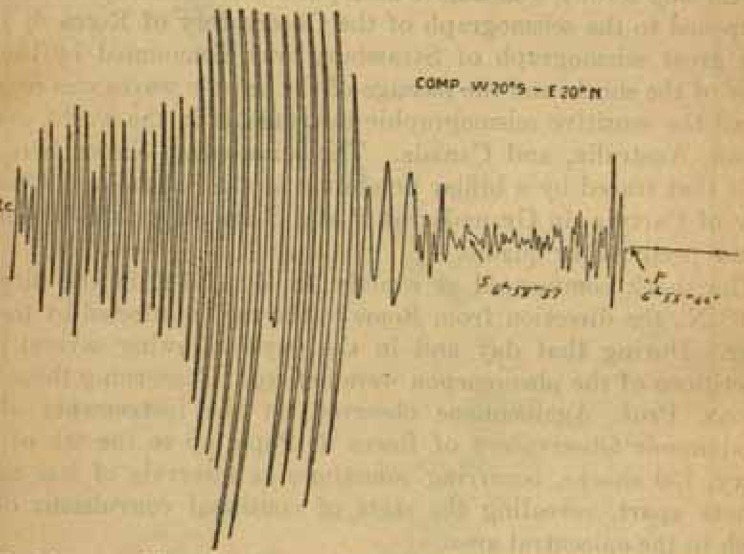

FIG. 3.—Seismogram of the earthquake of Jan. 13, 1915, recorded at the Seismological Observatory of Cartuja, in Granada.

tive was Avezzano, as shown by the two accompanying photographs reproduced on plate 1; from a population of 13,000 inhabitants only 2,300 were saved. Several persons still living were found after a long imprisonment underground, and among these the most extraordinary case is that of a peasant who, having taken refuge under an arch of his ruined stable, lived for 24 days, having for nourishment only a little water which leaked through the ruins, and he came forth from his prison in quite good condition.

This frightful disaster, which wiped out one of the most beautiful and thriving regions of Italy, has excited everywhere the warmest expressions of sympathy for a country so grievously stricken. Before the immensity of this misfortune the Government and citizens of Italy have united in a great charitable effort to aid the victims of this new calamity and to assure the life and future of the devastated region.

1.—RUINS OF AVEZZANO. THE REMAINS OF THE BANK OF NAPLES.

2.—RUINS OF AVEZZANO. THE TORLONIA PALACE.

ATLANTIS.[1]

By Pierre Termier,
Member of the Academy of Sciences, Director of Service of the Geologic Chart of France.

There is a somber poem, that of Atlantis, as it is unfolded to our eyes, marvelously concise and simple, in two of Plato's dialogues. We understand, after having read it, why all of antiquity and the Middle Ages, from Socrates to Columbus, for nineteen hundred years, gave the name "Sea of Darkness" to the ocean region which was the scene of so frightful a cataclysm. They knew it, that sea, full of crimes and menaces, wilder and more inhospitable than any other; and they questioned fearfully what there was beyond its mists, and what ruins, still splendid after a hundred centuries of immersion, were hidden beneath its peaceful waves. To brave a voyage across the Sea of Darkness and to pass the gulf where sleeps Atlantis, Columbus required a superhuman courage, an almost irrational confidence in the idea that he had apprehended the true shape of the earth, an almost supernatural desire to bear the Christ—after the manner of his patron, St. Christopher, the sublime river ferryman—to the unknown peoples who so long were awaiting Him, "seated in the shadow of death,"

On the mystic shores of the western world.

After the voyages of Columbus terror disappears, curiosity remains. Geographers and historians are occupied with the question of Atlantis; leaning over the abyss they seek to determine the exact location of the engulfed island, but, finding nowhere any definite indication, many of them slip into skepticism. They doubt Plato, thinking that this great genius might indeed have imagined, from beginning to end, the fable of Atlantis, or that he mistook for an island of gigantic dimensions a portion of Mauritania or of Senegambia. Others transpose Atlantis into northern Europe, while others at length do not hesitate to identify it with all America. The poets alone remain faithful to the beautiful legend; the poets who,

[1] Lecture given before the Institut Océanographique of Paris Nov. 30, 1912. Translated by permission from Bulletin de l'Institut Océanographique, No. 256, 1913.

according to the lofty phrase of Léon Bloy, "ne sont sûrs que de ce qu'ils devinent" [are sure of only what they dream]; the poets, who would never be satisfied with an Atlantic Ocean which had no drama in its past, and who would not be resigned to the belief that the divine Plato might have deceived them, or that he might himself have been entirely mistaken.[1]

It may be, indeed, that the poets were once more right. After a long period of disdainful indifference, observe how in the last few years science is returning to the study of Atlantis. How many naturalists, geologists, zoologists, or botanists, are asking one another to-day whether Plato has not transmitted to us, with slight amplification, a page from the actual history of mankind. No affirmation is yet permissible; but it seems more and more evident that a vast region, continental or made up of great islands, has collapsed west of the Pillars of Hercules, otherwise called the Strait of Gibraltar, and that its collapse occurred in the not far distant past. In any event, the question of Atlantis is placed anew before men of science; and since I do not believe that it can ever be solved without the aid of oceanography, I have thought it natural to discuss it here, in this temple of maritime science, and to call to such a problem, long scorned but now being revived, the attention of oceanographers, as well as the attention of those who, though immersed in the tumult of cities, lend an ear to the distant murmur of the sea.

Let us first, if you please, again read Plato's narrative. It is in the dialogue called "Timæus," or "Concerning Nature." There are four speakers: Timæus, Socrates, Hermocrates, and Critias. Critias has the floor; he is speaking of Solon, and of a journey that this wise lawgiver made to Saïs, in the delta of Egypt. An old Egyptian priest profoundly amazes Solon by revealing to him the history of the beginning of Athens, all but forgotten by the Athenians.

I will make no secret of it with you, Solon [says the priest], I agree to satisfy your curiosity, out of respect for you and for your country, and, above all, in order to honor the goddess, our common patroness, who reared and established your city, Athens, offspring of the Earth and Vulcan, and a thousand years later our own city, Saïs. Since the foundation of the latter our sacred books tell of a lapse of 8,000 years. I will then entertain you briefly with the laws and the finest exploits of the Athenians during the 9,000 years which have elapsed since Athens began to live. Among so many great deeds of your citizens there is one which must be placed above all else. The records inform us of the destruction by Athens of a singularly powerful army, an army which came from the Atlantic Ocean and which had the effrontery to invade Europe and Asia; for this sea was then navigable, and beyond the strait which you call the Pillars of Hercules there was an island larger than Libya and even Asia. From this island one could easily pass to other islands, and from them

[1] The latest comer of these poets of Atlantis is a young girl, Emilie de Villers (Les Ames de la Mer [The Souls of the Sea], Paris, 1911, pub. Eug. Figuière).

to the entire continent which surrounds the interior sea. What there is on this side of the strait of which we are speaking resembles a vast gateway, the entrance of which might be narrow, but it is actually a sea, and the land which surrounds it is a real continent. In the Island Atlantis reigned kings of amazing power. They had under their dominion the entire island, as well as several other islands and some parts of the continent. Besides, on the hither side of the strait, they were still reigning over Libya as far as Egypt and over Europe as far as the Tyrrhenian. All this power was once upon a time united in order by a single blow to subjugate our country, your own, and all the peoples living on the hither side of the strait. It was then that the strength and courage of Athens blazed forth. By the valor of her soldiers and their superiority in the military art, Athens was supreme among the Hellenes; but, the latter having been forced to abandon her, alone she braved the frightful danger, stopped the invasion, piled victory upon victory, preserved from slavery nations still free, and restored to complete independence all those who, like ourselves, live on this side of the Pillars of Hercules. Later, with great earthquakes and inundations, in a single day and one fatal night, all who had been warriors against you were swallowed up. The Island of Atlantis disappeared beneath the sea. Since that time the sea in these quarters has become unnavigable; vessels can not pass there because of the sands which extend over the site of the buried isle.[1]

Here surely is a narrative which has not at all the coloring of a fable. It is of an exactness almost scientific. It may be thought that the dimensions of the Island of Atlantis are slightly exaggerated here, but we must remember that the Egyptian priest did not know the immensity of Asia, and that the words "larger than Asia" have not in his mouth the significance that they have to-day. Everything else is perfectly clear and entirely probable. A large island, off the Strait of Gibraltar, mother of a numerous, strong, and warlike race; other smaller islands, in a broad channel separating the large island from the African coast; one may pass easily from the large island to the little ones, and from the latter over to the continent, and it is easy then to gain the shores of the Mediterranean and to subdue the peoples who have become established there, those of the south first, as far as the frontier of Egypt and of Libya, then those of the north, as far as the Tyrrhenian, and even to Greece. This invasion by the Atlantic pirates Athens resists with success. Perhaps, however, she might have been vanquished, when a cataclysm came to her aid, in a few hours engulfing the Island Atlantis, and resounding, with violent shocks and frightful tidal wave, over all the Mediterranean shores. The conflicting armies disappear, taken unawares by the inundation of the shores; and when the survivors recover themselves they perceive that their invaders are dead, and they learn then that the very source is wiped out whence descended those terrible hordes. When long, long after some hardy mariners venture to pass through the Pillars of Hercules and sail across the western seas,

[1] Works of Plato, translated [into French] by V. Cousin, vol. 12, pp. 109–113, Paris, pub. Rey and Gravier.

they are soon stopped by such a profusion of rocks and débris from the engulfed lands that fear seizes them, and they flee these accursed regions, over which seems to hang the anathema of a god.

In another dialogue, which is entitled "Critias," or "Concerning Atlantis," and which, like the foregoing, is from the "Timæus," Plato indulges in a description of the famous island. It is again Critias who is speaking. Timæus, Socrates, and Hermocrates are listening to him. Critias says:

> According to the Egyptian tradition a common war arose 9,000 years ago between the nations on this side of the Pillars of Hercules and the nations coming from beyond. On one side it was Athens; on the other the Kings of Atlantis. We have already said that this island was larger than Asia and Africa, but that it became submerged following an earthquake and that its place is no longer met with except as a sand bar which stops navigators and renders the sea impassable.

And Critias develops for us the Egyptian tradition of the fabulous origin of Atlantis, fallen to the share of Neptune and in which this god has placed the 10 children that he had by a mortal. Then he describes the cradle of the Atlantic race; a plain located near the sea and opening in the central part of the island, and the most fertile of plains; about it a circle of mountains stretching to the sea, a circle open at the center and protecting the plain from the icy blasts of the north; in these superb mountains, numerous villages, rich and populous; in the plain, a magnificent city, the palaces and temples of which are constructed from stones of three colors—white, black, and red—drawn from the very bosom of the island; here and there mines yielding all the metals useful to man; finally the shores of the island cut perpendicularly and commanding from above the tumultuous sea.[1] We may smile in reading the story of Neptune and his fruitful amours, but the geographic description of the island is not of the sort which one jokes about and forgets. This description tallies well with what we would imagine to-day of a great land submerged in the region of the Azores and enjoying the eternal springtime, which is the endowment of these islands; a land formed from a basement of ancient rocks bearing, with some fragments of whitish calcareous terranes, extinct volcanic mountains and lava flows, black or red, long since grown cold.

Such is the Atlantis of Plato, and such, according to the great philosopher, is the history of this island, a history fabulous in its origins, like the majority of histories, yet extremely exact and highly probable in its details and tragic termination. This is, furthermore, all that antiquity teaches us, for the accounts of Theopompus and Marcellus, much vaguer than that of Plato, are inter-

[1] Works of Plato, translated [into French] by V. Cousin, vol. 12, p. 247. Paris, pub. Rey and Gravier.

esting only from the impression that they leave us of the wide circulation of the legend among the peoples along the Mediterranean shores. On the whole, down to very nearly our own era, there was a general belief, all about the Mediterranean, in the ancient invasion by the Atlantians, come from a large island or a continent—come at all events from beyond the Pillars of Hercules, an invasion abruptly checked by the instantaneous or at least very sudden submergence of the country from which these invaders came.

Now, let us see what science teaches as to the possibility or the probability of such a collapsing, so recent, so sudden, so extended superficially, and so colossal in depth. But we must as a preliminary recall the facts of geography as to the region of the Atlantic Ocean where the phenomenon must have occurred.

For a ship sailing due west the distance across the Atlantic Ocean from the Strait of Gibraltar is about 6,400 kilometers (4,000 miles). Such a ship would touch the American coast in the locality of Cape Hatteras. She would not in her voyage meet any land. She would pass, without seeing them, between Madeira and the Azores, and she would leave the Bermudas very far to the south, though these coral islands, very small and low, might to the eyes of the crew have emerged from the marine horizon. Her passengers would have no suspicion of the relief of the ocean depths, so irregular notwithstanding, and none of the mysteries of the "sea of darkness" would have risen before them.

But had the ship lengthened her route a little by making a detour, first toward the southwest, then toward the northwest, then again toward the southwest, it would have been enough, successively, to bring in view Madeira, the more southern Azores, and finally the Bermudas. And if the travelers, whom we are supposing embarked on our vessel, had possessed a perfected instrument for sounding, and had known how to use it, they might have ascertained, not without surprise, that the marine depths over which they were passing are strangely unequal. Very near Gibraltar the bottom of the ocean is 4,000 meters down; it rises again abruptly to form a very narrow socle, which bears Madeira; it drops again to 5,000 meters between Madeira and the southern Azores; reascends at least 1,000 meters in the neighborhood of these latter islands; remains for a long distance between 1,000 and 4,000 to the south and southwest of the Azores, with very abrupt projections, some of which approach very nearly to the surface of the sea; then plunges to more than 5,000 meters, and for a short distance even to more than 6,000; rises again suddenly in a bound which corresponds to the socle of the Bermudas; remains buried under 4,000 meters of water to within a short distance of the American coast, and finally rises again in a steep acclivity toward the shore.

Let us imagine for a moment that we could entirely empty the Atlantic Ocean, drain it completely dry; and, that done, let us contemplate from above the relief of its bed. We shall see two great depressions, two enormous valleys extending north and south, parallel with the two shores, separated one from the other by a median zone elevated above them. The western valley, extending the length of the American coast, is the larger and deeper of the two; it shows oval fosses, or depressions, descending to more than 6,000 meters below the level of the shores, and also occasional elevations, one corresponding to the Bermudas, which, from the bottom of the gulfs, rise boldly toward the surface. The eastern valley, along the European coast, appears to us narrower and of less depth, but much more hilly; and numerous pyramids, some thin and slight like that of Madeira, others massive like those which bear the archipelago of the Canaries and Cape Verde, rise here and there in the midst of the valley or near its eastern border. The much elevated median zone outlines before us a long promontory, whose axis coincides with that of the Atlantic abyss. It curves in an S shape like the two valleys and the two shores, and, starting from Greenland and surrounding in its mass Iceland and the northern islands, goes tapering southward and ends in a point at the seventieth parallel of latitude south. In most of its course, this promontory has a mean breadth of about 1,500 kilometers (937.5 miles). Far from being regular and with a uniformly spherical curve, its surface is everywhere indented, bristling with projections, riddled with hollows, especially in the region of the Azores, what we call the Azores being merely the summits of the highest protuberances.

In this complete view of the ocean drained and dry we would certainly observe many other things, which are otherwise invisible beneath the waters. We would see not only the longitudinal arrangement which I have just described and which has been revealed to us by soundings but also the transverse irregularities which can not fail to exist and of which, at the present time, we know almost nothing, because the soundings have not yet been numerous enough. The map of the archipelago of the Azores shows clearly that the nine great islands of which it is composed are ranged along three parallel bands, in a direction from east-southeast to west-northwest; and these bands are staked out by the islands over a total length of nearly 800 kilometers (500 miles). No doubt such lines are prolonged very far under the waves, and they would have great importance in making a model of the ocean bed, but they are evidently not the only ones. The day will come when the charts of the Atlantic depths will be exact and detailed; we shall then see fault lines and bands of folds crossing the vast abyss and extending

from Europe to the United States, or from Morocco to the West Indies, or from Senegambia to the South American Continent.

Now, let geology say its word. In the same way that the painter's eye perceives a whole world of colors and reflections unsuspected by other men, so is the eye of the geologist impressed by the vague and very uncertain gleams which illumine, for him alone, the darkness of the gulfs and the still deeper night of the distant past. And his ear, sensitive as that of the musician, vibrates to the murmurs, the crackings, and the sighs which come from the earth's depths or from the depths of history and which the majority of men mistake for absolute silence.

Observe one primary fact: The eastern region of the Atlantic Ocean, over all its length and probably from one pole to the other, is a great volcanic zone. In the depression along the coast of Africa and of Europe and in the eastern part of the highly elevated strip which occupies the middle of the sea volcanoes are abundant. All the peaks which reach the surface of the sea outcrop in the form of volcanic islands or bearing volcanoes. Gough Island, Tristan da Cunha, St. Helena, Ascension, the Cape Verde Islands, the Canaries, the great Madeira and the neighboring isles, all the Azores, Iceland, Jan Mayen Island are either integrally or in greater part formed of lava. I will tell in a moment how certain dredgings in 1898 found lavas, at depths of 3,000 meters, on a line from the Azores to Iceland, and at about 500 miles or 900 kilometers to the north of the Azores. One navigator in 1838 established the existence of a submarine volcano on the Equator at about 22° west longitude, or on the line joining Ascension to the archipelago of Cape Verde; warm steam was rising from the waves and shallows had formed unlike those indicated on the charts. On the islands I have just named many volcanoes are still in activity, the extinct ones appear to have been extinguished only yesterday, everywhere earthquakes are frequent, here and there islets may spring up abruptly from the sea or rocks long known may disappear. The continuity of these phenomena is concealed by the ocean covering them, but to the geologist it is unquestionable.

The volcanic zone of the eastern Atlantic is comparable in length, in breadth, and in eruptive or seismic activity, to that which forms the western border of America, and coincides in the south with the cordillera of the Andes; it is one of the characteristic traits of the present phase of the earth, quite like the fiery girdle of the Pacific Ocean. Now, there is no volcano without a convulsion, or, at the very least, not without a subsidence of some portion of the terrestrial crust. The volcanoes of the fiery girdle of the Pacific stake out the border of a deep marine foss which compasses this ocean, and which,

undoubtedly, has not stopped growing deeper; the volcanoes of the Mediterranean appear on the margin of great abysses recently opened and into which enormous mountains have fallen. It must be, therefore, that there is also in the bottom of the Atlantic Ocean, still present, a certain mobility, and that the median wrinkle of this bottom, already much elevated above it, has not finished its relative movement upward in proportion to the eastern depression. While the continental shores of the Atlantic now appear immobile, and a hundred times more impassive than the Pacific shores, the bottom of the Atlantic is in movement in the entire eastern zone, about 3,000 kilometers (1,875 miles) broad, which comprises Iceland, the Azores, Madeira, the Canaries, and the Cape Verde Islands. Here there is even now an unstable zone on the planet's surface, and in such a zone the most terrible cataclysms may at any moment be taking place.

Some cataclysms certainly have occurred, and they date only as from yesterday. I ask all those who are concerned with the problem of Atlantis to listen attentively and to impress on their mind this brief history; there is none more significant: In the summer of 1898 a ship was employed in the laying of the submarine telegraphic cable which binds Brest to Cape Cod. The cable had been broken, and they were trying to fish it up again by means of grappling irons. It was in north latitude 47° 0′ and longitude 29° 40′ west from Paris, at a point about 500 miles north of the Azores. The mean depth was pretty nearly 1,700 fathoms, or 3,100 meters. The relaying of the cable presented great difficulties, and for several days it was necessary to drag the grappling irons over the bottom. This was established: The bottom of the sea in those parts presents the characteristics of a mountainous country, with high summits, steep slopes, and deep valleys. The summits are rocky, and there are oozes only in the hollows of the valleys. The grappling iron, in following this much-disturbed surface, was constantly being caught in the rocks by hard points and sharp edges; it came up almost always broken or twisted, and the broken pieces recovered bore large coarse striæ and traces of violent and rapid wear. On several returns, they found between the teeth of the grappling iron little mineral splinters, having the appearance of recently broken chips. All these fragments belonged to the same class of rocks. The unanimous opinion of the engineers who were present at the dredging was that the chips in question had been detached from a bare rock, an actual outcropping, sharp-edged and angular. The region whence the chips came was furthermore precisely that where the soundings had revealed the highest submarine summits and the almost complete absence of oozes. The fragments, thus torn from the rocky outcrops of the bottom of the Atlantic, are of a vitreous lava, having the chemical composition of the basalts and called *tachylyte* by the petrographers. We are

preserving some of these precious fragments at the Musée de l'Ecole des Mines at Paris.

The matter was described in 1899 to the Académie des Sciences. Few geologists then comprehended its very great import. Such a lava, entirely vitreous, comparable to certain basaltic stones of the volcanoes in the Hawaiian Islands, could solidify into this condition only under atmospheric pressure. Under several atmospheres, and more especially under 3,000 meters of water, it might have crystallized. It would appear to us as formed of confused crystals, instead of being composed solely of colloidal matter. The most recent studies on this subject leave no doubt, and I will content myself with recalling the observation of M. Lacroix on the lavas of Mount Pelee of Martinique: Vitreous, when they congealed in the open air, these lavas became filled with crystals as soon as they were cooled under a cover, even not very thick, of previously solidified rocks. The surface which to-day constitutes the bottom of the Atlantic, 900 kilometers (562.5 miles) north of the Azores, was therefore covered with lava flows while it was still emerged. Consequently, it has been buried, descending 3,000 meters; and since the surface of the rocks has there preserved its distorted aspect, its rugged roughnesses, the sharp edges of the very recent lava flows, it must be that the caving in followed very close upon the emission of the lavas, and that this collapse was sudden. Otherwise atmospheric erosion and marine abrasion would have leveled the inequalities and planed down the entire surface. Let us continue our reasoning. We are here on the line which joins Iceland to the Azores, in the midst of the Atlantic volcanic zone, in the midst of the zone of mobility, of instability, and present volcanism. It would seem to be a fair conclusion, then, that the entire region north of the Azores and perhaps the very region of the Azores, of which they may be only the visible ruins, was very recently submerged, probably during the epoch which the geologists call the present because it is so recent, and which for us, the living beings of to-day, is the same as yesterday.

If you recall now what I told you a little while ago of the extreme inequality of the depths to the south and the southwest of the Azores, you will agree with me that a detailed dredging to the south and the southwest of these islands would give the same results which have been shown at the north, in the operations of fishing up the telegraphic cable again. And before your eyes would increase then, almost immeasurably, the buried region, the region which was abruptly engulfed yesterday, and of which the Azores are no more than the evidences, escaped from the general collapse.

But observe other facts, always of the geologic order. The Atlantic abyss, almost as a whole, seems to be of relatively recent date;

and, before the collapse of the Azorian region, other collapses occurred there, the size of which, more easily measurable, staggers the imagination.

Since Eduard Suess and Marcel Bertrand taught us to regard our planet and to decipher the slow or rapid transformations of its face through unnumbered centuries we have become assured of the existence of a very ancient continental bond between northern Europe and North America and of another continental bond, also very ancient, between the massive Africa and South America. There was a North Atlantic continent comprising Russia, Scandinavia, Great Britain, Greenland, and Canada, to which was added later a southern band made up of a large part of central and western Europe and an immense portion of the United States. There was also a South Atlantic, or African-Brazilian, Continent extending northward to the southern border of the Atlas, eastward to the Persian Gulf and to Mozambique Channel, westward to the eastern border of the Andes and to the Sierras of Colombia and Venezuela. Between the two continents passed the *mediterranean depression*, that ancient maritime furrow, which has formed an escarp about the earth since the beginning of geologic times, and which we still see so deeply marked in the present Mediterranean, the Caribbean Sea, and the Sunda or Flores Sea. A chain of mountains broader than the chain of the Alps, and perhaps in some parts as high as the majestic Himalaya, once lifted itself on the land inclosed shore of the North Atlantic continent, embracing the Vosges, the Central Plateau of France, Brittany, the south of England and of Ireland, and also Newfoundland, Nova Scotia, and, in the United States, all the Appalachian region. The two coasts which front each other above the Atlantic waters 3,000 kilometers (1,875 miles) apart, that of Brittany, Cornwall, and the south of Ireland on one side, that of Newfoundland and Nova Scotia on the other side, are among the finest estuary shores in the world, and their estuaries are face to face. In the one as in the other, the folds of the ancient chain are cut abruptly, and often naturally, by the shore; and the dirigent lines of the European chain are directly aligned with those of the American chain. Within a few years it will be one of the pleasures of oceanographers, by clearing up the detailed chart of the ocean beds between Ireland and Newfoundland, to establish the persistence of a fold, of oriented mountainous aspect, on the site of this old engulfed mountain chain. Marcel Bertrand gave the name of "Hercynian" to this old chain. Eduard Suess calls it the chain of the Altaïdes, for it comes from far-off Asia, and to him the Appalachians are nothing less than the American Altaïdes.

Thus the region of the Atlantic, until an era of ruin which began we know not when, but the end of which was the Tertiary, was

occupied by a continental mass, bounded on the south by a chain of mountains, and which was all submerged long before the collapse of those volcanic lands of which the Azores seem to be the last vestiges. In place of the South Atlantic Ocean there was, likewise, for many thousands of centuries a great continent now very deeply engulfed beneath the sea. It is probable that these movements of depression occurred at several periods, the contours of the Mediterranean, which then separated the two continents, being frequently modified in the course of the ages. From the middle of the Cretaceous the Mediterranean advanced as far as the Canaries, and its southern shore was then very near the site to-day occupied by these islands. On this matter we have a precise datum recently found by M. Pitard, and very exactly fixed by MM. Cottreau and Lemoine. The region of the Cape Verde Islands, at the same era, still belonged to the African-Brazilian Continent.

While the Mediterranean in this Atlantic region was being enlarged by the gradual collapsing of its shores, it was being subdivided, perhaps, and in any case its bottom was becoming undulated by the formation underneath it of new folds and wrinkles. In this broad and deep furrow, where the sediments from the north and south continents were accumulating to enormous thicknesses, the movement was in fact developing which during the Tertiary period gave rise in Europe to the Alpine chain.

How far did this Tertiary chain, this Alpine chain, extend in the Atlantic region? And, also, what was the extent of its faultings in this now oceanic region? Did some fragments of the chain rise high enough to lift themselves for some centuries above the waters before returning, suddenly or slowly, into the starless night? Did the folds of the Alps or of the Atlas Mountains spread abroad as far as the Caribbean Sea? And must we admit, between our Alps and the Cordillera of the West Indies, which is itself only a sinuous outpost of the grand cordillera of the Andes, a tectonic bond, as we are admitting, since Suess has shown it to us, a stratigraphic bond? These questions are still unanswered. M. Louis Gentil has followed, in the western Atlas Mountains, the folds of the Tertiary chain to the shore of the ocean, and he has seen these folds, gradually diminishing, "drowning themselves,"[1] as the miners say, descend into the waves; their direction, on this coast of Agadir and of Cape Ghir, is such that, if prolonged in mind, they would lead us to the Canaries. But to be able to affirm that the Canaries are highly elevated fragments of the engulfed Atlas one must have observed the folds in their Cretaceous sediment, and I do not believe that this observation has been made. The Atlas Range,

[1] "S'ennoyant."

as every one knows, is only one of the branches of the great Tertiary chain; it is the prolongation in the north of Africa of the mountainous system of the Apennines. As to the true Alps, which are the principal branch of the same chain, they may be followed without difficulty as far as the Sierra Nevada, and even to Gibraltar. Under the Strait of Gibraltar they are reunited to the Rif Mountains. But the Rif, in which some geologists would see the continuation of the entire Alpine system, certainly correspond to only a part of this system; all of one northern band of Alpine folds, emerging from under the nappes of the Sierra Nevada, moves toward the west instead of turning toward Gibraltar. I see them, under the recent terranes, crossing Andalusia, forming a narrow band on the coast of Algarve, and finally, at Cape St. Vincent, abruptly cut off and not showing any tendency toward "drowning," hiding themselves in the sea. Their direction, if prolonged, would lead us to Santa Maria, the most southern of the Azores, where we observe undisturbed Miocene sediments.

Summing up, there are strong reasons for believing in the Atlantic prolongation of the Tertiary folds, those of the Atlas Mountains toward the Canaries, those of the Alps toward the southern islands of the Azores, but nothing yet permits of either extending very far or limiting very narrowly this prolongation. The sediments of Santa Maria prove only this, that at the Miocene epoch—that is, when the great Alpine movements were terminated in Europe—a Mediterranean shore extended not far from this region of the Azores, the shore of a continent or of a large island. Another shore of the same Miocene sea passed near the Canaries.

In every way the geography has singularly changed in the Atlantic region in the course of the later periods of the earth's history; and the extreme mobility of the bottom of the ocean, shown at the present time by such a multiplicity of volcanoes and such an extent of lava fields, surely dates from far back. Depressions during the secondary period, enlarging the Mediterranean and causing the ruins of the Hercynian chain to disappear; foldings in the entire Mediterranean zone during the first half of the Tertiary era, modifying the beds of this sea and causing mountainous islands to arise here or there near its northern coast; collapses again at the close of the Miocene, in the folded Mediterranean zone and in the two continental areas, continuing up to the final annihilation of the two continents and the obliteration of their shores; then, in the bottom of the immense maritime domain resulting from these subsidences, the appearance of a new design whose general direction is north and south and which conceals or, at the very least, partially obliterates the former marking; the pouring out of the lavas, everywhere a little, in the residual islands and even on the bottom of the seas, this pour-

ing forth being the necessary and inevitable counteraction of the very deep, downward sinking of such portions of the crust. Such, in brief, is the history of the Atlantic Ocean for several million years. Many incidents of this history will never be exactly correlated, but we know that certain of them are very recent. M. Louis Gentil has given us, in this connection, some very interesting observations, gathered along the Moroccoan coasts. The Strait of Gibraltar was opened at the beginning of the Pliocene. Already, at the Tortonian epoch, the sea was washing the shore of Agadir, and consequently Madeira and the Canaries were then already separated from the Continent. But the Tortonian and even the Plaisancian beds on this Moroccoan shore are faulted and folded. Therefore in the zone of prolongation of the Atlas Mountains there have been important movements posterior to the Plaisancian, and consequently Quaternary. The channel which separates Madeira and the Canaries from the African mass was again deepened in Quaternary times.

Such are the data of geology. The extreme mobility of the Atlantic region, especially in conjunction with the mediterranean depression and the great volcanic zone, 3,000 kilometers (1,875 miles) broad, which extends from north to south, in the eastern half of the present ocean; the certainty of the occurrence of immense depressions when islands and even continents have disappeared; the certainty that some of these depressions date as from yesterday, are of Quaternary age, and that consequently they might have been seen by man; the certainty that some of them have been sudden, or at least very rapid. See how much there is to encourage those who still hold out for Plato's narrative. Geologically speaking, the Platonian history of Atlantis is highly probable.

Now let us consult the zoologists. There is a young French scholar, M. Louis Germain, who is going to answer us; and I really regret very much not being able actually to give him the floor, but instead to be only his very inadequate interpreter.

First of all, the study of the present terrestrial fauna of the islands of the four archipelagoes, the Azores, Madeira, the Canaries, and Cape Verde, has convinced M. Germain of the clearly continental origin of this fauna. He even observes numerous indications of an adaptation to desert life. The malacological fauna especially is connected with that of the region about the Mediterranean, while differing from the African equatorial fauna. The same analogies with the fauna about the Mediterranean are observed in the Mollusca of the Quaternary.

Secondly, the Quaternary formations of the Canaries resemble those of Mauritania and inclose the same species of Mollusca; for example, the same species of Helix.

From these two primary facts M. Germain deduces the evident conclusion that the four archipelagoes were connected with the African Continent up to an epoch very near our own, at the very least until toward the end of the Tertiary.

Thirdly, in the present Mollusca of the four archipelagoes there are some species which seem to be the survivors of the fossil species of the European Tertiary; and a similar survival exists also in the vegetable series, a fern, the *Adiantum reniforme*, at present extinct in Europe, but known in the Pliocene of Portugal, continuing to-day to live in the Canaries and in the Azores.

M. Germain deduces from this third fact the bond, up to Pliocene times, with the Iberian Peninsula, of the continent which embraced the archipelagoes and the severing of this bond during the Pliocene.

Fourthly, the Pulmonata Mollusca, called Oleacinidæ, have a peculiar geographic distribution. They live only in Central America, the West Indies, the Mediterranean Basin, and the Canaries, Madeira, and the Azores. In America they have preserved the large size that they had in Europe in the Miocene epoch; in the Mediterranean Basin and in the Atlantic islands they have become much smaller.

This geographic distribution of the Oleacinidæ evidently implies the extension to the West Indies at the beginning of the Miocene of the continent which included the Azores, the Canaries, and Madeira, and the establishing during the Miocene, or toward its close, of a separation between the West Indies and this continent.

Two facts remain relative to the marine animals, and both seem impossible of explanation, except by the persistence, up to very near the present times, of a maritime shore extending from the West Indies to Senegal, and even binding together Florida, the Bermudas, and the bottom of the Gulf of Guinea. Fifteen species of marine Mollusca lived at the same time, both in the West Indies and on the coast of Senegal and nowhere else, unless this coexistence can be explained by the transportation of the embryos. On the other hand, the Madreporaria fauna of the island of St. Thomas, studied by M. Gravier, includes six species—one does not live outside of St. Thomas, except in the Florida Reefs; and four others are known only from the Bermudas. As the duration of the pelagic life of the larvæ of the Madreporaria is only a few days, it is impossible to attribute this surprising reappearance to the action of marine currents.

In taking all this into account, M. Germain is led to admit the existence of an Atlantic continent connected with the Iberian Peninsula and with Mauritania and prolonging itself rather far toward the south so as to include some regions of desert climate. During the Miocene again this continent extends as far as the West Indies.

It is then portioned off, at first in the direction of the West Indies, then in the south, by the establishment of a marine shore which extends as far as Senegal and to the depths of the Gulf of Guinea, then at length in the east, probably during the Pliocene, along the coast of Africa. The last great fragment, finally engulfed and no longer having left any further vestiges than the four archipelagoes, would be the Atlantis of Plato.

I will refrain in my incompetence from expressing the slightest opinion as to the zoologic value of the facts pointed out by M. Germain, and as to the degree of accuracy of the conclusions that he draws from them. But how can one fail to be struck by the almost absolute agreement of these zoologic conclusions with those to which geology has led us? And who could now, in the face of so complete an accord, based on arguments so different, still doubt the preservation, up to an epoch very near our own, of vast lands emerged in the part of the ocean which is west of the Pillars of Hercules?

That is sufficient; and this is what we should remember from our brief talk. To reconstruct even approximately the map of Atlantis will always remain a difficult proposition. At present we must not even think of it. But it is entirely reasonable to believe that, long after the opening of the Strait of Gibraltar, certain of these emerged lands still existed, and among them a marvelous island, separated from the African Continent by a chain of other smaller islands. One thing alone remains to be proved—that the cataclysm which caused this island to disappear was subsequent to the appearance of man in western Europe. The cataclysm is undoubted. Did men then live who could withstand the reaction and transmit the memory of it? That is the whole question. I do not believe it at all insolvable, though it seems to me that neither geology nor zoology will solve it. These two sciences appear to have told all that they can tell; and it is from anthropology, from ethnography, and, lastly, from oceanography that I am now awaiting the final answer.

Meanwhile, not only will science, most modern science, not make it a crime for all lovers of beautiful legends to believe in Plato's story of Atlantis, but science herself through my voice calls their attention to it. Science herself, taking them by the hand and leading them along the wreck-strewn ocean shore, spreads before their eyes, with thousands of disabled ships, the continents submerged or reduced to remnants, and the isles without number enshrouded in the abyssmal depths.

For my own part I can not help thinking of the abrupt movements of the earth's crust and, among others, of that terrifying phenomenon of the almost sudden disappearance of some outskirt of a continent,

some element of a chain of mountains, some great island, into a gulf many thousands of meters deep. That such a phenomenon may be produced, and even repeated many times, in the course of later geologic periods, and that it may often attain to gigantic size, this no geologist is right in questioning. We are surprised sometimes that similar cataclysms have left no traces on our shores, without reflecting that it is the very suddenness of their arrival and their flight which renders them scarcely conceivable. Not one of them, in fact, has ever occurred without initiating a lowering of the mean sea level, but the counteraction is never delayed at all, and the rapid rising of another division of the ocean bottom, or the slower issue of the by no means unimaginable submarine flows of lavas, has soon reestablished the equilibrium; so exact is the balance in which are weighed—on one side the deeps, on the other the mountains.

And when in thought I thus review those frightful pages of the earth's history, usually in presence of the smiling sea, indifferent, before the sea "more beautiful than cathedrals," I dream of the last night of Atlantis, to which perhaps the last night, that "great night" of humanity will bear semblance. The young men have all departed for the war, beyond the islands of the Levant and the distant Pillars of Hercules; those who remain, men of mature age, women, children, old men, and priests, anxiously question the marine horizon, hoping there to see the first sails appearing, heralds of the warriors' return. But to-night the horizon is dark and vacant. How shadowy the sea grows; how threatening is the sky so overcast! The earth for some days has shuddered and trembled. The sun seems rent asunder, here and there exhaling fiery vapors. It is even reported that some of the mountain craters have opened, whence smoke and flames belch forth and stones and ashes are hurled into the air. Now on all sides a warm gray powder is raining down. Night has quite fallen, fearful darkness; nothing can be seen without lighted torches. Suddenly seized with blind terror, the multitude rushes into the temples; but lo! even the temples crumble, while the sea advances and invades the shore, its cruel clamor rising loud above all other noise. What takes place might indeed be the Divine wrath. Then quiet reigns; no longer are there either mountains or shores; no longer anything save the restless sea, asleep under the tropic sky, with its stars unnumbered; and in the breath of the trade winds I hear the voice of the immortal poet singing:

> O, waves, how many mournful tales you know!
> Wide waves profound, that kneeling mothers fear!
> Those tales the flooding tides recount with care;
> And thus arise those voices of despair
> Which you to-night again bring with you here!

ROBSON PEAK FROM THE NORTHERN SIDE OF ROBSON PASS.

To the left the dark base of Iyatunga (Black Rock) Mountain with Blue Glacier extending down to Berg Lake. Robson Peak rises 7,000 feet above the lake to its snowy crest. Photograph by Mary Vaux Walcott.

EVIDENCES OF PRIMITIVE LIFE.

By Charles D. Walcott.

[With 18 plates.]

INTRODUCTION.

Few of us have a clear realization of the age of the earth. Under many deceptive aspects she carries with her the secrets of a long and busy life, one of such fascinating activity that it is not surprising that students are ever seeking to unravel the mysteries of the past. With all the evidences of youth there is to be felt, especially among the mountains, a sense of age and infinite power, and we are inspired with awe as we trace the base of worn-down rocks, miles in thickness, that formed the mountain ranges far back in geologic time.

The age of the earth in years I shall not attempt to discuss. A recent résumé[1] shows the relative age of the sedimentary strata for each period of its history. These figures point to a minimum time limit of scarcely less than 90,000,000 of years since water and wind began to transport continental earth and rocks over the land and into seas and lakes. How long before that the earth history began it is difficult even to conjecture. With the discovery of the stored-up energy of radium and the development of the planetesimal hypothesis by Dr. T. C. Chamberlin, the supposed fixed standards of the past generation have been swept away and new conceptions are being slowly formulated and subjected to all the tests that modern earth science can conceive.

A concrete conception of the age of life on the earth is suggested by recalling that the Cambrian system, with its early and semiprimitive forms of invertebrate marine fossils, stands, roughly speaking, midway in the earth's history; approximately as long a period of time was required to develop life to the Cambrian stage of evolution as has since elapsed up to the present time.

My own investigations have been mainly in the Cambrian and pre-Cambrian strata and have involved new and somewhat startling

[1] M. Joly: The Age of the Earth, Ann. Rept. Smithsonian Inst., 1911, Washington, 1912, pp. 271–293.

discoveries that helped to show how very much earlier life was developed on our planet than we had previously supposed. These researches have taken into consideration the records left on all the continents and many of the great islands. The Cambrian rocks of China and their included traces of life were compared and reviewed; the problem of the abrupt appearance of the Cambrian fauna on the North American continent was considered; comparisons were instituted from measurements of sections in the Cordilleran and Appalachian regions of the United States and Canada, including the Bow River Valley of Alberta, and the Robson Peak and Mount Burgess districts of British Columbia, where peculiarly rich fossil beds were discovered; more recently certain horizons of the Cambrian formations of the Mississippi Valley were discussed with their faunas, followed by the study now in hand of pre-Cambrian Algonkian traces of life.

In these inquiries I have had generous assistance in obtaining collections and exchanging publications with students all over the world, including geologists, paleontologists, zoologists, and paleobotanists in America and Europe and in far-away outposts of China, Siberia, India, Australia, and New Zealand.

Field work, with compass, hammer, and chisel, has been the rule, followed by laboratory and critical comparison of many thousands of specimens of fossil genera and species of ancient marine life, and often study of microscopic sections of rocks and fossils in the hope of finding evidence of the presence of minute and active bacterial and simple algal workers, such as exist in modern seas and lakes, which by their united efforts form great masses of the recent sea and lake deposits.

PRE-CAMBRIAN ALGONKIAN NORTH AMERICA.[1]

In North America, with its great epicontinental formations, the Algonkian era, between the inchoate Archean and the well-defined Cambrian, was a time of continental elevation and largely terrigenous sedimentation in nonmarine bodies of water, and of deposition by aerial and stream processes in favorable areas. Marine sediments undoubtedly accumulated in the waters along the outer ocean shores of the continent, but they are unknown to us, and great quantities of eruptive matter were extruded into the central Lake Superior region (Keweenawan). The agencies of diastrophism exerted their influence throughout this long period, though with decreasing energy, until they became practically quiescent during the latter part of Algonkian time.

[1] Problems of American Geology, Yale Univ. Press, 1915, pp. 166–167. Walcott: The Cambrian and its problems.

The North American continent was larger at the beginning of known Cambrian time than at any subsequent period, other than possibly at the end of Paleozoic time and the end of Cretaceous time, when the land area was equally extensive. Indeed, it is highly probable that its area was even greater then than now, for no marine deposits containing pre-Cambrian life, as they were laid down in Lipalian[1] time immediately preceding the Cambrian period, have been discovered in the North American Continent or elsewhere, so far as known.

I gradually came to the conclusion[2] that the most natural explanation of the absence of the traces of a distinct marine pre-Cambrian fauna is that the North American continent in pre-Cambrian time was at such an elevation above the sea that there is now no record of the sediments deposited on the under sea shelf about the continental area of that time. This presupposes that the great series of pre-Cambrian Algonkian sediments in the Rocky Mountain region were deposited in an inland mediterranean, or a series of great lakes and flood plains such as existed in Tertiary times.[3] The same conclusion applies to all of the later pre-Cambrian Algonkian formations of the Lake Superior region, Texas, Arizona, and so forth.

On this hypothesis the evolution of the pre-Cambrian fauna was taking place in waters contiguous to the continental area, and their remains, buried in the sediments then accumulating, have not been found, owing to the fact that those sediments are now hidden beneath the sea off the present coast lines of the continent. That such a condition existed is suggested by the almost total absence of any traces of life in the existing pre-Cambrian sediments.

EXTENT OF WITHDRAWAL OF SEAS IN ALGONKIAN TIME.[4]

That the present area of the North American Continent was higher than the level of the Atlantic and Pacific Oceans at the beginning of known Cambrian time is, I think, well established, and with the data available it would appear that all other continental areas were in a similar condition. What diastrophic action caused the with-

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[1] Abrupt appearance of the Cambrian fauna on the North American Continent. Smithsonian Misc. Coll., vol. 57, no. 1, 1910, p. 14 (footnote). Lipalian (λειπ+ἁλς) was proposed for the era of unknown sedimentation between the adjustment of pelagic life to littoral conditions and the appearance of the Lower Cambrian fauna. It represents the period between the formation of the Algonkian continents and the earliest encroachment of the Lower Cambrian sea.

[2] *Olenellus* and other genera of the Mesonacidæ, Smithsonian Misc. Coll., vol. 53, no. 6, 1910.

[3] The crustacean and annelid faunas described from these sediments [Walcott, 1899, Pre-Cambrian fossiliferous formations, Bull. Geol. Soc. America, vol. 10, p. 238] might quite as well have been fresh-water as marine forms. There is nothing as far as known to indicate that they were necessarily limited to a marine habitat.

[4] Abrupt appearance of the Cambrian fauna on the North American Continent. Smithsonian Misc. Coll., vol. 57, no. 1, 1910, p. 12.

drawal of the oceanic waters from the continental areas during the great period represented by the non-marine deposition of the later Algonkian sediments and the period of erosion preceding the deposition of the superjacent Cambrian sediments, is unknown. It may have been produced by a sinking of the ocean bed that lowered the shore line of all the continents. It was of world-wide extent and of great duration, and it was during this period that the open-sea fauna was presumably first developed in the open ocean, as outlined by Brooks.[1] It probably found its way to the littoral zone and developed in the protected waters along the ancient epicontinental shelves. Of this period we have no known record either in marine sedimentation or in life, but I think that the life of the oceans became adapted to littoral and shore conditions in Algonkian time during a period when the relation of all the continents to the sea level was essentially the same as at the present time, or possibly the continents may have been still more elevated in relation to the surrounding oceans.

The known fossils contained in the Algonkian sediments of the Cordilleran geosyncline lived in fresh or brackish waters that were rarely in connection with marine waters on the margins of the Algonkian continent of North America. This will explain the abrupt appearance of *Beltina*, a highly specialized shrimp-like crustacean, deep down in the Beltian series.

When the oceanic waters gained access to the Algonkian continental areas at the beginning of Cambrian time they brought with them the littoral marine fauna which had been developed during the Lipalian sedimentation, and buried its remains in the sands and muds which form the Lower Cambrian deposits. The apparently abrupt appearance of this fauna is to be explained by the absence on our present land areas of the sediments, and hence the faunas of the Lipalian period. This resulted from the continental area being above sea level during the development of the unknown ancestry of the Cambrian fauna.

I fully realize that the conclusions above outlined are based primarily on the absence of a marine fauna from the Algonkian rocks, but until such is discovered I know of no more probable explanation of the abrupt appearance of the Cambrian fauna.

ALGONKIAN FORMATIONS.

The Algonkian rocks are largely formed of mud, sand, gravel, and volcanic rocks that were deposited in lakes, on plains, or in valleys by the action of water, wind, and eruptive agencies.

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[1] Brooks, W. K.: The origin of the oldest fossils and the discovery of the bottom of the ocean, Jour. Geol., vol. 2, 1894, pp. 455–479.

On the eastern side of North America the rocks are mostly formed of siliceous mud and sand; in the Lake Superior region, siliceous mud, sand, gravel, and an immense mass of eruptive rock; in the Rocky Mountain and adjacent areas, siliceous and calcareous muds, fine sands, and a small amount of eruptive rock. In Montana the Algonkian rocks are from 12,000 to 25,000 or more feet in thickness and contain great beds of limestone, in which traces of life have been found. One of them, called the Newland limestone, is particularly rich in algal deposits.[1]

UNCONFORMITY BETWEEN THE CAMBRIAN AND PRE-CAMBRIAN ROCKS.[2]

The variation in thickness of the basal Cambrian conglomerate seems to indicate that the pre-Cambrian surface over which it was deposited was broadly irregular. The Cambrian sea was evidently transgressing across the dark siliceous shales of the pre-Cambrian land and reducing them to rolled pebbles, angular fragments, and mud. The mud gave origin to small lentiles of shale similar in character to the shale below the unconformity, while lentiles of sandstone of greenish tint indicate that fine material was being derived from still older pre-Cambrian formations than the shale.

Of greater importance is the evidence that the sediments of the two periods were deposited under different physical conditions. The Cambrian sandstones are composed of clean, well-washed grains, and the Cambrian calcareous and argillaceous shales were deposited as muds offshore along with the remains of an abundant marine life. The Algonkian Hector shales[3] of the pre-Cambrian are siliceous and without traces of life; the sandstones are impure and dirty, with the quartz grains a dead milky white or glassy and iron stained. These sediments were evidently deposited in relatively quiet, muddy, fresh or brackish waters.

I do not compare the limestone formations, as in the Cambrian they are 2,000 feet or more above the plane of unconformity at the base of the Cambrian and much farther below in the Algonkian series.

ORIGIN OF ALGONKIAN LIMESTONES.[4]

The stream flow and drainage into the Algonkian lakes undoubtedly afforded all of the soluble mineral matter necessary to account for the limestones, siliceous shales, and calcium carbonate deposits of

[1] Pre-Cambrian Algonkian algal flora, Smithsonian Misc. Coll., vol. 64, no. 2, 1914.

[2] Pre-Cambrian rocks of the Bow River Valley, Alberta, Canada, Smithsonian Misc. Coll., vol. 53, no. 7, 1910, p. 426.

[3] Algonkian, Hector-Corral Creek series, Bow River Valley, Alberta, Canada. See section, Smithsonian Misc. Coll., vol. 53, no. 7, 1910, p. 428.

[4] Pre-Cambrian Algonkian algal flora, Smithsonian Misc. Coll., vol. 64, no. 2, 1914, p. 84.

the Algonkian series of formations,[1] but the origin of the great pre-Cambrian limestones of western America has long been a mooted question, and the nature of the concretionarylike *Cryptozoon* (pl. 2) has not been so definitely determined as to be accepted by common consent either as of plant or animal origin. Twenty years ago I had a number of thin sections made of the matrix and "fossils" from the limestone of the Chuar terrane of the Grand Canyon series of Arizona[2] and later of specimens from the Belt series of Montana. Not being able to discover any traces of detailed or minute structure, the specimens and slides were put aside for future study. Recently I have had occasion to consider the question of the origin of the limestones of the great pre-Cambrian Algonkian formations of the Cordilleran area, and in this connection to determine if possible whether there was any relation between the so-called *Cryptozoon* and the presence of the Algonkian series of limestones.

The carbonaceous matter in the dark Newland limestones is shown by the black, flocculent residue that accumulates when a fragment of limestone is dissolved in hydrochloric acid and by the bituminous odor given off when the rock is struck with a heavy hammer. This carbonaceous matter was probably derived from the bacteria and algæ of the time.[3]

The limestones of the Newland formation have more or less magnesian content, but many of the layers are pure limestone, especially those containing the reefs or banks of algal remains. The specimens of algal remains are usually magnesian and siliceous, which accounts for the weathering in relief (pls. 2 and 3) and the ease with which they are etched by the solution of the limestone in weak hydrochloric acid.

The purer limestones are of considerable vertical thickness and their distribution indicates bodies of water several thousand square miles in area. The banks or reefs of algal deposits make a small percentage of the total mass of limestone, but if we assume, as I think we may, that the bacteria were active agents in the deposition of the soluble bicarbonate of lime in Algonkian waters, a plausible explanation is found for the occurrence of the homogeneous limestones of the Algonkian in which no traces of fossils have been found.[4]

FOSSIL BACTERIA.

The occurrence of bacteria in a fossil state has long been known.

Dr. Clement Reid, in an article on Paleobotany, states that[5]—

> the first evidence for the existence of Paleozoic bacteria was obtained in 1879 by Van Tieghem, who found that in silicified vegetable remains from the coal

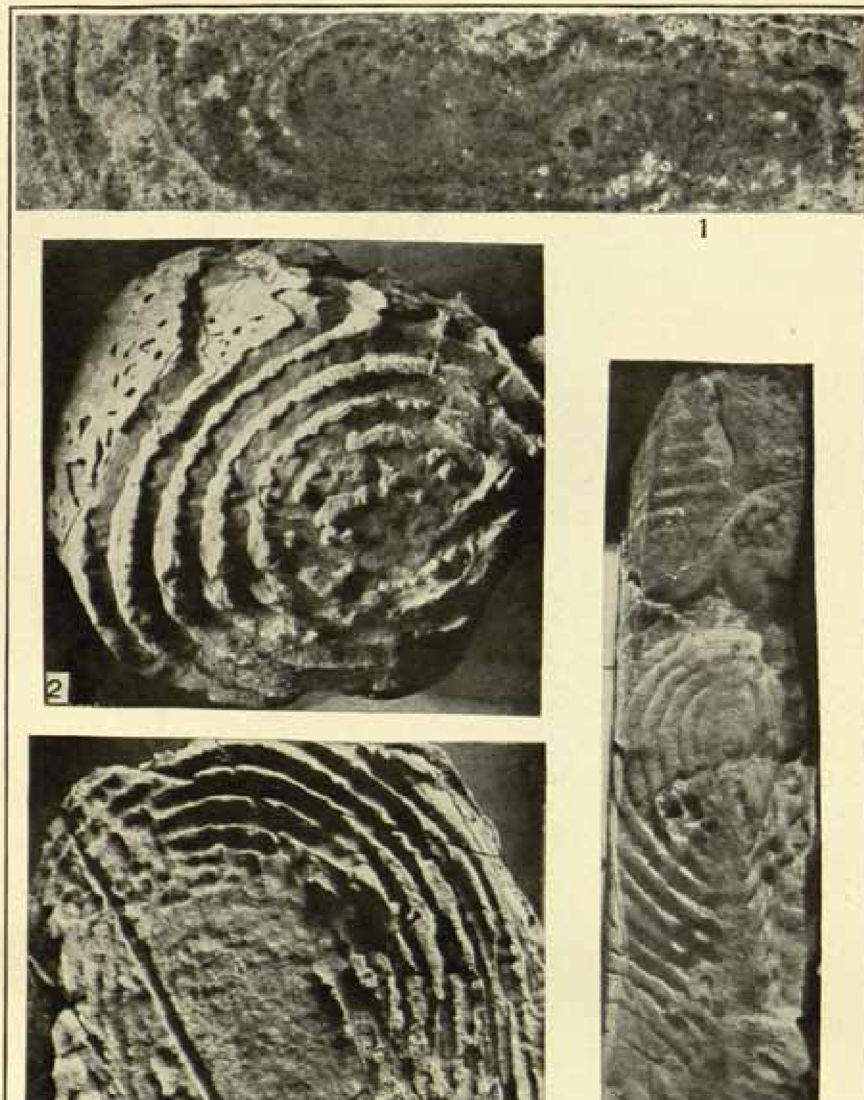
[1] Smithsonian Misc. Coll., vol. 64, no. 2, 1914, p. 89.

[2] *Cryptozoon ? occidentale* Dawson, Bull. Geol. Soc. America, vol. 10, 1899, pp. 232–234, pl. 23, figs. 1–4.

[3] Pre-Cambrian Algonkian algal flora, Smithsonian Misc. Coll., vol. 64, no. 2, 1914, p. 95.

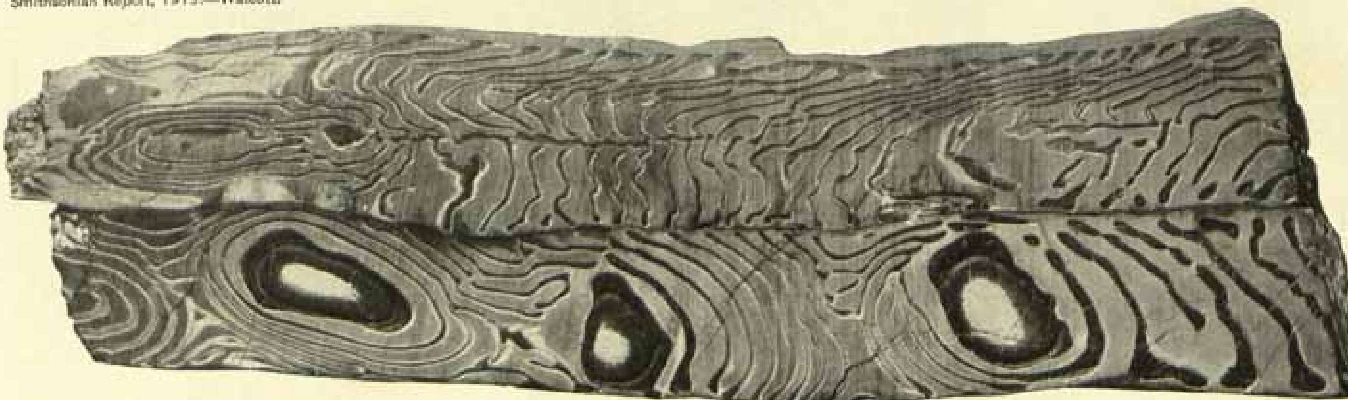
[4] Idem, p. 94.

[5] Encyclopædia Britannica, 11th ed., vol. 20, 1911, p. 525.



SECTIONS OF MODERN AND ALGONKIAN ALGAL FORMS.

1, Lake Ball; 2, 3, *Newlandia concentrica* Walcott; 4, *Newlandia frondosa* Walcott.



CURIOUS PATTERN IN LIMESTONE, SUPPOSED TO BE THE RESULT OF ALGAL DEPOSITS.

measures of St. Étienne the cellulose membranes showed traces of subjection to butyric fermentation such as is produced at the present day by *Bacillus amylobacter;* he also claimed to have detected the organism itself. Since that time a number of fossil bacteria, mainly from Paleozoic strata, have been described by Renault, occurring in all kinds of fossilized vegetable and animal débris. The supposed micrococci present little that is characteristic; the more definite, rodlike form of the bacilli offers a better means of recognition, though far from an infallible one; in a few cases dark granules, suggestive of endospores, have been found within the rods. On the whole, the occurrence of bacteria in Paleozoic times, so probable a priori, may be taken as established, though the attempt to discriminate species among them is probably futile.

M. Renault, in 1895, wrote:

It may be surprising that beings like the bacteria, whose teguments are so slightly distinct, should have been preserved in a manner clear enough so that their presence is often easier to discover when they are fossil than when they are living.[1]

The reason for this, M. Renault continues, is because this delicate tegument has taken on a certain discoloration, which makes it stand out clearly from the surrounding matrix. Though, of course, highly microscopic, its form is preserved with absolute perfection. In the secondary and Tertiary (Permian) strata he distinguished several varieties, both of bacteria and micrococci, resembling almost identically the living forms, and he stated that the only reason he hesitated to identify them as positively the same was because of the impossibility of subjecting fossil bacteria to the culture test. In this test, as is well known, the various genera of bacteria, though often looking alike, behave very differently and thus are distinguishable and separable. At present, therefore, we may only point out apparent generic differences in the fossil bacteria revealed by the microscope.

PRE-CAMBRIAN ALGONKIAN BACTERIA.

The presence of minute forms of algæ and bacteria in the ancient pre-Cambrian rocks was suspected for several years before they were found. From the part they both play in the deposition of calcium carbonate in modern waters and the fact that bacteria are usually present when animal or vegetable matter is broken down by decomposition it seems that they must have existed almost from the beginning of life on earth, and that in this way we may explain the presence of limestone of pre-Cambrian Algonkian time that is found in Montana and other parts of North America.

In the spring of 1914 after careful study of the problem it was concluded to be quite probable that bacteria were an important fac-

[1] M. Renault, Recherches sur les Bactériacées fossiles, Ann. Sci. Nat., Bot., Vol. 2, Paris, 1896, pp. 274–349.

tor in the deposition of the Algonkian limestones, but no definite bacteria had been discovered. From specimens collected in the summer of that year many thin sections were prepared, and in these Dr. Albert Mann, microscopist and student of diatoms and bacteria, discovered individual cells and apparent chains of cells (pl. 4, figs. 2 and 3) which correspond in their physical appearance with the cells of micrococci (pl. 4, fig. 1), a form of bacteria of to-day. The world at large has believed that bacteria were modern forms of life, but they had been found as explained above in fossil wood of Carboniferous time and now we are made to realize that they existed in the first known epoch of the earth's life history, many millions of years ago.

For the purpose of comparison an illustration is given of a group of recent forms as illustrated in the Encyclopædia Britannica[1] and of the form of cells shown in the thin sections cut from the fossil algal remains of the Newland limestone (pl. 4).

ALGONKIAN FOSSIL ALGAL REMAINS.

In Montana it was found that a great series of pre-Paleozoic sedimentary rocks was exposed by the uplift of the granite mass forming the summit of Mount Edith of the Big Belt Mountains, in such a way that the thickness of the sandstones, limestones, and shales could be readily measured in the numerous sections exposed in the canyons worn by waters descending from the higher points to the valley surrounding the range. Nearly 5 miles in thickness of rock were measured, and in them limestone reefs of fossil algal remains were found and large numbers of typical specimens were collected.

It was observed that some of the algal remains were deposited very much in the same manner as those that are now being deposited in many fresh-water lakes, and that many of the forms had a character similar to those being deposited through mechanical and algal agencies in the thermal springs and pools of the Yellowstone National Park. A comparison of microscopic cells from recent blue-green algæ and their Algonkian representatives disclosed surprising similarity (pl. 5) and led to the conclusion that this type of alga existed very early in the history of life.

On the north side of the East Gallatin River two very rich beds of algal remains were found, many of which, on account of the fossil being silicified and imbedded in a softer limestone, were weathered out in relief, as shown by plate 3.

[1] Eleventh ed., vol. 3, p. 160, fig. 5.

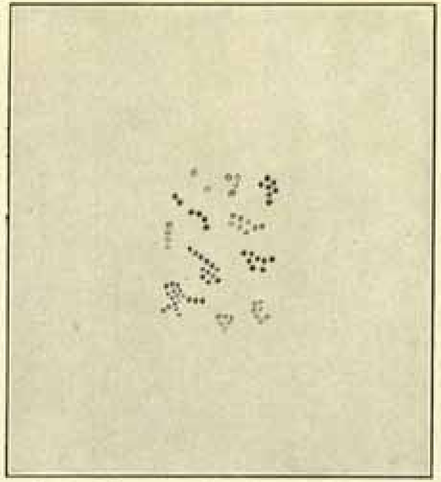
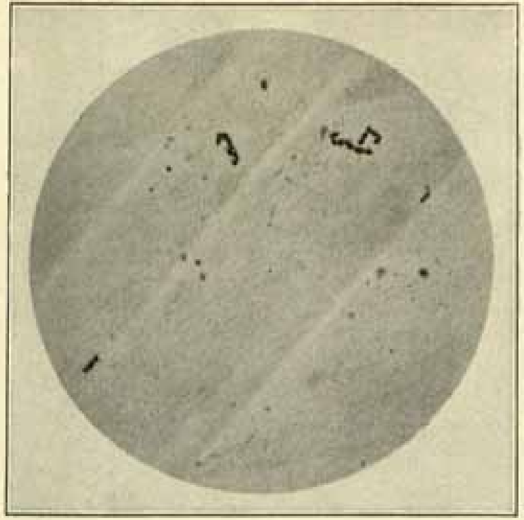
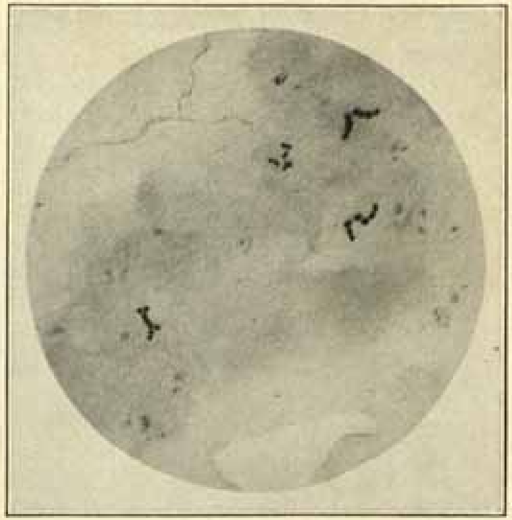
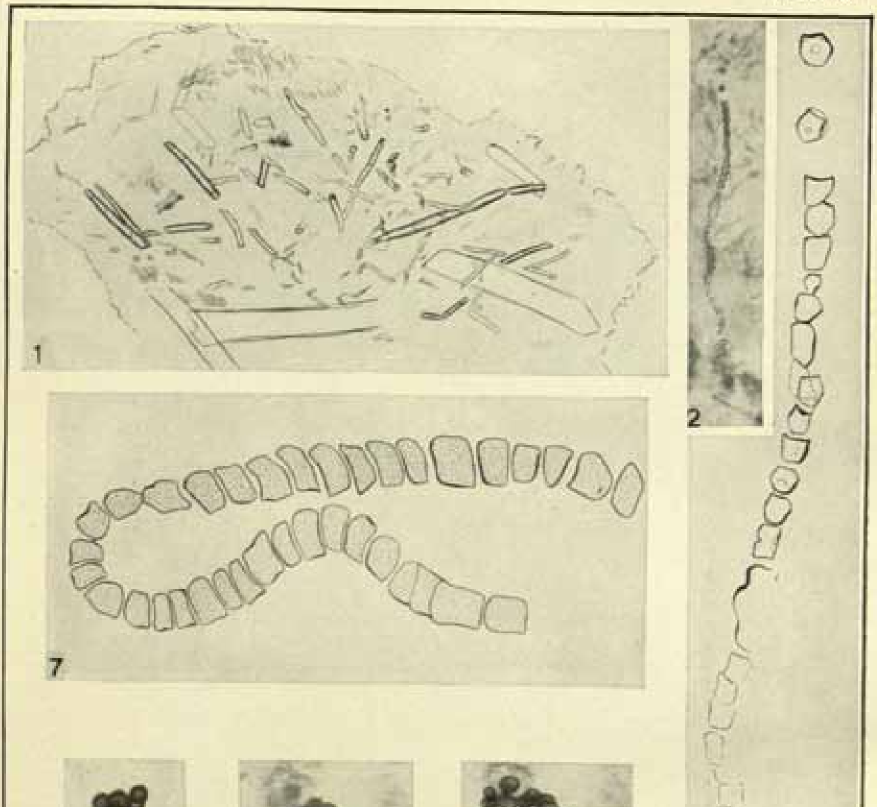


FIG. 1.—Characteristic groups of *Micrococcus vaccinae*. (After Cohn.) Very highly magnified. [Encyclopædia Britannica, 11th Ed., Vol. III, p. 160, fig. 5-B.]





FIGS. 2 and 3.—*Micrococcus* sp. undt. (× about 1,100 diameters.) Average size of Micrococci 0.95 to 1.3 microns in diameter. (Slide D.) From locality 401b, Algonkian: Gallatin formation; north side of East Gallatin River, 5 miles (8 km.) east of Logan, Gallatin County, Mont. [Reprinted from Proc. Nat. Acad. Sci., 1915.]



MICROSCOPIC CELLS FROM RECENT BLUE-GREEN ALGÆ AND THEIR ALGONKIAN REPRESENTATIVES.

Figs. 1 to 6a are from the ancient forms *Newlandia* and *Camasia;* figs. 7 to 8a are from the recent Blue-Green Algæ.

THE SEARCH AMONG THE ROCKS OF CAMBRIAN TIME, AND EARLY INCENTIVE TO GO TO THE ROCKY MOUNTAINS.

Friends have often asked how I happened to take up geologic work in the Rocky Mountains. The reason is a very simple one. As a boy of 17 I planned to study those older fossiliferous rocks of the North American Continent which the great English geologist, Adam Sedgwick, had called the Cambrian system on account of his finding them in the Cambrian district of Wales.[1]

The early explorers of the Rocky Mountains and large plateaus wrote of great masses of ancient bedded rocks exposed by mountain uplifts and deep canyons, and so I have taken advantage of every opportunity to visit and work in that great wonderland. This study has led me to many wild and beautiful regions, where nature has glorified these old sea beds by thrusting them up into mountain masses, with forests below and crowns of perpetual snow and ice on their summits.

From the vicinity of our Burgess Pass camp in the Canadian Rockies the views were most beautiful and varied, changing from hour to hour during the day and from day to day with the varying atmospheric conditions. Emerald Glacier was most attractive in the bright sunlight, in the gray light of early morning, the shadows of sunset, or when snow and fog were sweeping over the range, giving only now and then a glimpse of the ice and cliffs. The light-colored moraines on either side of its foot and the dark rocks afforded a beautiful setting for the ice, and across the Yoho Pass the cliff of Mount Wapta stood in bold relief, with a steep slope of broken rock on the west, and a huge bank of snow on the eastern side of its south ridge.

Our camp at Lake O'Hara (7,000 feet) (pl. 6) was in a beautiful mountain meadow at the foot of Mount Schaffer, where the morning and evening views of the surrounding mountains were often superb. Snow squalls are not infrequent on the higher summits, and on July 17 snow fell at the camp nearly all day. As seen from a slope of Mount Odaray, Lake O'Hara rests like an emerald in a bowl of mountains, reflecting the glaciers of Mounts Lefroy and Hungabee.

CAMBRIAN SECTIONS.

My first study of a great section of Paleozoic rocks of the western side of North America was that of the Eureka mining district of Nevada.[2] This was followed by the section of the Grand Canyon of

[1] Cambria (or Cymru) was the ancient name for Wales.
[2] Monograph 8, U. S. Geol. Survey, 1884.

the Colorado River, Arizona.[1] In this section the Cambrian strata extend down to the horizon of the central portion of the Middle Cambrian (Acadian) where the Cambrian rests unconformably on the pre-Cambrian formations.[2]

The object of my preliminary correlations of the several sections studied, was to show in a broad way the interrelations of the strata and faunas in the North American Cordilleran area west of the great continental land area of Lower and much of Middle Cambrian time.

In the course of my studies, particularly in recent years, data have also come to light which help us more definitely to outline the boundaries of the three great marine incursions of Cambrian time. There are also presented to us new conceptions of geological conditions in that period and more accurate information indicating the probable sources of the Cambrian fauna of the Cordilleran area.[3]

The change in the species from the Lower to the Middle Cambrian fauna is very great.[4] Of 77 species of brachiopods in the Lower Cambrian, six are found in the Middle Cambrian. Among the trilobites the disappearance of the Mesonacidæ[5] is the most marked change. Some of the species of the Conocephalidæ may have continued on into the Middle Cambrian, but the study of this and other crustaceans of the Cambrian time has not yet advanced so that any reliable data are available.

Most of the genera of the Lower Cambrian pass up into the Middle Cambrian, and this leads to the thought that the interruption, though important and of considerable duration, was not of a degree comparable with the unconformity immediately preceding the pre-Cambrian revolution, nor like the great faunal change that came at the close of Cambrian time, although the later diastrophic movement appears to have been relatively insignificant on the western side of the continent.

After the close of Middle Cambrian time the waters of the Pacific, the Gulf of Mexico, and the Atlantic began to rise and to flood lands that had not known the presence of marine waters since far back in the Proterozoic and may be since Archeozoic time. The margin of this area was as far westward as the present position of the main range of the Wasatch Mountains in the vicinity of Salt Lake, Utah; from this point the shore-line trended gradually south-southwest to southwestern Utah.

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[1] Tenth Ann. Rep. U. S. Geol. Survey, 1891, pp. 509–774: The fauna of the Lower Cambrian or *Olenellus* zone.

Smithsonian Misc. Coll., vol. 53, no. 5, 1908, p. 167. Cambrian sections of the Cordilleran area.

[2] See American Jour. Sci., 3d ser., vol. 26, 1883, pp. 437–442.

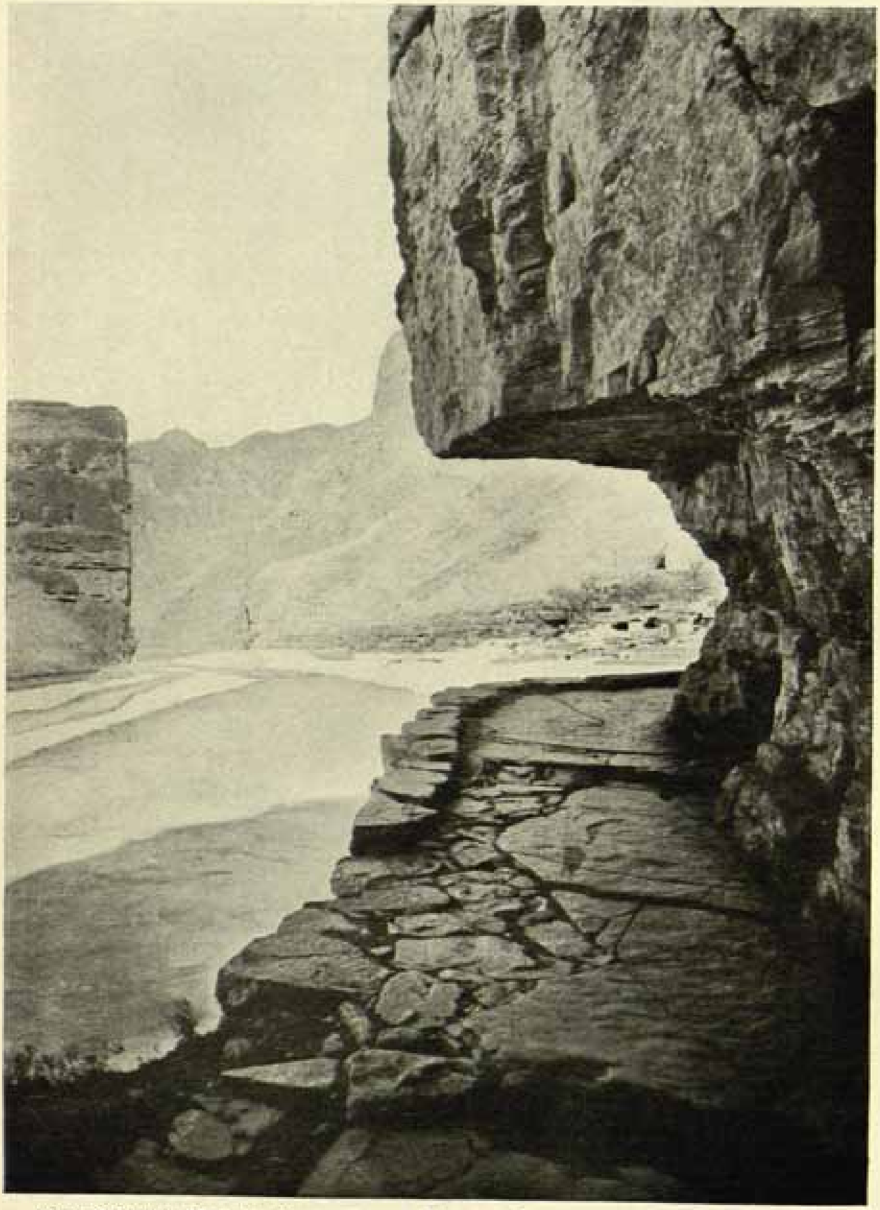
[3] The Cambrian and its problems, Yale Univ. Press, in Problems of American Geology, 1915, p. 162.

[4] Idem, pp. 189–190.

[5] See plate 14, Lower Cambrian trilobites, facing p. 252, this paper.

LAKE O'HARA (6,664 FEET).

From the lake to the top of Mount Lefroy 4,000 feet of Cambrian strata are seen in one unbroken section. Photograph by Charles D. Walcott. Courtesy of National Geographic Magazine.



VIEW SHOWING MASSIVE CHARACTER OF CAMBRO-ORDOVICIAN LIMESTONE, IN BROAD SYNCLINE EAST OF YAU-T'ÓU COAL FIELD, PROVINCE OF SHAN-SI, CHINA.

Illustrates abrupt walls of recent canyons cut in heavy limestone. On the T'ai-shan-ho 4 miles southwest of Shi-pan-k'óu, in the district of Wu-t'ai-hién, Province of Shan-si. (After Willis, Research in China, Pub. No. 54, Carnegie Institution of Washington, 1907.)

Attention is called to the close relationship between the great Cambrian section of the Province of Shantung, China, and the Cordilleran sections of North America. The thickness of the strata is very much less, but the general character and stratigraphic succession of the Cambrian faunas is very much the same. This relationship is further verified by the association of genera and species as shown by my subsequent study of the Cambrian faunas of China.

THE CAMBRIAN FAUNAS OF CHINA.[1]

When looking over the descriptions of China by Baron Ferdinand von Richthofen [2] and their contained Cambrian fossils described by Dr. W. Dames [3] from Liautung, and Dr. Emanuel Kayser,[4] I was impressed with the necessity of having the stratigraphic sections studied in detail, and extensive collections of fossils made, in order that comparisons of value might be instituted between the Cambrian sections and faunas of the western portion of North America and the Paleozoic sections and their contained faunas in eastern Asia. This project was held in abeyance 18 years, until in 1907 an expedition was sent by the Carnegie Institution of Washington, under the charge of Dr. Bailey Willis and his associate geologist, Mr. Eliot Blackwelder, resulting in the acquisition of large and interesting collections, of which I have made a careful study, comparing them with other collections from abroad, which I also had the opportunity to examine.

The chief results obtained from the study of the Chinese collections were the discovery of portions of the upper part of the Lower Cambrian fauna and a great development of a Middle Cambrian fauna of the same general character as that of the Cordilleran province of western North America; also an Upper Cambrian fauna comparable with that of the Cordilleran province and the upper Mississippi province of the United States. The fauna of the upper zone of the Lower Cambrian was found to be of the same general type as that of the Cambrian fauna of the Salt Range of India, and we were thus enabled definitely to locate the faunal horizons in India which had been referred to Upper Cambrian and post-Cambrian formations.

Another important discovery was that of the occurrence in the Middle Cambrian of China of a fauna comparable with that of the Middle Cambrian of Mount Stephen, British Columbia (pp. 246, 247), and the southern extension of the same fauna in the Middle Cambrian of Idaho, Utah, and Nevada in the United States.

[1] Research in China, Carnegie Inst. of Washington, Pub. No. 54, 1913, Walcott: The Cambrian Faunas of China.

[2] China, 1882, vol. 2.

[3] Idem, 1883, vol. 4, pp. 1–33.

[4] Idem, pp. 34–36.

There is much still to be learned by larger and more systematic collections in the Cambrian of China, and the future student of the Cambrian system in Asia should also consider carefully the Siberian Cambrian. The field is a large one, and what we now know of it indicates a rich reward to the individual who takes the time to thoroughly work out the formations and their contained faunas.

THE GREAT MIDDLE CAMBRIAN FOSSIL QUARRY OF BRITISH COLUMBIA.

Nature has a habit of placing some of her most attractive treasures in places where it is difficult to locate and obtain them. Nearly 30 years ago rumors came of a wonderful find of glaciers, forests, mountain peaks, lakes, and fossil beds along the line of the rugged pass through which the Canadian Pacific Railway was building,[1] but it was only during the past four or five years, while making researches in the Canadian Rockies, that it was my good fortune to discover highly organized marine fossils deep in the Middle Cambrian formation. In these the minutest details of the internal structure are wonderfully preserved and reveal a great deal not before known of the life history of that period.

To secure as complete a series of the fossils as possible work has been continued for several seasons. The great fossil quarry is 3,000 feet above Field and 8,000 feet above sea level on the southwestern flank of Mount Wapta. The conditions were such that in order to reach the finest fossils it was necessary to blast the solid beds out to a depth of 22 feet (pl. 8).

Most of the Cambrian rocks of this quarry section were deposited in waters teeming with marine invertebrate life.[2] As far as now known, this was before the day of fish or of any other vertebrate animal; no land plants are known to have existed then, and even marine vegetable life, except in the lowest forms, was unrepresented. Other animals, however, lived in great profusion, and here and there conditions were so favorable for their burial in the mud and sand of the Cambrian sea that they were imbedded unbroken, and throughout all the processes of rock making and mountain building they have escaped destruction (pl. 9).

One of these favorable places was at the quarry, where the most readily destroyed organisms, like the jellyfish (pl. 11, figs. 1, 2), have been exquisitely preserved; and we have crustaceans of numerous varieties (pls. 9, 10, 15), many of which preserve the most delicate branchiæ and appendages. One can hardly realize that these were buried in the mud 15,000,000 to 20,000,000 years or more ago and have remained undisturbed while several miles of thickness of

[1] Walcott, A Geologist's Paradise, Nat. Geog. Mag., June, 1911.
[2] Idem.

SOUTH END OF FOSSIL QUARRY, WHERE MANY OF THE MOST BEAUTIFUL SPECIMENS WERE SECURED FROM THE LOWER 3 FEET OF BEDS.

Near Field, British Columbia. Photograph by C. D. Walcott.

MIDDLE CAMBRIAN TRILOBITES.

Fragments of colony of marine animals on slab of black rock, with many trilobites (*Neolenus serratus* Rominger), (dark), and shells of the Sidney crab (light), whose claws are shown on plate 10. These creatures and other animals, like the delicate jellyfish, have been preserved many millions of years while sediment several miles deep was deposited over them. From Burgess Pass shale, Field, British Columbia. Photograph by Thomas W. Smillie.

sediment were deposited over them, changed into rock, elevated into mountain masses, and later eroded to form the present mountains and canyons.

We have long considered that the trilobite (pl. 9) was the most highly developed animal in Cambrian time, but a few summers ago[1] a crustacean was found by the author's son, Sidney, in the great fossil bed, that was the king of the animal world in its day (pl. 10, *Sidneyia inexpectans*). That it was prepared to assert its right to the control of the Cambrian sea is shown by the claws with which it was armed (pl. 10).

EVOLUTION OF EARLY MARINE LIFE.

Marine life, as already noted, began in times long antedating our oldest fossil records, but we are obliged to take up its study at the beginning of Cambrian time. Several groups have been studied in a preliminary way, and from these certain deductions have been drawn. The first that I will mention is one of the most unlikely of animals to be preserved in fine condition in the fossil state.

MIDDLE CAMBRIAN HOLOTHURIANS.[2]

That the tests or shells of trilobites and merostomes should be finely preserved in a fine-grained, silico-argillaceous rock is rather to be expected, but, with past experiences in mind, I was not prepared to find entire holothurians. That they are present and show many details of structure (pl. 11) is most instructive and satisfactory, since their occurrence records for the first time, with the exception of some scattered calcareous spicules and plates, the presence of this class of organisms in any geologic formation. Any calcareous matter that may have been present in them was probably removed by solution while the animal was in the mud and before it became fossilized. That carbonic acid was present in the mud and immediately adjoining water is suggested by the very perfect state of preservation of the numerous and varied forms of life. These certainly would have been destroyed by the worms and predatory crustaceans that were associated with them if the animals that dropped to the bottom on the mud or that crawled or were drifted onto it had not at once been killed and preserved with little or no decomposition or mechanical destruction. This conclusion applies to nearly all parts of a limited deposit in the fossil quarry (pl. 8) about 6 feet in thickness, and especially to the lower 2 feet of it.

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[1] In 1910.

[2] Smithsonian Misc. Coll., vol. 57, nos. 2 and 3.

A holothurian is defined as a sea-cucumber or similar echinoderm.

Medusa, a jellyfish.

CAMBRIAN ANNELIDS.[1]

I had often searched the fine shales of the pre-Cambrian and Cambrian strata for remains of annelids, but it was not until the summer of 1910 that anything more than trails and borings were found.

The annelids of the Burgess shale, like the holothurians and medusæ, are pressed so flat that the worm is represented by only a thin film. Fortunately this is darker than the shale and usually shiny, and the contents of the animal are often preserved as a glistening silvery surface, even to the fine details of structure. How clearly the specimens exhibit both external and internal characters is shown by the plate figures (pl. 12), which are reproduced from photographs made by reflected light.

RELATIONS TO LIVING ANNELIDS.

The discovery of this remarkable group of annelids in the Burgess shale member of the Stephen formation opened up a new point of view on the development of the Annulata. The fact that from one very limited locality there were collected 11 genera belonging to widely separated families points clearly to the conclusion that the fundamental characters of all the classes had been developed prior to Middle Cambrian time.

CAMBRIAN BRACHIOPODA.[2]

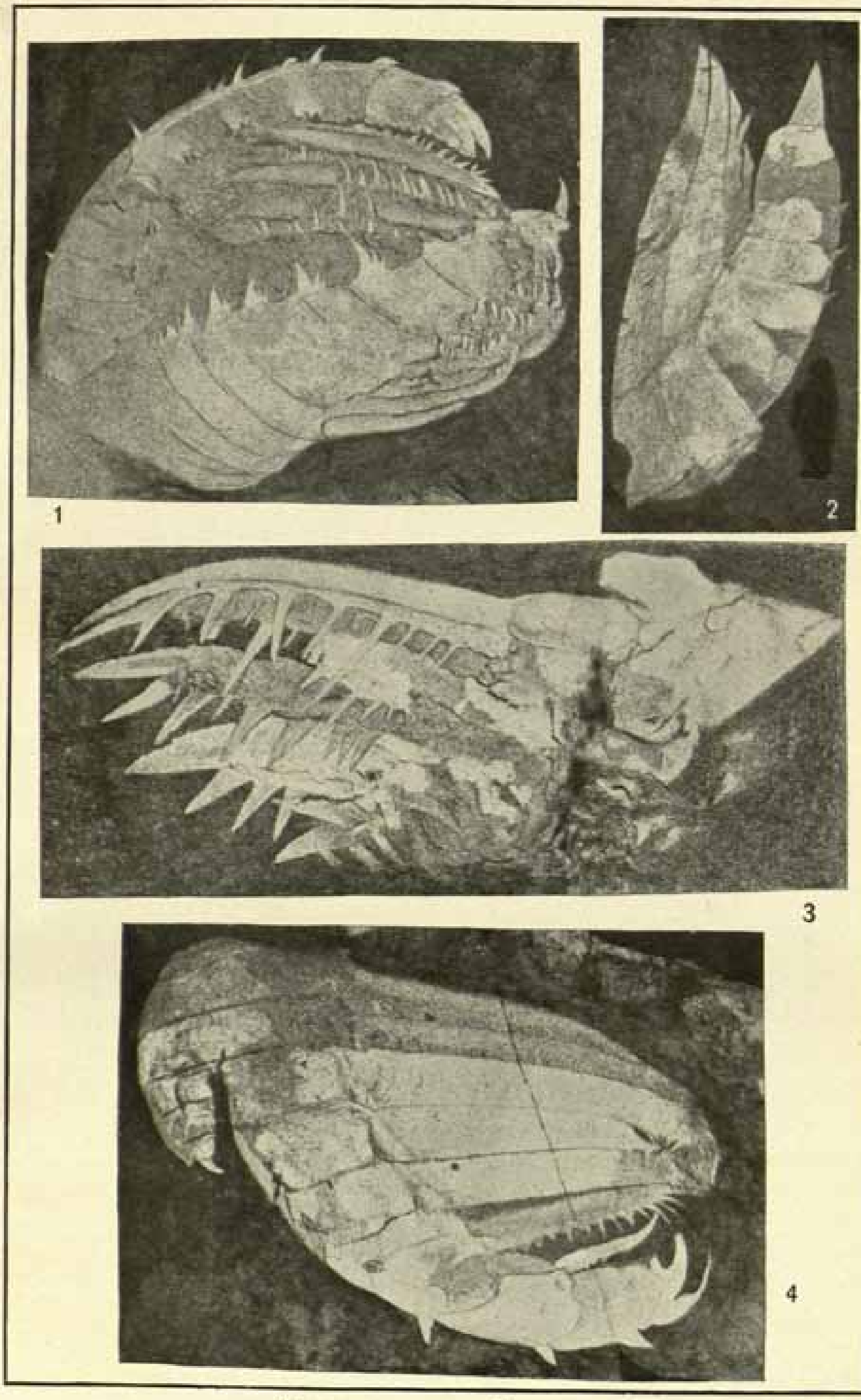
The chief characters of the Cambrian brachiopod are illustrated on plate 13. It may be studied in three ways—historically, geologically, and zoologically.

The conditions in which the Cambrian brachiopods are found indicate that some of them were gregarious in habit, and that many persisted through marked changes of environment and sedimentation. One species,[3] for instance, is found in sandstone, siliceous and argillaceous shale, and limestone. It has a wide distribution in the Cordilleran province of western North America and has a vertical range in the layers of rock of 2,000 feet or more. Other forms, such as *Micromitra haydeni*, are known only from one locality and one layer of rock. A large number of species occur in sandstone and shales that are evidently of shallow-water origin; others occur in limestones that were probably deposited in relatively deep water. The evidence indicates that their habitat largely ranged from between tides to a depth of 1,000 to 2,000 feet. Some forms may have

[1] Middle Cambrian Annulata, Smithsonian Misc. Coll., vol. 57, no. 5, 1911. Annelid, from *anulus*, ring; applied to worms.

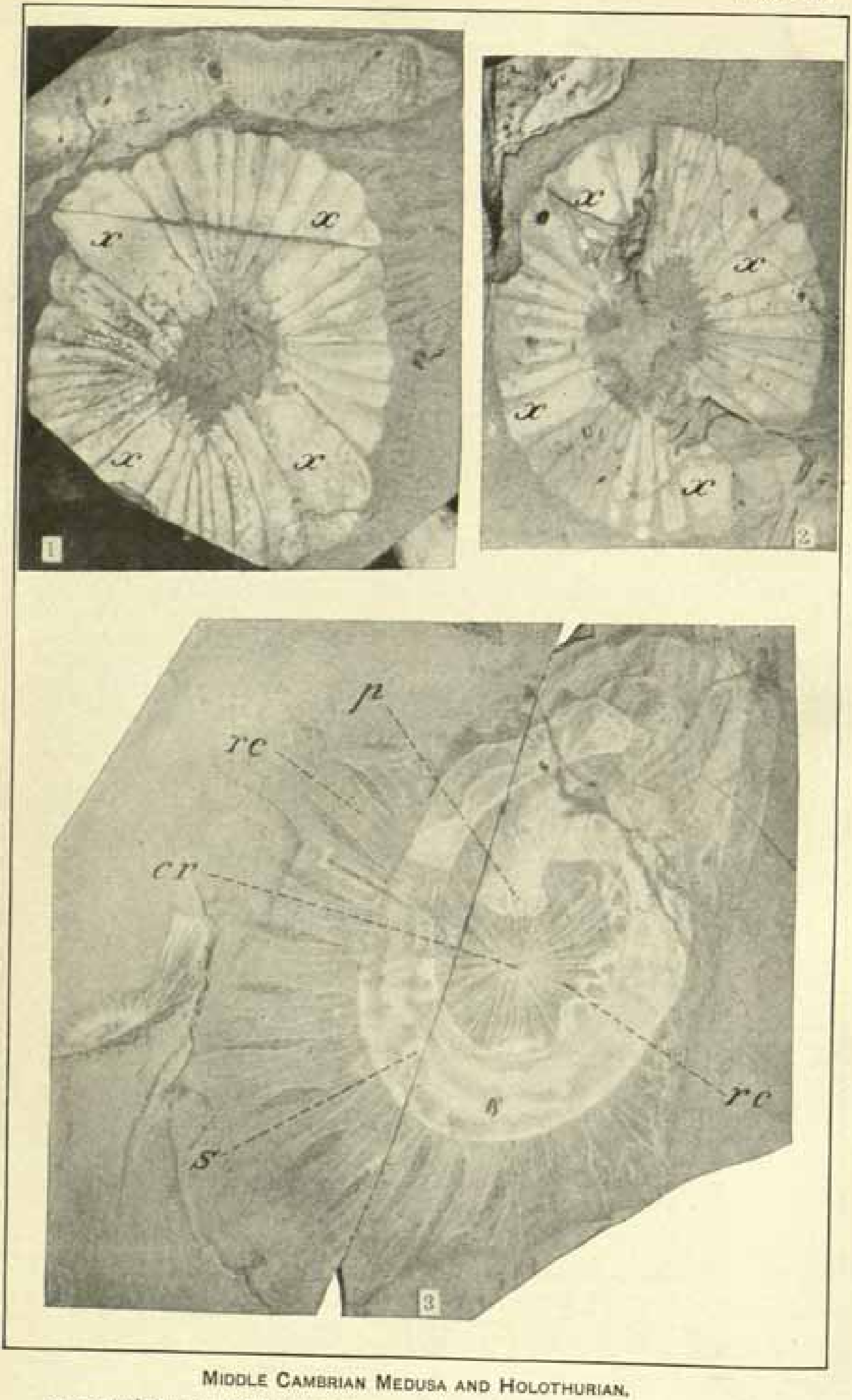
[2] Walcott, Monogr. 51, U. S. Geol. Survey, 2 vols., 1912.

[3] *Micromitra* (*Iphidella*) *pannula* Walcott.



SIDNEYIA INEXPECTANS WALCOTT.

The king of the animal world 15,000,000 years ago; discovered by Mr. Walcott. The spiny claws of the Middle Cambrian crustacean (*Sidneyia inexpectans* Walcott) are shown as a light patch in the center of Plate 9. From Burgess Pass shale, Field, British Columbia.



MIDDLE CAMBRIAN MEDUSA AND HOLOTHURIAN.

cr=central ring; *p*=digitate tentacle; *rc*=radial canals; *s*=stomach; *x*=four large lobes.
1, 2. *Peytoia nathorsti* Walcott. (Medusae, or jellyfish.) 3. *Eldonia ludwigi* Walcott. (Holothurian.)

From locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, west slope of ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

had a greater bathymetric range, but the evidence in favor of such a range is not known to me. A table of the species in the monograph showed that with few exceptions each of the species is confined to one type of sediment.

More than 500 species and varieties of Cambrian brachiopods were studied and between 40 and 50 of Ordovician. Of the Cambrian forms, 10 genera, 2 subgenera, 21 species, and 1 variety persisted into the Ordovician.

Approximately 1,050 different localities bearing brachiopods were examined, and the same genera were found often to exist in widely separated regions, as, for example, a clear relationship was shown between brachiopods from the Scandinavian Peninsula and those of eastern Canadian localities, while in many other instances those of the western Cordilleran region of North America were related to those from China.

MICROSCOPIC STRUCTURE.

One important deduction from microscopic examination of the shells was the differentiation of certain genera and species from the Cambrian and Ordovician hitherto classed together,[1] the microscopic shell structure of one being of granular material pierced by small pores, and in the other of fibrous material. On the other hand, the microscopic structure of two other orders[2] in question is so similar that an unbroken line of descent is indicated.

We do not know of any brachiopods in strata older than that containing Lower Cambrian fauna. Yet when the advanced stage of development of some of the earliest-known forms is considered it seems almost certain that such existed far back in pre-Cambrian time.

THEORETICAL EVOLUTION OF CAMBRIAN CRUSTACEA FROM THE BRANCHIOPODA.[3]

The Cambrian crustacean fauna suggests that five main lines or stems (Branchiopoda, Malacostraca, Ostracoda, Trilobita, and Merostomata) were in existence at the beginning of Cambrian time, and all of them had already had their inception in Lipalian time or the period of pre-Cambrian marine sedimentation, of which no known part is present on the existing continents. Examples of some of these forms are shown in plates 9, 10, 14, and 17.

In the accompanying diagram (p. 250) the attempt is made to show the relations of Cambrian crustaceans to a theoretical ancestral stock,

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[1] Cambrian Billingsellidæ and Ordovician Protremata.

[2] Cambrian and later Pentameracea.

[3] Walcott: Middle Cambrian Branchiopoda, Malacostraca, Trilobita, and Merostomata, Smithsonian Misc. Coll., vol. 57, no. 6, 1912.

which for convenience is correlated with the Apodidæ. From this stock it is assumed that the Branchiopoda came, and from the Branchiopoda stock three distinct branches were developed prior to or during Cambrian time. Of these the one of greatest interest in the present connection is that on the right of the diagram. In this line of descent it is assumed that the Trilobita are directly descendent from the Branchiopoda, and forms grouped under the order Aglaspina are derived from the Trilobita. The order Limulava is considered as being intermediate between Aglaspina and the Eurypterida, and that the two orders Limulava and Aglaspina serve to connect the Trilobita and the Eurypterida.

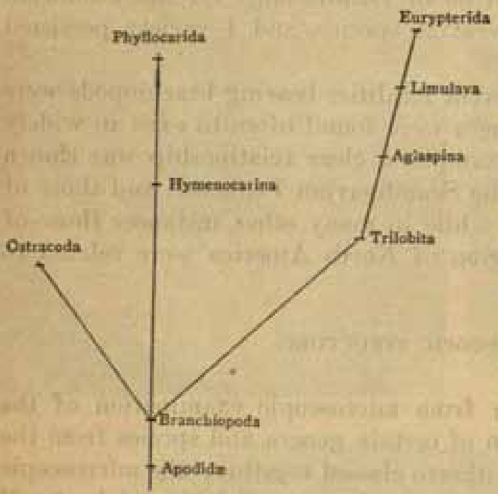


FIG. 1.—Theoretical evolution of Cambrian Crustacea from the Branchiopoda.

The line of descent of the various genera of the Mesonacidæ of the Lower Cambrian series[1] is indicated on plate 14, from figures 1 to 9, as stated in the description of the plate.[2]

MIDDLE CAMBRIAN CRUSTACEANS.[3]

Examples of a few others of the Middle Cambrian crustaceans found at the great quarry are illustrated on plate 15.

DISCOVERY OF ANOTHER CAMBRIAN FAUNA IN THE CANADIAN ROCKIES.

During the summer of 1911 a Smithsonian expedition, in cooperation with Mr. Arthur O. Wheeler, of the Alpine Club of Canada, visited the Robson Peak district.[4] My son Charles, who accompanied the party, brought back a few Cambrian fossils picked up while hunting and told me that ridge after ridge encircled the great Robson Peak with rocky layers, all sloping back toward and under the mountain. This suggested an opportunity to study another

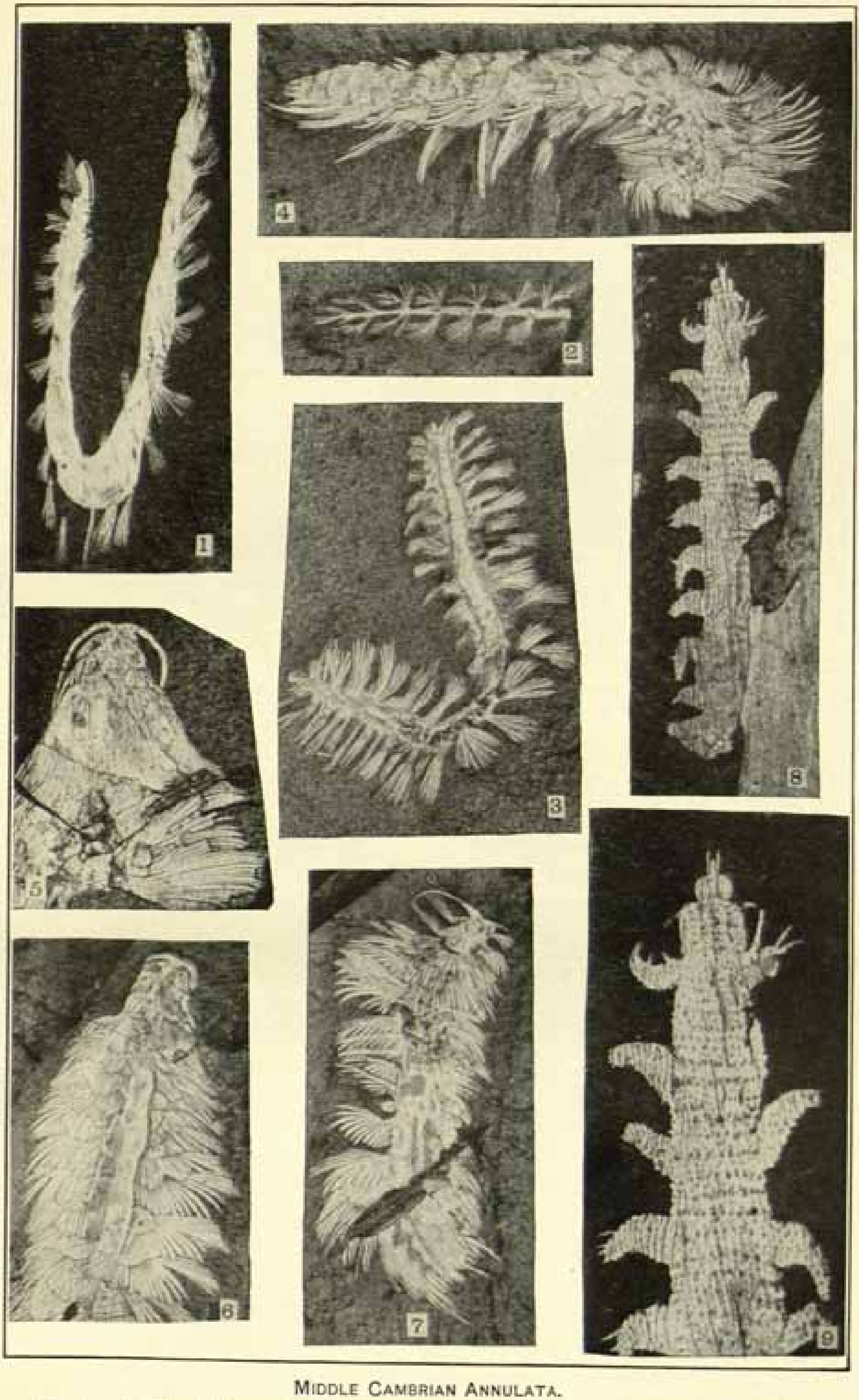
[1] Walcott: Fauna of the Lower Cambrian or *Olenellus* zone, Tenth Ann. Rept., U. S. Geol. Surv., pt. 1, 1890, pp. 509–763.

Olenellus: A large trilobite characteristic of the Lower Cambrian rocks. See pl. 14, fig. 9, this paper.

[2] Walcott: *Olenellus* and other genera of the Mesonacidæ, Smithsonian Misc. Coll., vol. 53, no. 6, 1910.

[3] Smithsonian Misc. Coll., vol. 57, no. 6, 1912.

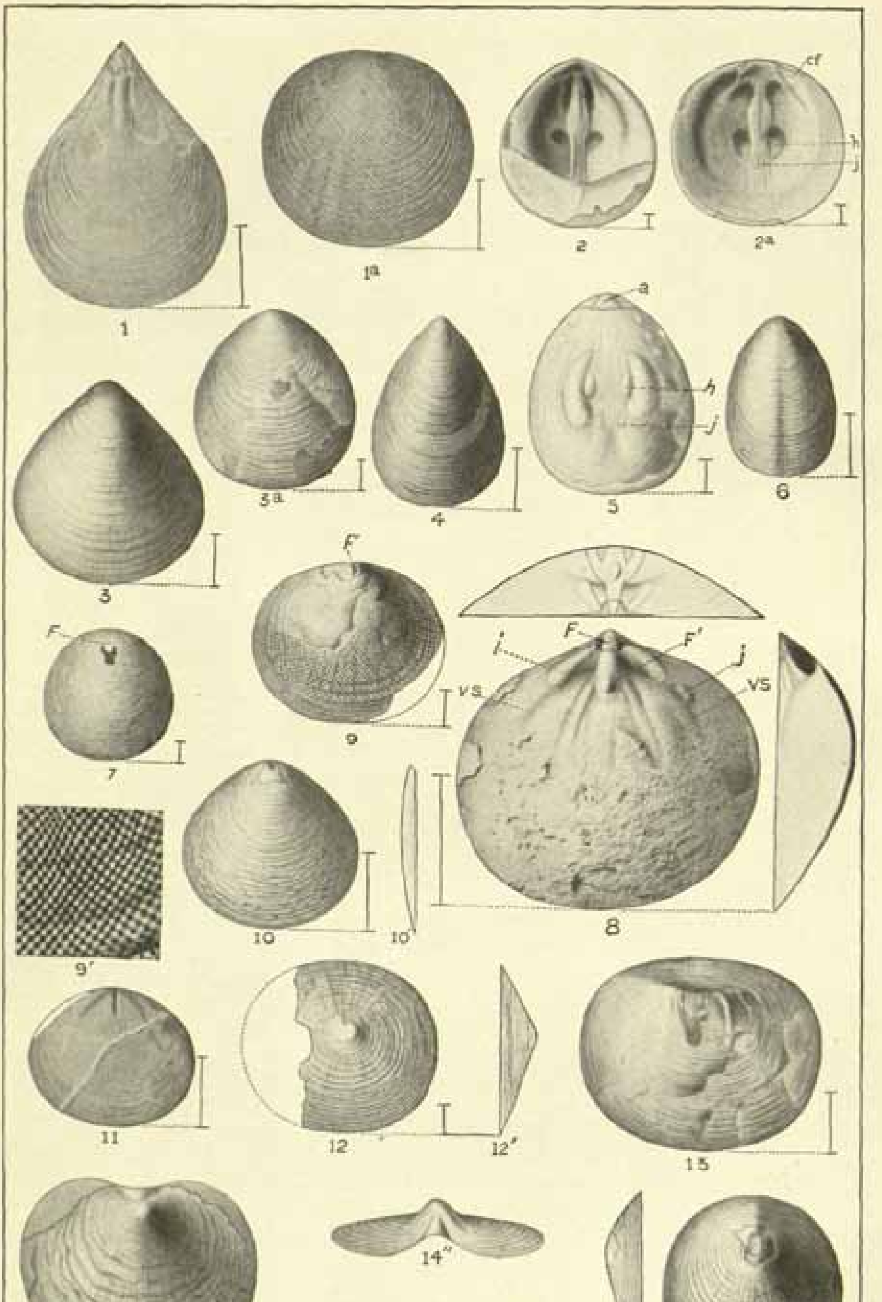
[4] Walcott: The Monarch of the Canadian Rockies, Nat. Geog. Mag., May, 1913.



MIDDLE CAMBRIAN ANNULATA.

1-3. *Canadia setigera* Walcott. 4-7. *Canadia spinosa* Walcott. 8, 9. *Aysheaia pedunculata* Walcott.

From locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, west slope of ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



CAMBRIAN BRACHIOPODA.

a=area; *cf*=cardinal muscle scar; *F*=foramen; *F'*=cast of foraminal tube; *h*=central muscle scar; *i*=transmedian muscle scar; *j*=anterior lateral muscle scar; *vs*=vascular sinus.

Obolus, Dicellomus, Lingulella, Acrothele, and other genera are represented from localities in the United States, Canada, Sweden, France, and China.

great section of the Cambrian of the Rockies 200 miles (328.8 kilometers) northwest of the Burgess Pass section near Field, British Columbia, and the following season accordingly found me again exploring new fossil localities in the midst of magnificent scenery.

Robson, the most majestic peak of the Canadian Rockies (pl. 1), is situated northwest of the Yellowhead Pass, through which the Grand Trunk Pacific and the Canadian Northern Railway have been building their lines to connect the great interior plains and granary of Canada with the Pacific coast. Known to trappers of the Hudson Bay Co. and a few hardy explorers who have penetrated the region in search of a practicable trail to the Pacific, it has until now remained to the rest of the world almost an undiscovered country.

NOMENCLATURE.

Although not an original explorer of the Robson Peak district it fell to my lot to be the first to study the geologic section, and in this connection it was necessary to apply additional names in order to properly locate, describe, and name the geologic formations.

In this région of ancient Indian association it seemed to me especially fitting that some appropriate Indian terms should be used in order to preserve from total oblivion a curious language typical of a picturesque and fast disappearing people. With the help of the Bureau of American Ethnology of the Smithsonian Institution I prepared a list of such names, of which the following are examples:

Titkana[1] (bird) Peak.
Iyatunga[1] (black rock) Mountain.
Hunga (chief) Glacier.
Hihuna (owl) River.
Chupo (fog, mist) Glacier, etc.

FOSSIL DISCOVERIES.

Chupo, the glacier of fog and mist, is usually half concealed by clouds and banks of mist that form on the edge of the mountain and drift over it. This glacier proved of great interest and service to us in our geologic work. On its surface blocks of rock from high up on the peak were carried down to the great moraine at its foot, and in those blocks I found the evidence that proved the upper third of the mountain to be of post-Cambrian age by the presence in the limestone of marine shells and fragments of crablike animals that lived in so-called Ordovician time.

The beautiful Hunga Glacier is literally a flowing river of ice. At its left Titkana (bird) Peak rises as a black limestone mass that

[1] Approved by National Geographic Board of Canada, December, 1912.

with Iyatunga (black rock) Mountain forms the mighty portals of the great glacier.

Day after day we passed between these portals and climbed over the crevassed and hummocky ice in order to trace the connection of the rocky section of Titkana Peak with that of Robson (pl. 16). Thanks to the fine fossil fauna found in Billings Butte and the slope of the layers of rock a satisfactory "tie" was made across the glacier to the limestones of Robson.

The work was trying and tedious, but nature kindly assisted by bringing down long trains of bowlders on the ice of the glacier. From these was revealed the story concealed in the cliffs far above, and thus we learned the history of the rocks connected with those of the more accessible cliffs on the opposite side of the glacier.

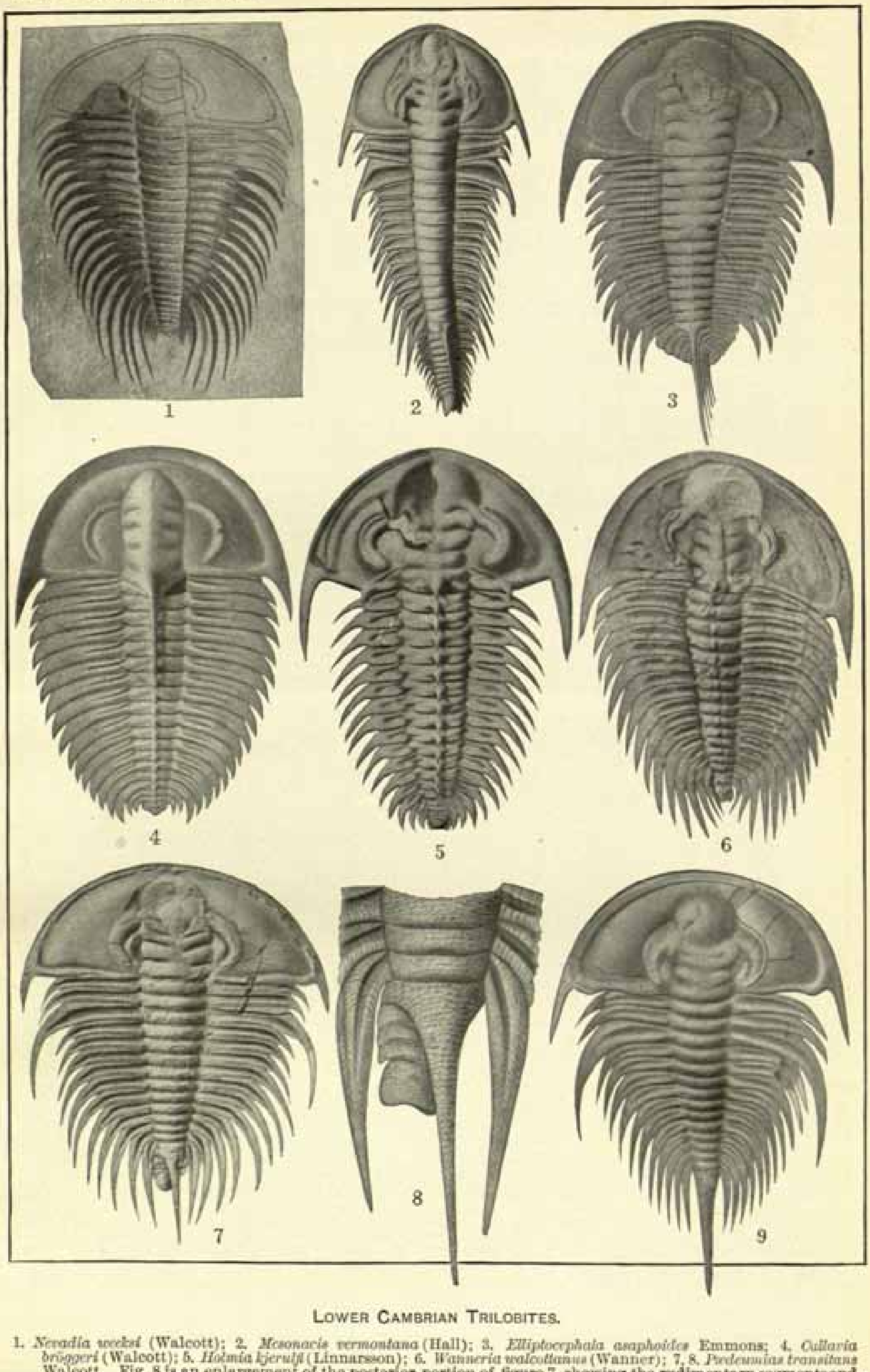
The geologic story of this enchanting region is too long and complicated to be related here. Suffice it that I found over 12,000 feet in thickness of Cambrian beds capped by 3,000 feet or more of Ordovician strata high up on Robson Peak.

A new fossil find was made by chance. Mr. Harry Blagden and I were sitting on a huge block of rock at the lower end of Mural Glacier, munching our cold luncheon, when I happened to notice a block of black, shaly rock lying on the ice. Wishing to warm up, for the mist drifting over the ice was cold and wet, I crossed to the block and split it open. On the parting there were several entire trilobites belonging to new species of a new subfauna of the Lower Cambrian fauna (pl. 17).

There were also some fine marine shells of a kind that occurs in the Lower Cambrian rocks west of Petrograd, Russia. We found the bed from which this block had come by carefully tracing fragments of the shale scattered on the upward-sloping surface of the ice to a cliff 2 miles (3.2 kilometers) up the glacier at the foot of Mumm Peak, which is a high point (9,740 feet=2,968 meters) directly north of Robson Peak. The fossil locality is high up, where rain, fog, and snow squalls may be expected nearly every day of the year. Working until late in the afternoon, we carried all of the rock we could pack over the glacier and down through the cliffs to the valley of the Smoky River.

One of our horses had taken leave on his own account, so we loaded faithful Billy with the rock specimens, two rifles, two shotguns, a camera, and our raincoats and plodded over the muddy trails, forded two icy-cold rivers, and "dropped" in at camp three hours after dark. At the last ford the powerful animal carried us both and all our impedimenta through the broad, rushing glacial stream.

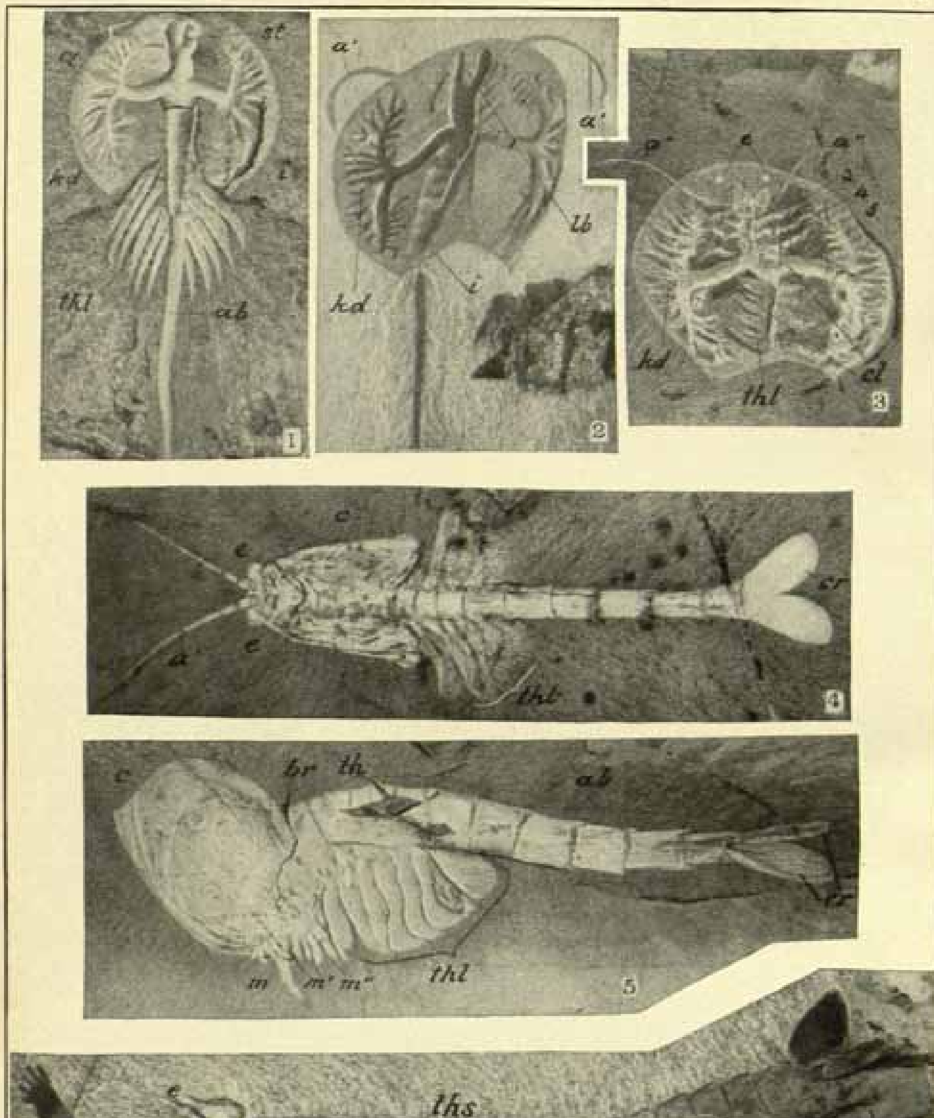
If any readers wish to visit Robson Peak they can readily do so by going to Edmonton and thence by railroad to Mount Robson Station, which is in sight of Robson Peak. The Alpine Club of



LOWER CAMBRIAN TRILOBITES.

1. *Nevadia weeksi* (Walcott); 2. *Mesonacis vermontana* (Hall); 3. *Elliptocephala asaphoides* Emmons; 4. *Callavia bröggeri* (Walcott); 5. *Holmia kjerulfi* (Linnarsson); 6. *Wanneria walcottanus* (Wanner); 7, 8. *Pedeumias transitans* Walcott. Fig. 8 is an enlargement of the posterior portion of figure 7, showing the rudimentary segments and pygidium beneath the telsonlike segment. 9. *Olenellus thompsoni* Hall.

Illustrates variation in principal genera of the Mesonacidæ; shows changes from most primitive form *Nevadia* (figure 1) through one line of descent, as represented by figures 2, 3, and 7, to *Olenellus* (figure 9), also another line of descent through figures 1, 3, 4, 5, and 6, probable line of descent from *Nevadia* (figure 1) to *Holmia* (figure 5), and on to *Paradoxides*. (See pl. 17.)



MIDDLE CAMBRIAN CRUSTACEANS.

1-3. *Burgessia bella* Walcott; 4, 5. *Waptia fieldensis* Walcott; 6. *Opabinia regalis* Walcott. From Burgess Pass fossil quarry, near Field, British Columbia.

Canada has recently held its summer camp on the shores of Berg Lake, and soon this wonderland will be open to all who love the mountains and outdoor life.

Some of the fossil trilobites of this region are illustrated on plate 17 (*Olenellus truemani* Walcott, figs. 2–10),[1] and may be correlated with another similar species (pl. 14, fig. 9, *Olenellus thompsoni* (Hall)) from a Lower Cambrian shale in Pennsylvania and other Appalachian localities. Often the discovery of these correlations proves of great importance in the assignment of strata to their proper formations, and it has frequently been of great service in prospecting and exploiting mining districts in the West and elsewhere. A fault or break in the strata is sometimes detected only by this means.

UPPER CAMBRIAN FAUNA OF THE MISSISSIPPI VALLEY.

The importance of the distribution of a single family or genus in determining the stratigraphic position and succession of layers is shown in a recent study of the Dikelocephalinæ[2] (pl. 18).

It had been evident for several years that the various Cambrian formations of the Upper Mississippi Valley, which had been referred first to one formation (Potsdam) and then to another (St. Croix sandstones), needed careful revision in relation to their stratigraphic position and succession. This was accomplished through the study of the distribution of the *Dikelocephalus*[3] fauna in this wide region, and its correlation with related genera and species elsewhere.

THE SARDINIAN CAMBRIAN GENUS *OLENOPSIS* IN AMERICA.[4]

An example of the significance of distribution in showing unsuspected relationship of widely separated faunas, and consequently a bond between the marine bodies of water which covered the land at an early age, is found in the study of the geographic distribution of a remarkable trilobite. Until the publication of the report in 1912 the presence of the genus *Olenopsis* in America had not been announced, although a number of the cranidia of species referred to the related *Ptychoparia* were very much like the cranidia of *Olenopsis*.

The type species, *Olenopsis zoppii*, occurs on the island of Sardinia at Canal Grande and vicinity. Investigation in North America

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[1] Fig. 1 on this plate represents a related species, *Holmia ? macer* Walcott, from the Lower Cambrian shale, Fruitville, Lancaster County, Pennsylvania.

[2] Walcott: *Dikelocephalus* and other genera of the Dikelocephalinæ. Smithsonian Misc. Coll., vol. 57, no. 13, 1914.

[3] *Dikelocephalus*, a large trilobite characteristic of the later (Upper) Cambrian rocks. *Dikelocephalus*, from Greek δικελλα, a mattock or two-pronged hoe, and κεφαλη head. This trilobite has been called "shovel-head," well suggested by fig. 1, pl. 18.

[4] Walcott, Smithsonian Misc. Coll., vol. 57, no. 8, 1912.

disclosed *Olenopsis roddyi* on the eastern side of the continent, near Lancaster, in the central part of Pennsylvania; on the western side of the continent *Olenopsis americanus* in the northern central part of Montana, and *Olenopsis ? agnesensis* on the line of the Continental Divide, near the Canadian Pacific Railway, in both Alberta and British Columbia. It is quite probable that if entire specimens of a number of species now represented by cranidia and referred to the genus *Ptychoparia* were available for study other species of *Olenopsis* would be found at approximately the same stratigraphic horizon.

AN EARLY DISCOVERY BY THE AUTHOR.

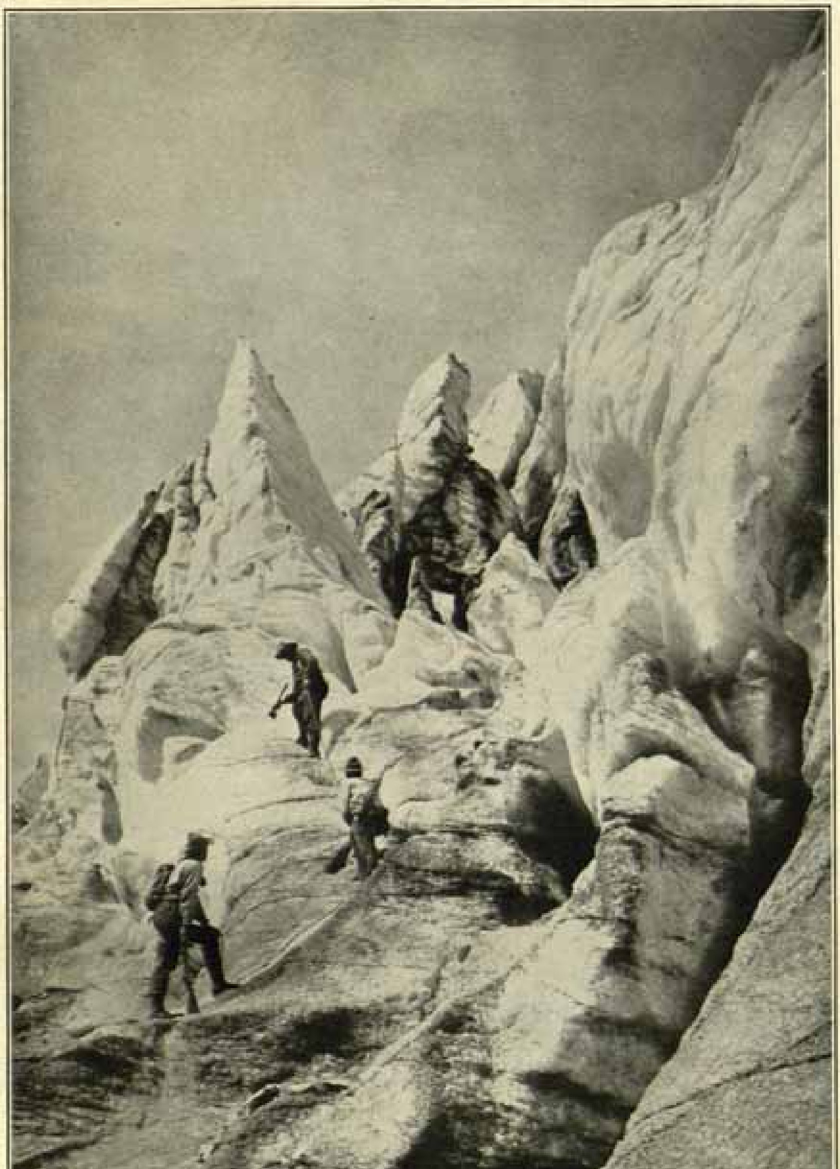
Another instance of settling a disputed horizon[1] recalls a personal experience. In a small drift block of sandstone which I found in 1867 on the road from Trenton to Trenton Falls, Oneida County, N. Y., there is an unusual apparent association of Upper Cambrian (Hoyt limestone) and Ordovician (Aylmer sandstone, Chazy) fossils. The Hoyt limestone species are *Ptychaspis speciosus* and *Agraulos* cf. *saratogensis*. The Aylmer sandstone species are *Leperditia armata* and *Bathyurus* cf. *angelina* Billings.

When as a boy I found the rounded block of sandstone referred to I broke out all the fossils possible, as at the time I was well acquainted with the Trenton limestone fauna, and the fossils in the block were strangers to me, with the exception of *Leperditia armata*. The following winter I endeavored to locate the stratigraphic position of the trilobites, but could not, further than that they were evidently of pre-Trenton age. This study aroused an interest in the American early Paleozoic fossils that gradually led me to take up the Cambrian rocks and faunas as my special field of research.

The block of sandstone I had found was about 3 inches in thickness by 12 in diameter. The impact of the wheel of the wagon in which I was riding split the block open and exposed several cranidia of the trilobite now known as *Ptychaspis speciosus*. Neither this nor *Agraulos* cf. *saratogensis* occurred in direct association with the Chazy *Leperditia* and *Bathyurus*.

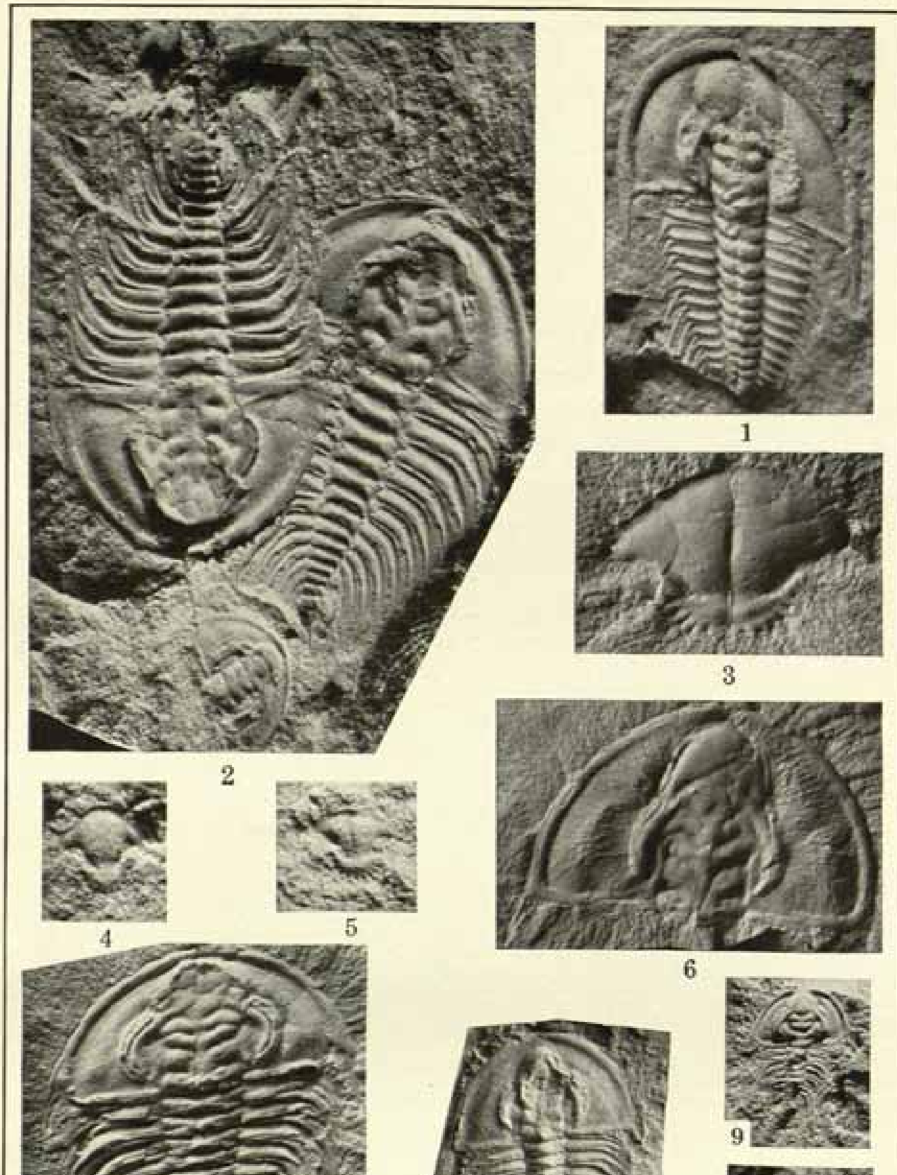
In explaining this connection I have recently been led to adopt a suggestion of Dr. E. O. Ulrich that the block of sandstone was part of a bed formed by the overlap of the Aylmer sandstone of the Chazy on a layer of Potsdam sandstone. This would make the line of demarcation between the Cambrian and Ordovician deposits within the block of sandstone that I found. With this view in mind, the Hoyt limestone species have now been referred by me to the Upper Cambrian and the Aylmer sandstone species to the Ordovician.

[1] Walcott: New York Potsdam-Hoyt fauna, Smithsonian Misc. Coll., vol. 57, No. 9, 1912.



WORKING UP THROUGH THE VAST AND BROKEN FRONT OF HUNGA GLACIER.

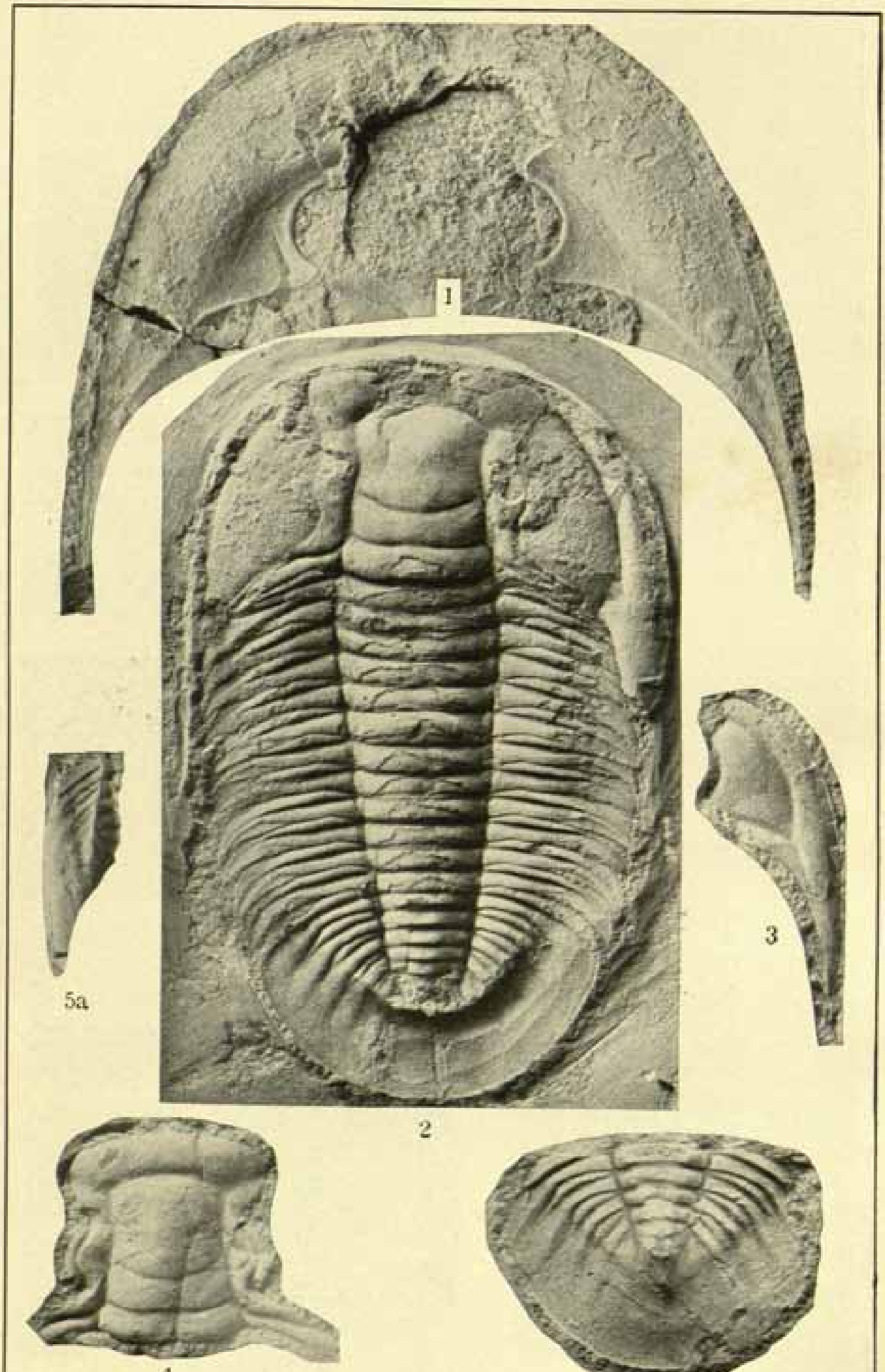
Photograph by R. C. W. Lett, by courtesy of Grand Trunk Pacific Railway. Reprinted from National Geographic Magazine.



LOWER CAMBRIAN TRILOBITES.

1. *Holmia ? macer* Walcott; 2-10, *Olenellus truemani* Walcott.

Mahto formation: From Mumm Peak, 6 miles north of Robson Peak and northwest of Yellowhead Pass, in western Alberta. (See pl. 14).



DIKELOCEPHALINÆ: UPPER CAMBRIAN TRILOBITES.

1. *Dikelocephalus minnesotensis* Owen. From Goodhue County, Minn.
2–5, 5a. *Saukia crassimarginata* (Whitfield). From Sauk County, Wis.

CAMBRO-ORDOVICIAN BOUNDARY WEST OF CONTINENTAL DIVIDE.[1]

As a third instance of similar kind, the discovery of fairly well-characterized specimens of the trilobitic genus *Ceratopyge* associated with brachiopods of the same general type as those found in the *Ceratopyge* shale of Sweden is most important, as it gives the first definite suggestion of a base for the Ordovician in the section along the Canadian Pacific Railway west of the Continental Divide. In Sweden the *Ceratopyge* shale and limestone are now by general assent placed at the base of the Ordovician, and with our knowledge of the stratigraphy of the upper portion as determined by Mr. Allan[2] I am inclined to agree with him in placing, at least tentatively, the boundary between the Cambrian and the Ordovician at the summit of the Ottertail limestone and the base of the Goodsir formation.

The broad question of the Cambro-Ordovician boundary in other sections of North America is one that is still in process of adjustment, owing to the absence of detailed information as to the boundaries between formations and the character of the faunas in the formations. Investigations now in hand will throw new light on the relations of the Appalachian formations and their invertebrate faunas.[3]

CONCLUSION.

The varied investigations of the past few years have opened very interesting problems which have been barely touched upon in this brief review.

How much earlier than the pre-Cambrian and Algonkian faunas the study of primitive life may be extended will depend very largely upon the discovery and study of now unknown fossil faunas and floras. All of this comparative study requires a world-wide activity in the fields of geology and paleontology. That science is universal is shown by a recent incident. The writer lately received a scientific pamphlet from a European paleontologist, with the request that it be forwarded to a fellow paleontologist in a country with which his nation was at war, and there was no communication between the two. The friend replied, through the intermediary, acknowledging its receipt and asking that his thanks and kind wishes be conveyed to the sender.

Students and investigators everywhere are invited to cooperate with the writer in his studies of the evidences of primitive life, and in his effort to correlate all procurable data on the subject and make them available for study and research by all those interested in these fascinating problems.

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[1] Smithsonian Misc. Coll., vol. 57, no. 7, 1912.

[2] Allan, John A.: Ice River District, British Columbia, Geol. Survey of Canada, Sum. Rept., Dept. of Mines, 1910, pub. 1911, pp. 135–144.

[3] Smithsonian Misc. Coll., vol. 64, no. 3, 1916, Cambrian Trilobites.

THE PLACE OF FORESTRY AMONG NATURAL SCIENCES.[1]

By Henry S. Graves,

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In an old forest magazine, Sylvan, is a story about Germany's great poet, Karl von Schiller. Schiller, taking rest at Illmenau, Thuringen, met by chance a forester who was preparing a plan of management for the Illmenau Forest. A map of the forest was spread out, on which the cuttings for the next 220 years were projected and noted with their year number. By its side lay the plan of an ideal coniferous forest which was to have materialized in the year 2050. Attentively and quietly the poet contemplated the telling means of forest organization, and especially the plans for far-distant years. He quickly realized, after a short explanation, the object of the work, and gave vent to his astonishment:

> I had considered you foresters a very common people who did little else than cut down trees and kill game, but you are far from that. You work unknown, unrecompensed, free from the tyranny of egotism, and the fruit of your quiet work ripens for a late posterity. Hero and poet attain vain glory; I would like to be a forester.

An opinion not unlike that held by Schiller before meeting with the forester still commonly prevails in scientific circles in this country. It is quite generally believed that foresters are pure empiricists; something on the order of gardeners who plant trees, of range riders who fight forest fires, or lumbermen who cruise timber, carry on logging operations or manufacture lumber and other forest products; that for whatever little knowledge of a scientific character the forester may need in his work, he depends on experts in other branches of science; on the botanists for the taxonomy of the trees; on physicists, chemists, and engineers for the proper understanding of the physical, chemical, and mechanical properties of the wood; on the geologists and soil physicist for the knowledge of sites suitable for the growth of different kinds of trees; upon the plant pathologist for the diseases of trees; upon the entomologist for the insect enemies of the forest, and so on.

[1] Paper delivered before the Washington Academy of Sciences on Dec. 3, 1914. Reprinted by permission from the Journal of the Washington Academy of Sciences, Washington, D. C., Vol. 5, No. 2, Jan. 19, 1915.

Such an impression is undoubtedly strengthened when the activities of such an organization as the Forest Service are considered. The placing under management of about 165,000,000 acres of forest land has been an administrative problem of enormous magnitude. The administration of this vast public property involves many large industrial and economic questions, and affects intimately a number of varied and important interests; the lumber industry, the grazing industry, water-power development, navigation, municipal water supplies, agricultural settlement, mining development, and the railroads. In launching this great public enterprise, undertaken in the face of strong opposition, administrative activities appeared to overshadow research work. In this way doubtless many scientific men have gained the impression that forestry has little to do with science, which seeks for the causal relationship of things and for the establishment of laws and principles; that forestry is rather a patchwork of miscellaneous knowledge borrowed from other sciences and assembled without particular system to help the practical administrator of forest property.

My endeavor in this paper will be to show that this impression is erroneous. While it is true that forestry as an art, as an applied science, utilizes results furnished by the natural and engineering sciences; while it is also true that the forester's activities, particularly during the pioneer period of establishing forest practice, may be largely administrative in character, there is nevertheless a fundamental forest science which has a distinctive place. As with all others, the science of forestry owes its distinctive character to its correlation, from a certain point of view, of parts of certain other sciences, such as mathematics, botany, entomology, civil engineering, and chemistry. But these are only auxiliary to the resultant science—forestry—which rests upon a knowledge of the life of the forest as such, and which, therefore, depends upon the discovery of laws governing the forest's growth and development.

It is in this field chiefly that foresters may claim some scientific achievement, some contribution to general science. Sciences do not develop out of curiosity; they appear first of all because there are practical problems that need to be solved, and only later become an aim in themselves. This has been equally true of the science of forestry. The object of forestry as an art is to produce timber of high technical quality. In pursuing this object the forester very early observed that tall, cylindrical timber, comparatively free of knots, is produced only in dense stands, in forests in which the trees exert an influence upon each other as well as upon the soil and climate of the area occupied by them. He further discovered that the social environment produced by trees in a forest is an absolutely essential condition for the continuous natural existence of the forest

itself. If the forester had not found forests in nature, he would have had to create forests artificially in order to accomplish his practical purpose, since it is only through the control and regulation of the natural struggle for existence between trees in the forest that the forester is capable of managing it for the practical needs of man. Thus from the very nature of his dealings with the forest the forester was forced from the beginning to consider the forest not merely as an aggregation of individual trees but as communities of trees—tree societies—and first, from purely utilitarian reasons, developed a science upon which the practice of silviculture now rests.

Forestry as a natural science, therefore, deals with the forest as a community in which the individual trees influence one another and also influence the character and life of the community itself. As a community the forest has individual character and form. It has a definite life history; it grows, develops, matures, and propagates itself. Its form, development, and final total product may be modified by external influences. By abuse it may be greatly injured, and the forest as a living entity may even be destroyed. It responds equally to care and may be so molded by skillful treatment as to produce a high quality of product, and in greater amount and in a shorter time than if left to nature. The life history of this forest community varies according to the species composing it, the density of the stand, the manner in which the trees of different ages are grouped, the climatic and soil factors which affect the vigor and growth of the individual trees. The simplest form of a forest community is that composed of trees of one species and all of the same age. When several species and trees of different ages occupy the same ground, the form is more complex, the crowns overlapping, and the roots occupying different layers of the soil. Thus, for instance, when the ground is occupied with a mixed stand of Douglas fir and hemlock, the former, requiring more light, occupies the upper story and because of its deeper root system extends to the lower-lying strata of the soil. The hemlock, on the other hand, which is capable of growing under shade, occupies the under story, and, having shallow roots, utilizes largely the top soil.

There are forest communities, such, for instance, as those typical of northwestern Idaho, where western larch, Douglas fir, western white pine, white fir, western red cedar, and hemlock all grow together. Such a forest is evidently a very complex organism, the stability of which is based on a very nice adjustment between the different classes and groups occupying the same ground. Any change in one of these classes or groups must necessarily affect the other. If, for instance, in the Douglas fir-hemlock forest the Douglas fir is cut out, the remaining hemlock trees are likely to die out because their shallow roots are left exposed to the drying effect of the sun and wind.

It is only by a thorough understanding of such mutual adjustments that the forester is capable of intelligently handling the forest. With the great number of species that are found in this country, with the great variety in climatic and other physical factors which influence the form of the forest, it is self-evident that there are many forest communities, each with distinctive biological characteristics, which offer a wide field for scientific inquiry. Amid the great volume of administrative phases of the work in the Forest Service this main objective has never been lost sight of in handling the national forests. The Forest Service is now spending nearly $300,000 annually for research work; it maintains eight forest experiment stations and one thoroughly equipped forest-products laboratory, and is doing this work solely to study the fundamental laws governing the life of the forest and their effect upon the final product—wood.

Forestry may be called tree sociology, and occupies among natural sciences the same position as sociology among humanistic sciences. Sociology may be based upon the physiological functions of man as a biological individual. A physician, however, is not a sociologist, and social phenomena can be understood and interpreted only in the light of sociological knowledge. So also with forestry. Forestry depends upon the anatomy and physiology of plants, but it is not applied anatomy and physiology of plants. With foresters anatomy and physiology of plants is not the immediate end, but enters only as one of the essential parts, without which it is impossible to grasp the processes that take place in the forest.

As the science of tree societies, forestry really is a part of the larger science dealing with plant associations, yet its development was entirely independent of botanical geography. When the need arose for the rational handling of timberlands no science of plant association was in existence. Foresters were compelled to study the biology of the forest by the best methods available; they used the general scientific methods of investigation and developed their own methods when the former proved inadequate. I am frank to admit that the present knowledge of plant associations in botany has not yet reached a point where foresters could leave wholly to botanists the working out of the basic facts about the life of the forest which are needed in the practice of forestry. When the general science of plant associations has reached a higher state of development the two may possibly merge, but not until then.

In developing the science of tree associations the forester has been unquestionably favored by the fact that the forests, being the highest expression of social plant life, afford the best opportunity for observing it.

The reason for the ability of forest trees to form most highly organized plant societies lies in their mode of growth. Each annual

ring of growth, together with the new leaves that appear every year, is in reality new colonies of cells. Some of the cells die toward the end of the vegetative season; others continue to live for a number of years. When the conditions of life in a forest have changed for a certain tree, when, for instance, from a dominant tree it became a suppressed one, the new colonies of cells formed during that year, and which sustain the life of that tree, are naturally adapted to these new conditions. The same is true when a suppressed tree, through some accident to its neighbors, comes into full enjoyment of light. The last annual growth is at once capable of taking advantage of the new situation created in the forest. Therefore as long as a tree can form annual rings it possesses the elasticity and adaptability essential for trees living in dense stands. It is only when a tree is suppressed to a point when it can not form new growth that it dies and is eliminated from a stand.

Because of the fact that the forest is the highest expression of social plant life, the foresters occupy the strategic position from which they command vistas accessible only with difficulty to other naturalists. In this lies the strength of forestry, its peculiar beauty, and the debt which natural science owes to it. It is a significant fact, although, of course, only of historic importance, that, according to Charles Darwin[1] himself, it was "an obscure writer on forest trees" who, in 1830, in Scotland—that is, 29 years before the Origin of Species was published—most expressly and clearly anticipated his views on natural selection in a book on Naval Timber and Arboriculture. For the same reason it was foresters, who, long before the word "ecology" was coined, had assembled a vast amount of material on the life of the forest as a plant association—the basis of their silvicultural practice. Warming, Schimper, and other early writers on ecology borrowed most of their proofs and examples from the facts established by the foresters, and the forest literature of to-day is still practically the only one which contains striking examples of the application of ecology to the solution of practical problems.

One discovery recently made at the Wind River Forest Experiment Station, in Oregon, comes particularly to my mind. In northwestern Idaho, where the western white pine is at its optimum growth and is greatly in demand by the lumberman, our former method of cutting was to remove the main stand and leave seed trees for the restocking of the ground. In order to protect the seed trees from windfall they were left not singly but in blocks, each covering several acres. The trees left amounted often to from 10 to 15 per cent in volume of the total stand, and since they could not be utilized later they formed a fairly heavy investment for reforesting the cut-over land. A study of the effect of these blocks of seed trees upon

[1] Origin of Species.

natural reforestation has proved that they can not be depended upon, at least within a reasonable time, to restock naturally the cut-over land. The distance to which the seed is scattered from these seed trees is insignificant compared with the area to be reforested. Splendid young growth, however, is found here and there on cut-over land, away from any seed trees, where the leaf litter is not completely burned. It is evident, therefore, that the seed from which this young growth originates must have come from a source other than the seed trees. The study of the leaf litter in a virgin stand showed that the latter contained on the average from one to two germinable seed per square foot. Some of the seed found was so discolored that it must have been in the litter for a long time. Thus, it was discovered that the seed of the western white pine retains its vitality for years while lying in the duff and litter beneath the mature stands, and then germinates when the ground is exposed to direct light by cutting. It was found similarly that in old Douglas fir burns, where the leaf litter was not completely destroyed, the young growth invariably sprung up from seed that had escaped fire and had been lying dormant in the ground. Should a second fire go through the young stand before it reaches the bearing stage, the land may become a complete waste, at least for hundreds of years, although there may be seed trees left on the ground. This conclusively proves that the young growth comes from the seed stored in the ground before cutting took place and not from the seed scattered after cutting by the seed trees left.

The wonderful capacity of the leaf litter and duff of the cool, dark forests of the Northwest to act as a storage medium for the seed until favorable conditions for its germination occur is confined not only to the Douglas fir and western white pine but to the seed of other species which often grow together with them, such as noble fir, amabilis fir, western red cedar, and hemlock. The subsequent appearance of other species in a Douglas fir or western white pine stand depends apparently, to a large extent, upon the seed stored in the ground at a time when the original forest still existed. This discovery revolutionizes our conception of the succession of forest stands, since it shows that the future composition of the forest is determined by the seed stored in the leaf litter; and the appearance of seedlings first of one species and then of another results simply from the differences in the relative endurance of seed of the different species that are lying in the ground. Besides being of scientific importance this discovery has also a great practical significance. It accentuates the disastrous consequence of a second fire in an old burn, because no more seed remains in the ground while the capacity of the few seed trees that may be on the burn is very limited in restocking the ground. This discovery enabled the Service to

change materially the present methods of cutting in the white pine and Douglas fir forests, to the mutual advantage of the Government and of the logging operators.

I shall give briefly a few other illustrations of the life of the forest which stamp it as a distinct plant society.

The first social phenomenon in a stand of trees is the differentiation of individuals of the same age on the basis of differences in height, crown development, and growth, the result of the struggle for light and nourishment between the members of the stand. A forest at maturity contains scarcely 5 per cent of all the trees that have started life there. Yet the death of the 95 per cent is a necessary condition to the development of the others. The process of differentiation into dominant and suppressed trees takes place particularly in youth and gradually slows down toward maturity. Thus, in some natural pine forests, during the age between 20 to 80 years, over 4,000 trees on an acre die; whereas at the age between 80 to 100 years only 300 trees die. With some trees this natural dying out with age proceeds faster than with others. Thus in pine, birch, aspen, and all other species which demand a great deal of light, the death rate is enormous. With spruce, beech, fir, and species which are satisfied with less light, this process is less energetic. The growing demand for space with age by individual trees in a spruce forest may be expressed in the following figures:

	Square feet.
At 20 years of age	4
At 40 years of age	34
At 60 years of age	70
At 80 years of age	110
At 100 years of age	150

If we take the space required by a pine at the age between 40 and 50 years as 100, then for spruce at the same age it will be 87, for beech 79, and for fir 63. This process of differentiation is universal in forests everywhere.

Another peculiarity that marks a tree community is the difference in seed production of trees which occupy different positions in the stand. Thus, if the trees in a forest are divided into five classes according to their height and crown development, and if the seed production of the most dominant class is designated as 100, the seed production for trees of the second class will be 88, for the third class 33, for the fourth class only 0.5 per cent; while the trees of the fifth class will not produce a single seed, although the age of all these trees may be practically the same. The same struggle for existence, therefore, which produced the dominant and suppressed trees works toward a natural selection, since only those which have conquered in the struggle for existence and are endowed with the greatest individual energy of growth, reproduce themselves.

In a forest there is altogether a different climate, a different soil, and a different ground cover than outside of it. A forest cover does not allow all the precipitation that falls over it to reach the ground. Part of the precipitation remains on the crowns and is later evaporated back into the air. Another part, through openings in the cover, reaches the ground, while a third part runs down along the trunks to the base of the tree. Many and exact measurements have demonstrated that a forest cover intercepts from 15 to 80 per cent of precipitation, according to the species of trees, density of the stand, age of the forest, and other factors. Thus pine forests of the north intercept only about 20 per cent, spruce about 40 per cent, and fir nearly 60 per cent of the total precipitation that falls in the open. The amount that runs off along the trunks in some species is very small—less than 1 per cent. In others, for instance beech, it is 5 per cent. Thus if a certain locality receives 50 inches of rain, the ground under the forest will receive only 40, 30, or 20 inches. Thus 10, 20, and 30 inches will be withdrawn from the total circulation of moisture over the area occupied by the forest. The forest cover, besides preventing all of the precipitation from reaching the ground, similarly keeps out light, heat, and wind. Under a forest cover, therefore, there is altogether a different heat and light climate and a different relative humidity than in the open.

The foliage that falls year after year upon the ground creates deep modification in the forest soil. The changes which the accumulation of leaf litter and the roots of the trees produce in the soil and subsoil are so fundamental that it is often possible to determine centuries after a forest has been destroyed whether the ground was ever occupied by one.

The effect which trees in a stand have upon each other is not confined merely to changes in their external form and growth; it extends also to their internal structure. The specific gravity of the wood, its composition, and the anatomical structure which determines its specific gravity differ in the same species, and on the same soil, and in the same climate, according to the position which the tree occupies in the stand. Thus in a 100-year-old stand of spruce and fir the specific gravity of wood is greatest in trees of the third crown class (intermediate trees). The ratio of the thick wall portion of the annual ring to the thin wall of the springwood is also different in trees of different crown classes. The difference in the size of the tracheids in trees of different crown classes may be so great that in one tracheid of a dominant tree there may be placed three tracheid cells of a suppressed tree. The amount of lignin per unit of weight is greater in dominant trees than in suppressed trees.

Forest trees in a stand are thus influenced not only by the external physical geographical environment, but also by the new social

environment which they themselves create. For this reason forest trees assimilate, grow, and bear fruit differently and have a different external appearance and internal structure than trees not grown in a forest.

Forestry, unlike horticulture or agriculture, deals with wild plants scarcely modified by cultivation. Trees are also long-lived plants; from the origin of a forest stand to its maturity there may pass more than a century. Foresters therefore operate over long periods of time. They must also deal with vast areas; the soil under the forest is as a rule unchanged by cultivation and most of the cultural operations applicable in arboriculture or agriculture are entirely impracticable in forestry. Forests, therefore, are largely the product of nature, the result of the free play of natural forces. Since the foresters had to deal with natural plants which grew under natural conditions, they early learned to study and use the natural forces affecting forest growth. In nature the least change in the topography, exposure or depth of soil, etc., means a change in the composition of the forest, in its density, in the character of the ground cover, and so on. As a result of his observations, the forester has developed definite laws of forest distribution. The forests in the different regions of the country have been divided into natural types with corresponding types of climate and site. These natural forest types, which, by the way, were also developed long before the modern conception of plant formations came to light, have been laid at the foundation of nearly all of the practical work in the woods. A forest type became the silvicultural unit which has the same physical conditions of growth throughout and therefore requires the same method of treatment. The manner of growth and the method of natural regeneration, once developed for a forest type, hold true for the same type, no matter where it occurs. After the relation between a certain natural type of forest and the climate and topography of a region has been established, the forest growth becomes the living expression of the climatic and physical factors of the locality. Similarly, with a given type of climate and locality it is possible for the forester to conceive the type of forest which would grow there naturally. The forester, therefore, may speak of the climate of the beech forest, of the Engelmann spruce forest, of the yellow-pine forest. Thus, if in China, which may lack weather observations, we find a beech forest similar to one found in northern New York, we can be fairly certain of the climatic similarities of the two regions. More than that, a type of virgin forest growth may serve as a better indication of the climate of a particular locality than meteorological records covering a short number of years. A forest which has grown on the same ground for many generations is the result not of any exceptional climatic cycle, but is the product of the average

climatic conditions that have prevailed in that region for a long time. It expresses not only the result of one single climatic factor, but is the product of all the climatic and physical factors together. Similarly, the use of the natural forest types for determining the potential capacity of the land occupied by them for different purposes is becoming more and more appreciated. When the climatic characteristics of a certain type of forest, for instance those of Engelmann spruce in the Rocky Mountains, is thoroughly established, the potential capacity of the land occupied by it for agriculture, grazing, or other purposes is also largely determined.

Observations of the effect of climate upon forest growth naturally brought out facts with regard to the effect of forests upon climate, soil, and other physical factors and led to the development of a special branch of meteorology, known as forest meteorology, in which the foresters have taken a prominent part. While there are some phases in forest meteorology which still allow room for disagreement, some relationships established by foresters are widely accepted. One of these is the effect which forests have upon local climate, especially that of the area they occupy and of contiguous areas. Every farmer who plants a windbreak knows and takes advantage of this influence. Another relation is that between the forest and the circulation of water on and in the ground, a relation which plays such an important part in the regimen of streams. Still a third one, as yet beyond the possibility of absolute proof, is the effect of forests in level countries, in the path of prevailing winds, upon the humidity and temperature of far-distant regions lying in their lee.

If in the field of botany the forester has contributed to the progress of botanical geography and in the realm of meteorology has opened new fields of investigation, his influence in wood technology has been in changing entirely the attitude of engineers, physicists, and chemists in handling wood products. The methods of studying the physical, mechanical, and chemical properties of wood were, of course, those used in engineering by chemists and physicists; but the forester has shown that wood, unlike steel, concrete, or other structural material, is subject to altogether different laws. Wood, he has shown, is not a homogeneous product, but is greatly influenced by the conditions in the stand from which it comes. Were it not, therefore, that mechanical properties can be tied up with some definite forest conditions and correlated with some readily visible expression of tree growth, such as the number of rings per inch or the specific gravity of the wood, timber would be too much of an indefinite quantity for architects and other users of wood to handle with perfect safety. To find such a relation is just what the foresters have been attempting to do, and most of the studies of the strength

of wood have been with the view of establishing certain relations between the mechanical, physical, and anatomical properties of the wood. Some of these relations I may mention here.

One of the earliest relations which foresters have established with a fair certainty is that between the specific gravity of the wood and its technical qualities. Some of the foresters even go so far as to claim that the specific gravity of wood is an indicator of all other mechanical properties and that the strength of wood increases with the specific gravity, irrespective of the species and genus. In other words, the heavier the wood, all other conditions being equal, the greater its strength. Even oak, which formed apparently an exception, has been recently shown to follow the same law. If there is still some doubt that the specific gravity of wood can be made a criterion of all mechanical and technical properties of wood, the correlation between the specific gravity and the resistance to compression endwise (parallel to the grain) is apparently beyond question. Thus by the specific gravity the resistance to compression endwise can be readily determined. The compression endwise equals 1,000 times the specific gravity minus 70, when the moisture content of the wood is 15 per cent, or $C=1{,}000\ S-70$.

Since in construction work the most desirable wood is the one which possesses the highest strength at a given weight, the ratio between the compression strength and the specific gravity was found to express most clearly the strength of wood. This ratio, however, increases with the increase in the specific gravity, a fact which further substantiates the law that the specific gravity of wood determines its mechanical properties.

Another relation which has been fairly established is that between the resistance to compression endwise and the bending strength of timber. By the resistance compression endwise, therefore, the bending strength of timber can be determined.

One of the other properties of wood—namely, hardness—was found to have a definite relation to the bending and compression strength of wood and this fact tempts the conclusion that by hardness alone all other mechanical properties can be determined. The test for hardness is very simple; it can be made even by a small manufacturer and therefore the whole problem of wood testing would be greatly simplified. Hardness was also found to have a definite relation to the proportion of the summerwood in the annual ring, and consequently to the specific gravity of the wood. The specific gravity of wood is determined by its anatomical structure, by the proportion of fibro-vascular bundles, their thickness and length, the proportion of thick-walled cells, medullary rays, etc. The anatomical structure in its turn is probably determined by the combination of two factors—the amount of nourishment in the soil and the in-

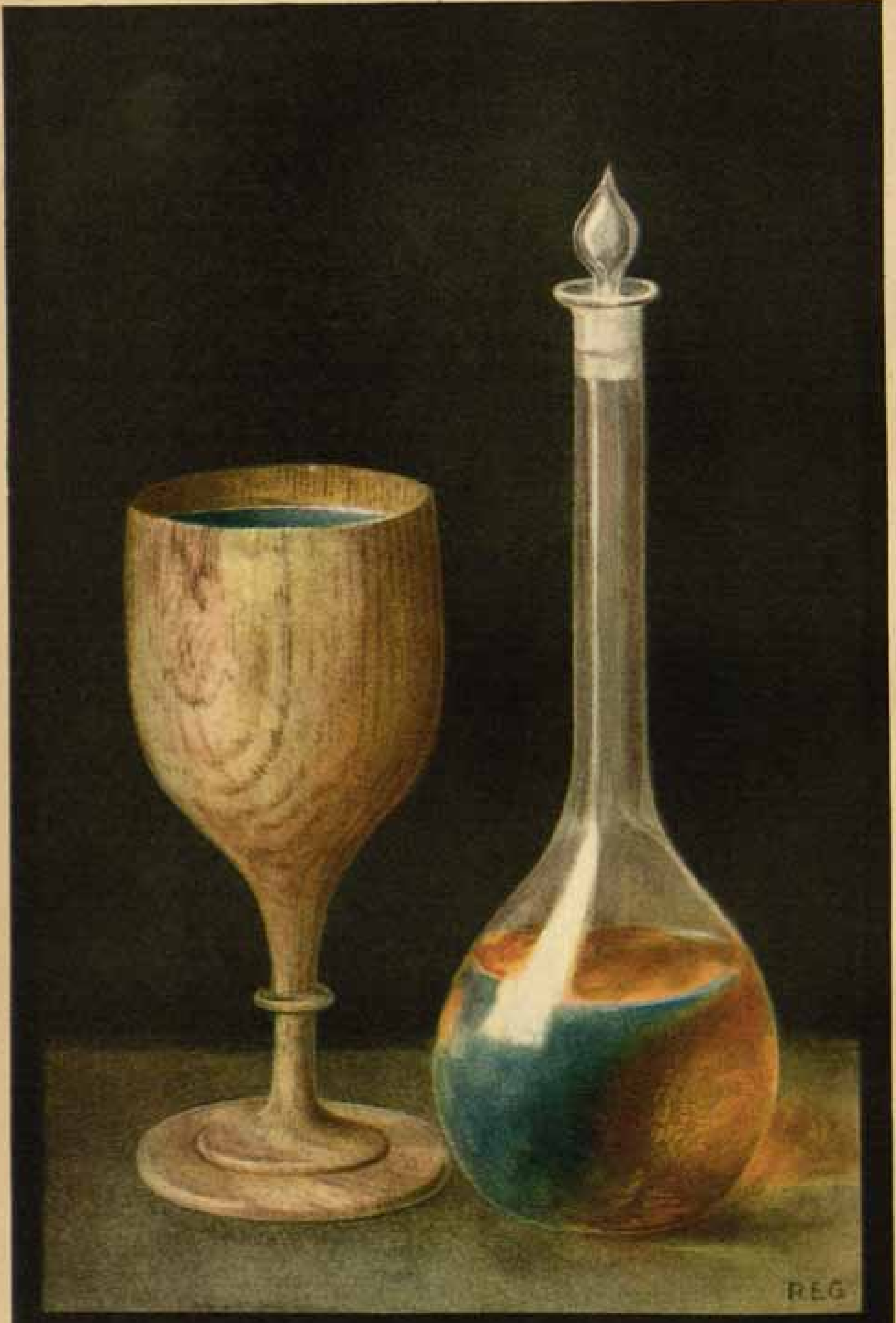
tensity of transpiration. The mechanical properties of wood come, therefore, within the control of the forester who raises and cares for the forest.

There is another field of scientific endeavor in which foresters in this country may claim some credit. This is in the field of forest mathematics. One unfamiliar with forest growth can hardly realize the difficulties in the way of measuring the forest crop, the amount of wood produced in a forest composed, for instance, of many different species, sizes, and ages. If a tree resembled any geometric body, such as a truncated cone, or an Appolonian paraboloid, it would be a simple matter to determine its contents by applying the formula for such body. But a tree's form does not coincide with that of any known geometric body, so that it would seem that the only possible way of determining the contents of the trees forming a forest would be by measuring each single tree. Evidently this would be an entirely impracticable task.

The common practice of determining the contents of trees either in board measure or in cubic feet is to measure a large number of trees of a given species in a given locality and apply the average figures to the trees of the same diameters and heights within that locality. Since there are, however, a great many species of trees in this country some of which have a very wide geographic range, this method necessarily involves the preparation of a large number of local volume tables and hence the measurement of hundreds of thousands of trees. The measurement of the taper of a large number of trees has shown that there are certain critical points along the stem of a tree the ratio between which expresses the form of the tree in a sufficiently accurate manner. It was found that trees having the same total height, the same diameter breast high ($4\frac{1}{2}$ feet from the ground) and the same ratio between the diameter at half the height of the tree and the diameter breast high, must invariably have the same cubic contents irrespective of the species of the tree or the region in which it grows. Thus whether it be a Scotch pine of northern Sweden, a yellow pine of Arizona, a mahogany of the Tropics, or a scrubby birch of the Arctic Circle, the volume of the tree may be expressed by means of one simple relationship. The discovery of this very simple relation provides, for the first time, a basis for the construction of a universal volume table. The mathematicians of the earlier period sought in vain to find a formula by which the cubic contents of a tree could be expressed. What the mathematicians failed to develop by the deductive method, foresters have found by the inductive method. With a reliable table for converting cubic measure into board measure for trees of different sizes, the universal volume table expressed in cubic feet could be translated

into a universal table expressed in board feet, which is the measure peculiar to this country.

There is another contribution of which I am somewhat hesitant to speak, for it is not a contribution to pure science, if by science is meant only the physical or natural sciences. Since, however, it touches the interests of a large number of people, I may be forgiven if I say a few words about it. It is a contribution to what one economist has aptly called the "science of social engineering." The transfer of the forest reserves in 1905 to the Department of Agriculture marked a new departure in the national economic life. It recognized the new principle that the Nation's resources should be managed by the Nation and directly in the interests of the whole people; it recognized that these resources should be developed collectively rather than individually and indirectly. Nearly 10 years have now passed since the inauguration of this policy. The record of what has been accomplished and the manner in which many of the problems have been approached and solved must unquestionably be considered a contribution to the methods by which similar problems may be handled by the Nation in the future. In the administration of the national forests there is being developed gradually what I believe to be a truly scientific system for attaining a concrete economic end, a system of controlling certain correlated industries with a single purpose in view—the maximum of the welfare of the Nation as a whole. In spite of many mistakes which we have undoubtedly made and which we have attempted to correct as we went along, in spite of the lack of practice and experience in solving the problems at hand, this new policy, it seems to me, has already proved to be entirely safe and workable.



CUP OF PHILIPPINE LIGNUM NEPHRITICUM, *Pterocarpus indicus*, AND FLASK CONTAINING ITS FLUORESCENT INFUSION.

LIGNUM NEPHRITICUM—ITS HISTORY AND AN ACCOUNT OF THE REMARKABLE FLUORESCENCE OF ITS INFUSION.[1]

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[With 7 plates.]

INTRODUCTION.

Lignum nephriticum is a remarkable wood which was celebrated throughout Europe in the sixteenth, seventeenth, and the early part of the eighteenth centuries, not only for its reputed medicinal virtues but on account of the strange color phenomena displayed by its infusion in spring water. Cups turned from it were deemed fit gifts for emperors and princes. The water drunk from these cups, or from bowls in which a few chips were allowed to remain, was declared to work marvellous cures; and its beautiful opalescence and changes in sunlight and shadow were the subject of investigations by the most celebrated physicists of that period. Strange to say, scarcely a fragment of this wood is now to be found in museums or drug collections. Its very name has disappeared from modern pharmacographies and encyclopedias; and its botanical identity has remained doubtful until the present day. In the present paper I propose to show that this classic wood came from two distinct sources, from trees of distinct genera. I shall also give an account of the fluorescence of their extracts, and endeavor to explain the causes which led to the confusion of their identity.

EARLY HISTORY.

The Spanish physician Monardes was the first to call attention to the wood. In 1565 he wrote the following account of it:

> They also bring from New Spain a wood resembling that of a pear tree, dense and without knots, which they have been using for many years in these parts for diseases of the kidneys and of the liver. The first person I saw use it was a pilot, 25 years ago, who was afflicted with urinary and kidney trouble, and who after using it recovered his health and was very well. Since then

[1] Based upon a paper entitled "The Rediscovery of Lignum nephriticum," read by the author Feb. 2, 1915, at a meeting of the Botanical Society of Washington. Published by authority of the Secretary of Agriculture.

I have seen much of it brought from New Spain and used for these and kindred maladies. * * * It is used in the following manner: They take the wood and make of it chips as thin as possible and not very large and put them into clear spring water, which must be very good and pure, and they leave them in the water all the time that it lasts for drinking. A half hour after the wood is put in, the water begins to assume a very pale blue color, and the longer it stays the bluer it turns, though the wood is of a white color. Of this water they drink repeatedly and with it they dilute their wine, and it causes very wonderful and manifest effects without any alteration nor any other requisite than good order and regimen. The water has no more taste than if nothing had been put into it, for the wood does not change it at all. Its complexion is hot and dry in the first degree.

Francisco Hernandez, protomedico of Philip II, who returned to Spain in 1577 after having spent seven years in Mexico studying the resources and useful products of that country, added nothing to Monardes's description of the wood, but gave testimony as to its medicinal virtues, and for the first time described the plant producing the *Lignum nephriticum* of Mexico. He was a physician rather than a naturalist, and many of his descriptions and illustrations of both plants and animals are so crude as to be unrecognizable. Of *Lignum nephriticum* he gave no illustration. He even expressed his uncertainty regarding its source, stating that the plant had been described to him as a shrub, but that he had seen specimens which exceeded very large trees in size.

Hernandez's work on the products of Mexico never appeared as a whole. The portions of it relating to medicine were grouped together and prepared for publication by Nardo Antonio Recchi, physician to Philip II, but owing to lack of funds or for other reasons it did not appear until 1651, 73 years after Hernandez's death. A Spanish translation of Recchi's Latin epitome appeared in Mexico in 1615, the prolix title of which, rendered in English, is as follows:

Four books of the Nature and Virtues of Plants and Animals which are received in the practice of Medicine in New Spain, and the Method and Correct Preparation required for their administration, with that which Doctor Francisco Hernandez has written in the Latin language. Very useful for all kinds of people who live on farms and in villages where there are no physicians nor Apothecary-shops—Translated, and augmented with many simples, and compounds, and many other curative secrets, by Fray Francisco Ximenez, son of the Convent of Santo Domingo of Mexico, Native of the Villa de Luna, Kingdom of Aragon. . . . In Mexico, at the house of the Widow of Diego Lopez Davalos, 1615. On sale in the shop of Diego Garrido, on the corner of the calle Tacuba, and in the Portería of Santo Domingo.

In this work is presented Hernandez's account of *Lignum nephriticum*, including Monardes's description of the wood, its medicinal virtues, and the wonderful blue color of its infusion.

In 1646 Athanasius Kircher, a German Jesuit living in Rome, celebrated for his great learning and his contributions to science, published an account of *Lignum nephriticum* in his Ars Magna Lucis et Umbræ, under the heading "On a certain wonderful wood, coloring water all kinds of colors." (Op. cit., p. 77.) He calls attention to the fact that other writers before him had described the wood as coloring water only a blue color; yet in his experiments he had found that it transformed water into all kinds of colors. His description of the plant yielding the wood was not made from observation but was undoubtedly taken from Ximenez's translation of Hernandez's work, published 31 years previously. He then goes on to say:

The wood of the tree thus described, when made into a cup, tinges water when poured into it at first a deep blue, the color of a Bugloss flower; and the longer the water stands in it the deeper the color it assumes. If then the water is poured into a glass globe and held against the light, no vestige of the blue color will be seen, but it will appear to observers like pure clean spring water, limpid and clear. But if you move this glass phial toward a more shady place the liquid will assume a most delightful greenness, and if to a still more shady place, a reddish color; and thus it will change color in a marvelous way according to the nature of its background. In the dark, however, or in an opaque vase, it will once more assume its blue color.

Kircher announces that he was the first to observe this chameleon-like color, as far as he knew, in a cup given to him as a present by the procurator of the Society of Jesus in Mexico. This cup he afterwards sent as a gift to his Sacred Majesty the Emperor, as something rare and little known. "But," he adds, "as to the cause of the strange phenomenon which I observed, I failed at first to understand it; for I saw that the color could be counted neither among the apparent nor the true colors; not among the former, because the true or real color comes from the nature of the wood and not from the light variously modified, as is usual with apparent colors; nor can it be considered a real color, since no color is seen in it when it is held up against the light; and it assumes different kinds of colors only when held against different objects." The learned philosopher, true to his boast that there was no problem in nature that he could not solve, concludes with the statement: "Taught, however, by various experiments, I have at last found the cause, which I shall publish hereafter." This, however, he never did.

Four years after the publication of Kircher's work Johan Bauhin, in his Historia Plantarum (1650), describes a second cup made of *Lignum nephriticum*, which he had received under the name of *Palum indianum* from a colleague, Dr. Schopffius, physician to the Duke of Würtemberg. This ingeniously made cup, almost a span in diameter and of no common beauty, resulting from the variegated

lines adorning it, was accompanied by sawdust or shavings of the same wood of a reddish color and of no manifest taste. When water was poured into the cup and the sawdust macerated in it, the water assumed in a short time "a wonderful blue and yellow color, and when held up against the light beautifully resembled the varying color of the opal, giving forth reflections, as in that gem, of fiery yellow, bright red, glowing purple, and sea green most wonderful to behold." After quoting Monardes's account of *Lignum nephriticum*, the author notes that Cæsalpinius believed the latter to be a species of ash (*Fraxinus*).

The following year (1651) Recchi's epitome of Hernandez's work was published at Rome. It contained a description of *Lignum nephriticum* almost identical with that in Ximenez's previously published Spanish translation. For one of its Nahuatl names, however, the form *coatli* instead of *coatl* was used. The latter name, signifying "snake water," as well as *tlapalezpatli*, "blood-tincture medicine," which was also used by Hernandez, has been frequently misquoted. Thus Pomet, in his Histoire Générale des Drogues, under the heading *Bois Néfrétique*, says that the latter "nous est apporté de la Nouvelle Espagne, principalement du Royaume de Mexique où il est appellé *Coult* et *Tlapalcypaty*." These names are meaningless and misleading; and the same may be said of Pomet's figure of the plant, which represents a miniature tree bearing toothed leaves like those of *Cicer arietinum* ("pois chiches"), out of all proportion to the size of the tree itself.

Padre Bernabé Cobo, in his Historia del Nuevo Mundo (finished in 1653, but not published until 1890–1895), speaks of wooden drinking cups, used for medicinal purposes in New Spain, which turn water blue. He describes the wood from which these cups are made as of a purple color and pretty grain, suitable for carving, and therefore counted among the most precious woods of the country; and he also states that staffs are made of it. Although he gives the vernacular names for many other woods and useful plants in various parts of tropical America he gives none for this, but says that the source of the wood is a certain large tree called *arbol de la inmortalidad*. Of this he gives no description nor definite habitat, and it is probable that he never saw a specimen growing. It is quite possible that he confused two woods, the dark-colored *coatl*, from the heart wood of which beautiful walking sticks can be made, but which never grows to great size, with some species of *Pterocarpus* of greater dimensions. It is quite certain that his description does not at all apply to the woods out of which the cups of Kircher and Bauhin were made, nor to Monardes's wood, which was "of a white color" and resembled pear wood.

BOYLE'S EXPERIMENTS.

The color phenomena displayed by the extract of *Lignum nephriticum* were first investigated in a truly scientific manner by the Hon. Robert Boyle in 1663. The results of his studies were embodied in his Experiments and Considerations Touching Colors, page 203, 1664, a Latin translation of which (1667), and also a summary of the results of Boyle's studies in Richard Boulton's edition of Boyle's works (1700), are in the library of the Surgeon General of the Army at Washington. Boyle's account, as published by Boulton, is as follows:

I am told that *Lignum Nephriticum* is us'd in the Country where it grows as an excellent Medicine against the Stone; which Virtues Monardes likewise ascribes to it given in Infusion. An Infusion of this Wood, if it be not too strong will appear, betwixt the Eye and the Light, to be of a golden Colour, except that upon the Top it will be covered with a sky colour'd Circle; but if your Eye be plac'd betwixt the Window and the Vial, the Liquor will appear to be of a lovely Blew. And this Experiment hath succeeded by Candle Light: If the Liquor be held partly before the Eye and a Light, and partly betwixt the Eye and an Opacous Body, it will half of it seem of a golden Colour, and half a Blew; but if turning your back on the Window you observe the Liquor as it is poured out, it will at the first seem Blew; but when it hath fallen lower, and the Rays of Light penetrate it more, it will seem Parti-coloured. If a little of this Tincture be pour'd into a Basin of Water, partly in the Sun Beams and partly shaded, it will afford several pleasing *Phænomena*. If some of it be pour'd upon white Paper, the drops about it will appear of different Colours, as the Position of the Eye in reference to them varies; and when it is pour'd off, the Paper will be dyed Yellow; and if this be plac'd in a Window in the Sun-shine, and a Pen held betwixt the Sun and part of the Paper, the Verge of the Shadow next the Body that Causes it will be Golden, and the other Blew. Which *Phænomena* proceeded from the most subtile Parts of the Wood Swimming in the Water, and in Several Positions variously reflecting the Rays of Light. Some of this Liquor being carefully Distill'd, it yielded a colourless Limpid Water, a deep ceruleous Liquor remaining behind. Spirit of Wine and Salt of Harts-horn, being mixed together I observ'd, that it required a certain proportion betwixt the Liquor and the Salt, which enabl'd it to vary it's Colour. So that tho I was induc'd to believe that our Tincture receiv'd its Colour from a Salt dispers'd through it, yet I suspected, that this Salt would be either alter'd or incorporated by Acid Salts; and accordingly, dropping Spirit of Vinegar into some of the Tincture, it lost its Blew, but not the Golden Colour; but upon an Affusion of Oyl of *Tartar per deliquium*, that correcting the Acid Salts, it presently regain'd its Blew Colour again, the ponderous Tartarous Liquor first altering the Bottom of the Liquor and gradually rising again.

And since *Kercherus, Art. Mag. lucis & umbrae Lib.* I, *Part* 3, writes something of this Exotick Plant, which agrees not with our account of it, since he says it will, according to the difference of the Medium, in respect of Light and its several Positions, vary its Colour; yet from the Account he gives of it, it appears, that the Wood he made use of, was different from Ours since he calls it a white *Mexican* Wood, whereas ours, as Monardes witnesses, is brought from *Nova Hispania*, and is not of a White, but a darker Colour, except on the outside, which part is much weaker than the other. Besides, he tells us that his Tincture was like Spring Water when held betwixt the Light, whereas ours

is Yellowish or Reddish, as the Tincture is weaker or stronger. And since he tells us, that the Tincture will afford all sorts of Colours, and resume a ceruleous Colour in the Dark, I could wish to know how he was convinced of the latter; and as for the Former, I have tryed that it would not at all answer. Tho' this I must needs own, that having held a Tincture of *Lignum Nephriticum* in the Rays of the Sun, in a darken'd Room, partly in and partly out, and also, wholly out of the Beams but partly near them, it afforded a much greater Variety of Colours than in a lighten'd Room.

In this Experiment it is not a little to be admir'd, that the Blew Colour should be so easily destroyed, whereas the Yellow Colour is so durable; and further, that Acid Salts should destroy it and a Sulphureous one restore it.

CONFUSION OF BOTANICAL NAMES.

The source of lignum nephriticum remained unknown for centuries. Monardes (1565) knew nothing of its origin except that it came to Spain from Mexico. Cæsalpinius (1583) and Caspar Bauhin (1623), as we have seen, supposed it to be a species of *Fraxinus*. Terrentius, in Recchi's epitome of Hernandez (1651), referred it to the leguminosæ but did not attempt to identify it. Johan Boeclerus (1745), believing it to be a laburnum, called it *Cytissus mexicanus*. Linnæus, in his Materia Medica (1749) added to the confusion by referring it to *Moringa pterygosperma*, an East Indian tree; while Guibourt, in his Histoire abregée des drogues (1820), identified it with the West Indian cats-claw (*Mimosa unguis-cati* L.).

The first to indicate its true botanical classification was Dr. Leonardo Oliva, professor of pharmacology in the University of Guadalajara, in his Lecciones de Farmacología, vol. 2, p. 429, 1854, who identified it with *Varennea polystachya* DC. (*Viborquia polystachya* Ortega; *Eysenhardtia amorphoides* H. B. K.). Subsequent authorities, however, did not accept his identification. Dr. Fernando Altamirano (1878), while recognizing the identity of the *coatli* of Hernández with the tree called by the modern Mexicans *palo dulce* and referring it to *Viborquia polystachya* Ortega, was not aware that the latter was the same as *Eysenhardtia amorphoides* H. B. K., and he followed Alfonso Herrero in referring lignum nephriticum to *Guilandina moringa*, a mistake which may be traced at once to Linnaeus. In describing the uses of *coatli* wood by the modern Mexicans, he states that the country people make drinking troughs of it for their fowls to guard against certain epidemics to which the latter are subject; or, if the vessel from which they drink is of some other substance, they put a piece of wood in the water and allow it to remain there. The water assumes a blue color, he says; but Mariano Bárcena, who experimented with it, observed that the blue color was the result of the refraction of light, and the water, instead

EYSENHARDTIA POLYSTACHYA (ORTEGA) SARGENT, FROM THE BARRANCA OF GUADALAJARA, MEXICO.

of yielding a blue pigment like indigo, yielded a yellowish brown dyestuff.[1]

Sargent in his Silva of North America gave an amended description of the genus Eysenhardtia, in which he for the first time established the combination *Eysenhardtia polystachya*, but it is evident that he was unaware that this species had anything to do with the classic lignum nephriticum or that its wood yielded a fluorescent infusion. Concerning it he simply says: "The wood of some species is hard and close-grained and affords valuable fuel. The genus is not known to possess other useful properties."[2]

The third edition of the Nueva Farmacopéa Mexicana (1898) repeats Oliva's observations under the heading "Taray de Mexico," but in a footnote states that *leño nefrítico* had been erroneously attributed to *Varennea polystachya*, or *Eysenhardtia amorphoides* H. B. K., and that its classification was not known.[3]

In a subsequent edition of this work the name *palo dulce* is omitted, except as applied to the European licorice. Flückinger and Hanbury, in their well-known Pharmacographia (1879), are silent about lignum nephriticum, although for several years before the publication of this work Hanbury had been seeking to identify it.[4] Dragendorff refers to it as a species of Guajacum.[5]

Dr. Otto Stapf, guided by Ramirez and Alcocer's Sinonimía vulgar y científica de las Plantas Mexicanas (1902), referred a piece of wood, labeled "cuatl" in the Paris Exposition, to *Eysenhardtia amorphoides;* but the wood was unaccompanied by botanical material by which it might be identified with certainty.[6] He gives a history of the wood known as lignum nephriticum in early literature, and also quotes several Mexican authorities but not Oliva, cited above, nor any Philippine author. He accounts for the fact that the flowers were described by Hernandez as yellow, by the supposition that there are varieties of Eysenhardtia yielding lignum nephriticum which have yellow flowers, although, as a matter of fact, no such forms occur in the localities cited by writers on the subject; and the only species in which the flowers are yellow are low scrubby plants, belonging to a distinct section, which never attain the size even of a small tree, nor have a stem with a diameter sufficiently great for a cup, or even approaching the dimensions of the pieces of lignum nephriticum hitherto described.

[1] Altamirano, Fernando. "Leguminosas indigenas medicinales," in La Naturaleza, 4: 97–98. 1879.

[2] Sargent, Charles Sprague, The Silva of North America, 3: 30. 1892.

[3] Nueva Farm. Mex. 153. 1896.

[4] See Oliver and Hanbury, in Admiralty Manual of Scientific Inquiry, p. 391. 1871. "*Lignum nephriticum.*—This rare wood, noticed by some of the earliest explorers of America, is a production of Mexico. To what tree is it to be referred? Its infusion is remarkable for having the blue tint seen in a solution of quinine."

[5] "*Das Lignum nephriticum* der älteren Medicin wird wohl von einer Guajacum-Art stammen." Dragend. Heilpfl. 345. 1898.

[6] See Stapf, Otto. Kew Bull. Information, 1909, pp. 293–305. 1909.

The last author to investigate the origin of lignum nephriticum is Dr. Hans-Jacob Möller, of Copenhagen, who, after an exhaustive study of the subject, referred it to a Mexican tree belonging to the genus Pterocarpus. Dr. Möller made a careful examination of the various woods hitherto supposed to be the true *lignum nephriticum mexicanum*, among them specimens of the wood of *Eysenhardtia amorphoides* sent to him by C. A. Purpus—the latter described as "das Kernholz von einem recht dicken Ast"—but with negative results ("*keine Fluoreszenz*"). On examining the heartwood of a Philippine species of Pterocarpus, however, he found that in water containing lime it yielded an infusion having the characteristic sky-blue fluorescence of lignum nephriticum described by early investigators. He therefore assumes that the mother plant of *lignum nephriticum mexicanum*, "sought in vain for 300 years by so many investigators is a Mexican species of Pterocarpus," in all probability *Pterocarpus amphymenium* DC. (*Amphymenium pubescens* H. B. K., *Pterocarpus pubescens* Sprengel); and he refers a second kind mentioned by Hernandez, endemic in Quauhchinango, to *Pterocarpus orbiculatus* DC.[1]

TWO DISTINCT SOURCES OF THE WOOD.

In these attempts to trace lignum nephriticum to a single mother plant the writers have been confronted with serious difficulties. How could *Eysenhardtia polystachya*, a shrub or small tree, be its origin, when, according to Hernandez, logs of lignum nephriticum of great size were transported to Spain. And how could the wood of this species, with its dark-colored heart and yellow infusion, be identified with the "white" woods of Monardes and Kircher yielding an infusion as white and clear as spring water, or with the wood of Johan Bauhin with its variegated lines and its red sawdust? And, if lignum nephriticum originated in Mexico, why has the long search in that country for cups made of it been unavailing? On the other hand, it may be asked, How could the mother plant of lignum nephriticum be a species of Pterocarpus if, as Hernandez writes, its compound leaves are composed of minute leaflets suggesting those of *Cicer arictinum* or the ultimate divisions of the leaves of *Ruta chalepensis?*

Figure 1 shows a leaf of Humboldt and Bonpland's original type plant of *Pterocarpus pubescens* (*Pt. amphymerium* DC.), to which

[1] Möller, Hans-Jacob. Lignum nephriticum. Berichte der Deutschen Pharmaz. Gesellsch. 23: 88–154. 1913.

dulce, which has the largest leaflets of any of its genus hitherto described.

There is a simple solution to the problem. Two distinct woods have, beyond a doubt, been called lignum nephriticum: *Eysenhardtia polys-*

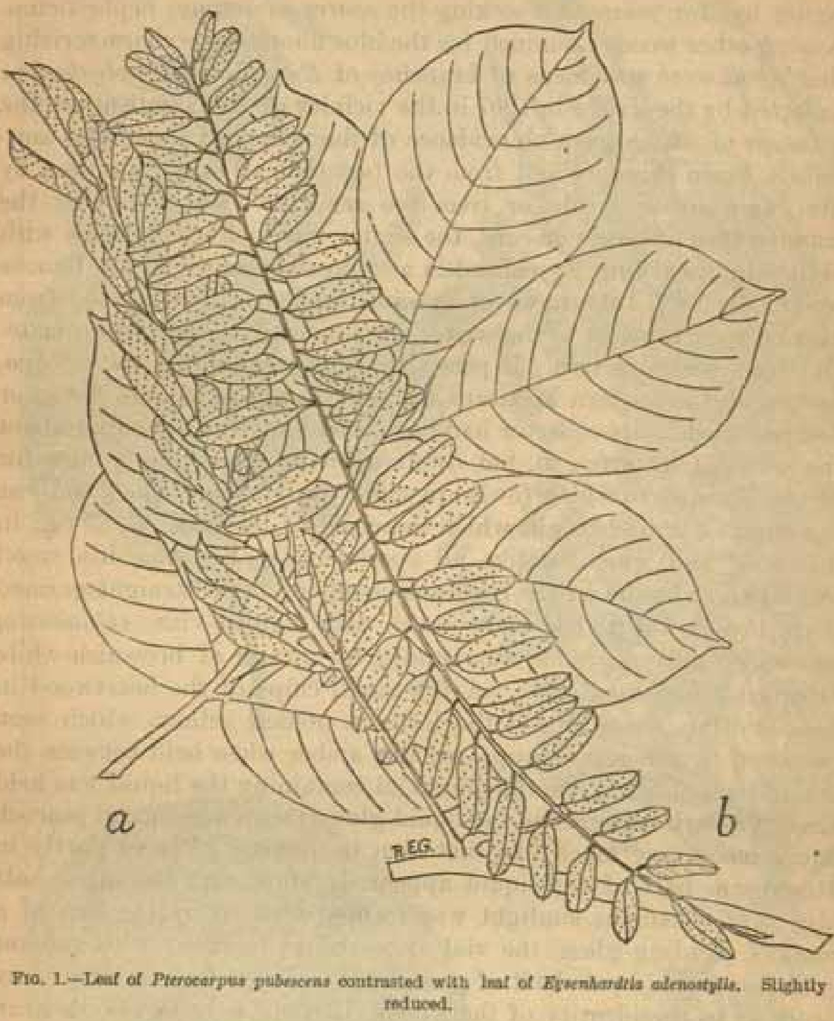


FIG. 1.—Leaf of *Pterocarpus pubescens* contrasted with leaf of *Eysenhardtia adenostylis*. Slightly reduced.

tachya, endemic in Mexico, and *Pterocarpus indica*, a forest tree of the Philippine Archipelago and adjacent islands. Trees of the genus Pterocarpus also occur in Mexico, and it is possible that cups were made from their wood, but we have no definite evidence to prove this conjecture.

I. Mexican Lignum Nephriticum.

Eysenhardtia polystachya.

In connection with his work on the economic botany of Mexico the writer has for years been seeking the source of lignum nephriticum. Among other woods examined for the blue fluorescence characterizing this wood were specimens of branches of *Eysenhardtia polystachya* collected by the writer in 1907 in the vicinity of Aguascalienthes, the infusion of which gave no evidence of fluorescence in ordinary sunlight. From this fact and from the fact that all specimens seen by him were either shrubs or trees too small to yield wood for the manufacture of bowls or cups, the writer was inclined to agree with Möller in discarding Eysenhardtia as a possible source of the famous wood. In July, 1914, however, specimens of a medicinal wood from Mexico were brought to the writer accompanied by herbarium material from the same tree. It proved to be *Eysenhardtia polystachya*, known by the modern Mexicans in many localities as *palo dulce*, or "sweet wood." Its collector had not noticed anything peculiar about the color of its infusion, but dwelt upon its efficacy as a cure for certain diseases to which fowls are subject in Mexico. The wood was a section of a tree trunk, which deprived of its bark was 7 cm. in diameter, and which, unlike all specimens of Eysenhardtia wood hitherto seen by the writer, consisted chiefly of dense, straight-grained dark brown heartwood very much like lignum-vitæ (*Guaiacum officinale*) in appearance, surrounded by a ring of brownish-white sapwood 5 to 8 mm. thick. A few small chips of the heartwood in ordinary tap water tinged the latter a golden yellow, which soon deepened to orange and appeared like amber when held between the eye and window. When the glass vial containing the liquid was held against a dark background the liquid glowed with a beautiful peacock fluorescence very much like that seen in quinine. Placed partly in a sunbeam half of the liquid appeared yellow and the other half blue; and when the sunlight was focused upon it by the lens of a common reading glass, the vial appeared to be filled with radiant gold penetrated by a shaft of pure cobalt. There was no longer any doubt as to the identity of the wood. It could only be the Mexican lignum nephriticum of Robert Boyle's experiments, and it was undoubtedly the wood of *Eysenhardtia polystachya*, a tree with small pinnately compound leaves which might indeed suggest those of a chick-pea or of the common wild rue of Spain, and with spikes of small flowers which had turned yellowish in drying, corresponding well with Hernandez's description of the coatl of the Aztecs.

Plate 3 shows a photograph of a section of the wood of *Eysenhardtia polystachya* together with the botanical material which served to identify it.

LIGNUM NEPHRITICUM MEXICANUM, EYSENHARDTIÁ POLYSTACHYA (ORTEGA) SARGENT.

Chips of the sapwood tinged tap water only slightly at first, but when left overnight the infusion deepened to a greenish yellow and glowed with a decided fluorescence. With distilled water neither the sapwood nor the heartwood produced fluorescence as seen by ordinary sunlight; but this phenomenon was distinctly visible when, at the suggestion of Dr. Arno Viehoever, pharmacognosist of the Bureau of Chemistry, these infusions were held in the ultra-violet rays of a fluorescence lamp; and it was also displayed in ordinary daylight, when a small amount of carbonate of sodium or other alkali was added to the infusions of the wood in distilled water. By boiling chips of the wood in tap water for several hours a deep amber-colored extract was obtained not unlike Madeira wine in color. When placed on the table before a window the surface of this extract appeared to be outlined by a deep blue marginal ring, and when held away from the light or when the light fell upon it obliquely the fluorescence of the liquid gave it an opalescent appearance not unlike that of certain mineral oils. A drop of the extract in a glass of water caused the whole glass to glow with fluorescence when held in the rays of the sun admitted through a hole in a screen.

At the residence of Dr. Alexander Graham Bell, in Washington, on the evening of January 6, 1915, where the wood and accompanying herbarium material were shown by the writer, specimens of the infusion exhibited by ordinary electric light failed to show fluorescence; but afterwards, when held in the rays of an arc light, the liquid glowed with an intense blue light which illuminated the faces of those standing near by.

Experiments were made by Dr. Lyman J. Briggs, biophysicist of the Bureau of Plant Industry, with a view to determine the possible value of lignum nephriticum as an indicator in titrimetric determinations. The result of Dr. Briggs's observation have not been published, but he recognized at once the advantage which this, like other fluorescent substances, must have over those indicators which show color changes only by transmitted light, especially in testing dark liquids, in which the color of the liquid masks the color changes of the indicator. Eysenhardtia wood has a great advantage over fluorescein itself, from the fact that its extract is readily soluble in cold water. With most acids it does not fluoresce, but in the presence of acetic acid its fluorescence is not destroyed. It can not, therefore, be used as an indication of alkalinity in all cases. As compared with phenolphthalein it has a neutral point nearer the acid end of the scale; that is to say, it will fluoresce in a solution in which phenolphthalein develops no color whatever.

Plate 4 is a colored drawing by Mr. J. M. Shull, showing a section of the wood of *Eysenhardtia polystachya*, together with an infusion in tap water of the sapwood, in the smaller phials, and an

extract of the heartwood in the larger phials, also in tap water containing a small percentage of lime. The outer phials are represented with the light shining through them; the inner ones, against the black background, display the fluorescence, as seen by reflected light.

Plate 5 is a colored drawing by Mrs. R. E. Gamble of two phials containing an extract of Eysenhardtia wood in distilled water, made slightly alkaline by the addition of a little carbonate of sodium. The flask against the dark background is illuminated by light coming obliquely from the left; the other flask is shown against the light, with the surface of the deep amber-colored extract bounded by a bluish circle.

BOTANICAL DESCRIPTION.

The plant positively identified as yielding the lignum nephriticum mexicanum of Hernandez and Robert Boyle may be described briefly as follows (see pl. 3):

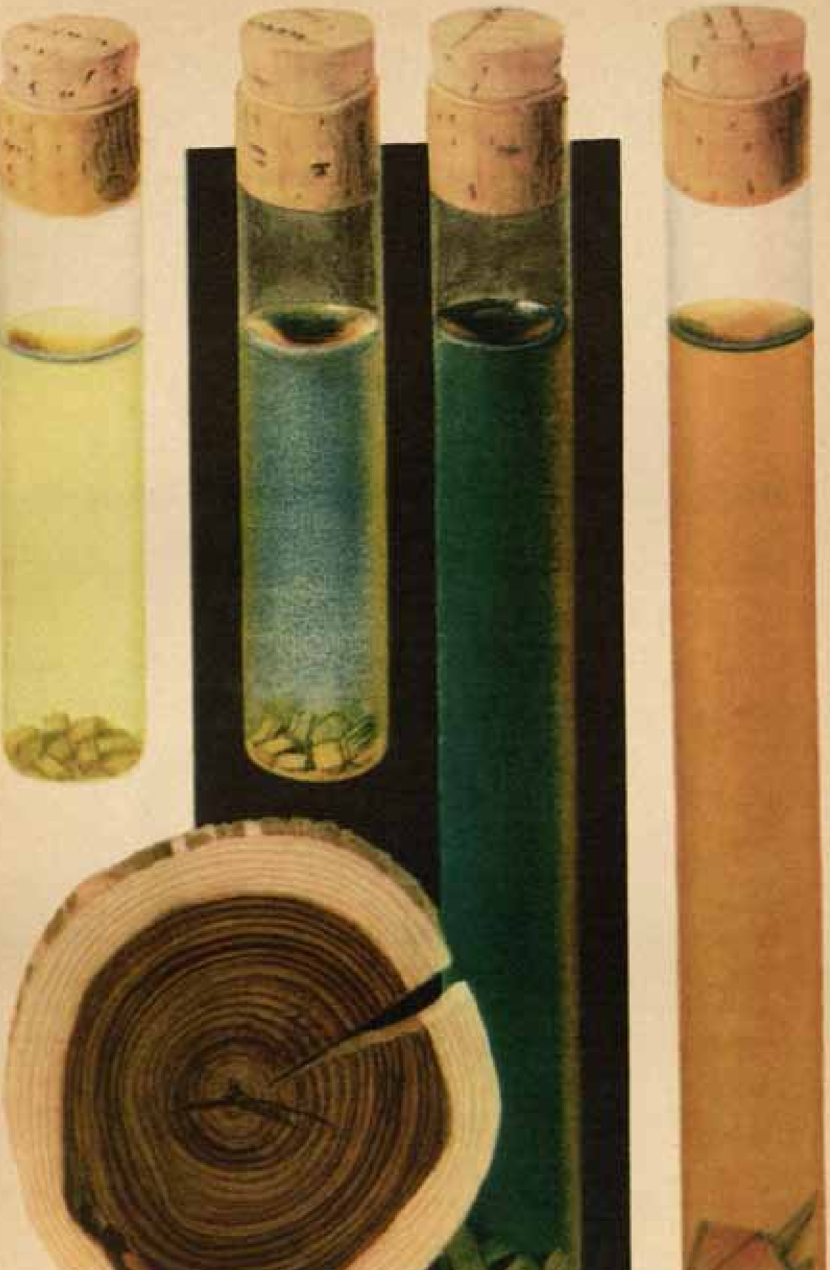
Eysenhardtia polystachya (Ortega) Sargent. Silv. N. Am. **3**: 29. 1892. (Excl. Texas references).

Viborquia polystachya Ortega, Hort. Matr. Dec. **5**: 66. *pl. 9*. 1798.

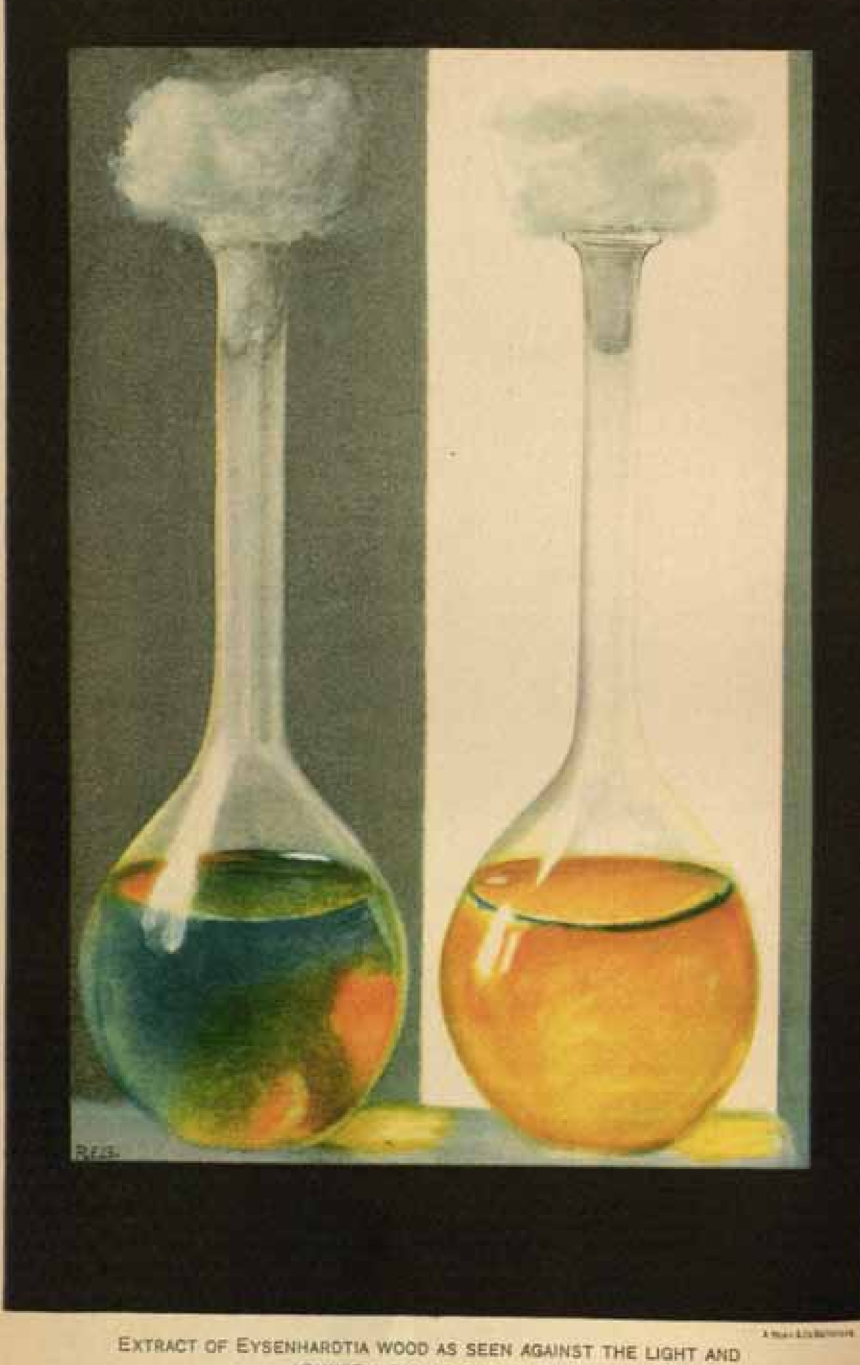
Eysenhardtia amorphoides H. B. K. Nov. Gen. et Sp. **6**: 494. *pl. 592*. 1823.

Varennea polystachya (Ort.) DC. Prodr. **2**: 522. 1825. Oliva, Lecc. Farm. **2**: 429. 1854.

An erect, sweetly aromatic shrub or small tree, glandular-punctate, with spreading, recurved branches. Leaves even-pinnate or odd-pinnate, with numerous small opposite or alternate stipellate leaflets; leaflets oval, or oblong-elliptical, entire, usually decreasing in size toward the extremity of the rachis, the terminal one of odd-pinnate leaves often obcordate, the others rounded or slightly retuse at the apex and often terminating in a short acumen, pubescent when young, sometimes becoming glabrate, usually punctate with glandular dots on the lower surface. Flowers fragrant, small, white, turning yellow in drying, borne in terminal densely spicate racemes; pedicels subtended by a lanceolate deciduous bracteole, short and slender, often reflexed at length, but sometimes ascending or widely spreading; calyx glandular-punctate, 5-toothed, persistent; corolla scarcely at all papilionaceous, composed of 5 nearly equal unguiculate petals; the standard slightly broader than the wings and keel, emarginate, carinate, with involute margins; stamens 10, diadelphous, the superior one free, the filaments of the others united into a tube; ovary subsessile, oblong, compressed, terminating in a slender style, somewhat longer than the stamens, geniculate and glandular below the apex; stigma introrse. Legume very small, oblong, compressed flat, subfalcate or almost straight, subtended by the persistent calyx



SECTION OF WOOD OF EYSENHARDTIA POLYSTACHYA, WITH INFUSIONS OF SAP-WOOD AND HEART-WOOD.



EXTRACT OF EYSENHARDTIA WOOD AS SEEN AGAINST THE LIGHT AND AGAINST A DARK BACKGROUND.

and tipped by the persistent base of the style, usually glandular-punctate, indehiscent, pendent or abruptly reflexed, sometimes widely spreading or ascending, but never erect and appressed, purplish at the apex when fresh, usually containing a single seed near the apex.

The earliest description of this plant was that of Hernandez, as already indicated, which, though written about the year 1575, remained unpublished until 1615, when it appeared in the form of Ximenez's Spanish translation of the original Latin, in Mexico City. Of the identity of Hernandez's plant there can be no doubt; for it had small pinnately compound leaves suggesting those of a garvanzo (*Cicer arietinum*), but smaller and almost like the pinnately divided leaves of the common rue (*Ruta chalepensis*), though "somewhat larger, a mean between these two extremes; and small longish flowers, yellow and delicate, arranged in spikes." According to Hernandez it grows in moderately warm regions like the Valley of Mexico, and still warmer situations like Guachinango [in the present State of Puebla], Chimalhuacan [in the district of Texcoco], Chalco, and Tepuztlan [near Cuernavaca, State of Morelos], and almost throughout the entire extent of the mal pais [the *pedregal*, or lava beds] of Coyohuacan; and in many other places."

The first botanical description of the plant, in the modern sense of the word, was that of Gomez Ortega, in 1798, as cited above; but Ortega, in spite of the fact that he had but recently included a description of the Mexican lignum nephriticum, or coatl, in the Madrid edition of Hernandez's works,[1] which he himself edited, had not the slightest idea that his Viborquia, grown in the Royal Garden of Madrid from seeds sent by Sessé from Mexico, had any connection whatever with lignum nephriticum, or even that its wood would yield a fluorescent infusion.

Ortega named the genus in honor of "Viborq, most distinguished professor of the botanical garden of Copenhagen, who, when recently he journeyed through Spain and visited Madrid, left in us a deep appreciation of his kindliness and conversation." Unfortunately, the generic name Viborquia had, according to the laws of nomenclature, to be abandoned on account of its prior use by Moench of Marburg for another genus (written Viborgia) named for the same man (1794), and the much later name, Eysenhardtia of Humboldt, Bonpland and Kunth, proposed in 1823, had to be substituted for it. In this connection it is also interesting to note that Humboldt and Bonpland, like Ortega, had no idea of the connection of their plant with lignum nephriticum.

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[1] "De Coatli, seu Aqueo Serpente.—Coatli, quam alii *Tlapalezpatli*, seu medicinam *sanguinis coccineam* vocant, frutex est magnus, foliis Ciceris, minoribus tamen, rutaceisve, sed majoribus, flore luteo elanguescenti, parvo et longiusculo, composito in spicas."—Hernandez, ed. Matr., 1: 349. 1790.

Ortega's original figure of *Eysenhardtia polystachya*, showing the young leaves with stipels at the base of the leaflets, the flowers in spicate racemes just beginning to bloom, and the reflexed seed pods, together with details of the flower and fruit, is reproduced in the Journal of the Washington Academy of Sciences, vol. 5, page 512, figure 1, 1915.

VARIABILITY.

Eysenhardtia polystachya, as understood by the author, is remarkably variable in size and form of leaves, density of pubescence, and appearance of seed pods. It sometimes occurs as a stunted bush with very small leaflets, sometimes as a spreading shrub with straight stems and recurved branches, and sometimes as a slender tree of dimensions sufficient to furnish a valuable cabinet wood.

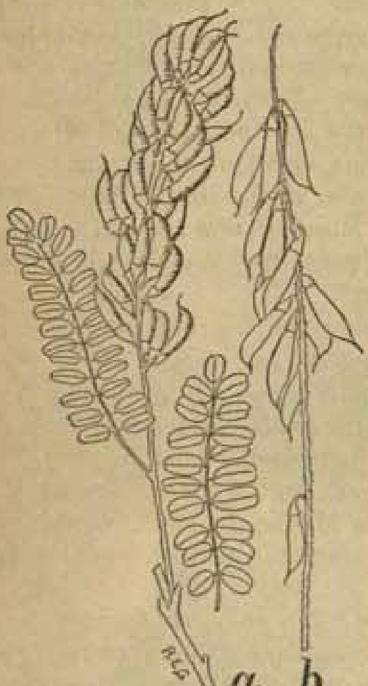

FIG. 2.—Fruits of Eysenhardtia. *a*, Ascending pods of *E. texana*; *b*, reflexed pods of *E. polystachya*.

A distinction has been made between the forms having reflexed seed pods, as shown in plate 3 and in figure 1 *b*, and those with ascending or spreading pods, as shown in figure 3; but in certain localities, as in the barrancas of the State of Jalisco, closely allied forms occur almost side by side, some with reflexed and others with spreading or ascending seed pods; but the latter can never be confused with the closely appressed pods of the dwarf *Eysenhardtia texana*, shown in figure 1 *a*. Figure 3 shows a subglabrous form with very pronounced glandular dots on the leaflets and with spreading seed pods almost twice as large as those of the typical plant.

On account of this tendency to vary it is difficult to delimit the species. It is quite certain, however, that *Eysenhardtia texana* Scheele, the type of which was collected by Lindheimer in the vicinity of New Braunfels, Texas, is a valid species quite distinct from *E. polystachya* of central and southern Mexico. Figure 2 shows the fruits of the two species side by side, *a*, *Eysenhardtia texana* in fruit, drawn from a specimen of the type collection, showing the appressed subfalcate pods; *b*, *Eysenhardtia polystachya*, showing

the reflexed almost straight pods, like those in Ortega's figure already referred to.

It is also quite probable that the more robust *Eysenhardtia adenostylis* Baillon of Guatemala is a valid species, with pods and leaves much larger than the typical *E. polystachya*. A leaf of this species is shown in figure 1, *b*. On the other hand, *Eysenhardtia orthocarpa* Watson, based upon *E. amorphoides* var. *orthocarpa* Gray, collected by Charles Wright in Sonora, approaches so closely to forms of *E. polystachya* of central and southern Mexico that it can scarcely be separated from that species. Watson recognized that

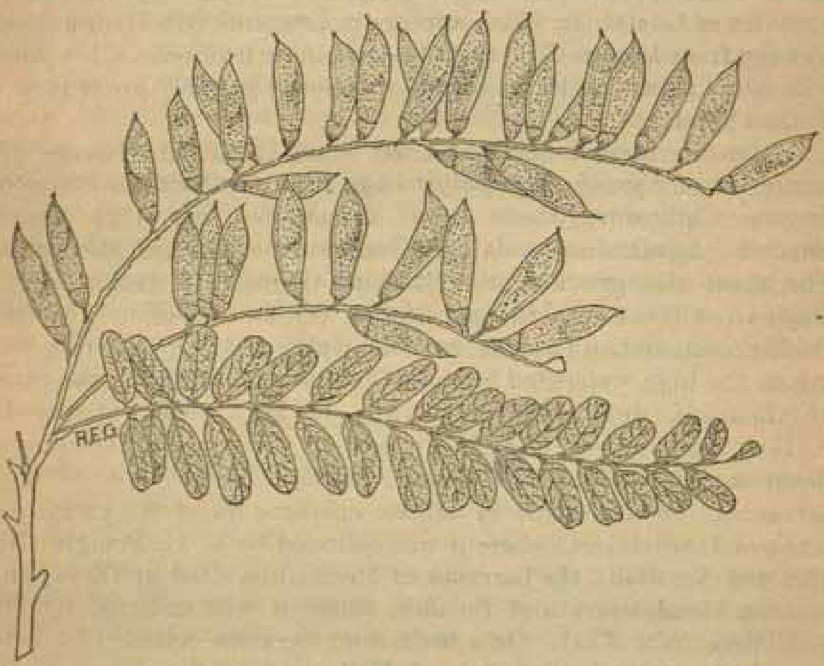

FIG. 3.—*Eysenhardtia polystachya*, a Jaliscan form with spreading fruit.

the plants with straight reflexed pods, referred by him to *E. orthocarpa*, were specifically distinct from Lindheimer's Texas plant, which was erroneously believed to be identical with *E. polystachya* (*E. amorphoides* H. B. K.). *E. texana* Scheele has much smaller leaves and fewer leaflets, and its pods are ascending on the rachis and subfalcate-incurved, as shown in figure 2. The group of low scrubby plants including *Eysenhardtia spinosa* Engelmann, *E. parvifolia* Brandegee, and *E. peninsularis* Brandegee, is so distinct from typical Eysenhardtia that it may possibly have to be removed from this genus. To the recently described *E. Olivana* Safford I have already referred in the footnote on page 279.

GEOGRAPHICAL DISTRIBUTION.

The genus Eysenhardtia is confined to America. Its range extends from Texas and Arizona on the north to Guatemala on the south. On the elevated plateau of northern Mexico it usually grows as a shrub about 2 meters high, in southern Mexico as a tree 6 to 8 meters high, yielding wood which is valued for cabinet purposes. It is probably this wood which Padre Cobo had in mind, when he described the "arbol de la immortalidad;" and, as the wood resembles lignum-vitae, it is possible that the latter suggested the name which Cobo applied to it and led to its incorrect identification as a species of Guaiacum, which appears in Dragendorff's Heilpflanzen. Not far from Mexico City, on the pedregal, or lava beds, a low form with small pubescent leaves occurs, which may possibly prove to be a distinct species.

In the Herbarium of the United States National Museum are specimens of *Eysenhardtia polystachya* from the Mexican States of Sonora, Chihuahua, Nuevo Leon, Tamaulipas, San Luis Potosi, Coahuila, Aguascalientes, Jalisco, Guerrero, Oaxaca, and Michoacan. The plant also grows in the State of Guanajuato (according to Dugès), on the volcanic slopes of the Nevado of Colima near the Pacific coast, and on Orizaba, near the Gulf coast. Specimens growing on the high watershed between Chilapa and Tixtla, in the State of Guerrero, were collected by Mr. E. W. Nelson, of the U. S. Biological Survey (No. 2159), and in the State of Oaxaca at elevations of 1,500 to 1,800 meters, usually on the slopes of deep barrancas. It also occurs in Jalisco, on the sides of the great barranca of Guadalajara, where it was collected by C. G. Pringle (No. 8762 and No. 9752), the barranca of Mochitiltic, cited by Oliva; and between Guadalajara and Bolaños, where it was collected by Dr. J. N. Rose (No. 3734). On a herbarium specimen collected by Langlasseé (No. 226) in the State of Michoacan, at the station of La Junta, the tree is described by the collector as an "arbre au tronc elancé; bois, recherché pour ébénisterie, produit une teinture bleue."

A photograph of the specimens from Tamaulipas described in this paper is shown on plate 3 (opp. p. 280) and the wood with its infusion on the colored plate 4.

STRUCTURE OF THE WOOD.

Microscopic sections of the wood of *Eysenhardtia polystachya* were made at the writer's request by Dr. Albert Mann, plant morphologist of the Bureau of Plant Industry, and by Mr. C. D. Mell, recently attached to the Forest Service as assistant dendrologist, now attached to the Bureau of Chemistry. Dr. Mann found the heartwood to be extremely compact, heavily lignified, and impregnated

with a peculiar substance which could be called neither a resin nor a gum, insoluble in water, and not breaking down in alcohol or xylol. This substance is contained in pitted tracheae, or tubular vessels, which in a cross section appear like pores either solitary or in groups of two or three. Radial and tangential sections show the pitted tracheae throughout their length either partly or entirely filled with the resin-like substance, and they also show the medullary or pith rays, which in the cross sections are quite inconspicuous. The annular lines of growth, however, are well marked in the cross sections.

The accompanying drawings (p. 288) were made by Mrs. Gamble from photographs of sections of the wood of *Eysenhardtia polystachya* cut by Mr. C. D. Mell. Figure 4 shows a cross section of the wood in which the annular lines of growth, *a*, the tracheae, *b*, either empty or containing the resin-like substance, and the intervening wood parenchyma, *c*, are indicated. Figure 5 shows a radial section in which the pitted tracheae, *b*, either empty or containing the resinoid substance, the intervening wood parenchyma, *c*, and the transverse medullary rays are shown throughout their length. Figure 6 shows a tangential section in which the tracheae, *b*, appear very much as in the radial section, but the medullary rays, *d*, are only seen in cross section between the tracheae and the mass of wood parenchyma, *c*.

SOURCE OF ITS FLUORESCENCE.

Experiments were made to determine the source of the fluorescence of Eysenhardtia wood by Dr. Arno Viehoever, pharmacognosist of the Bureau of Chemistry, assisted by his collaborators, Mr. C. O. Ewing and Mr. J. F. Clevenger. The results obtained show that the fluorescence is not inherent in the resin-like substance contained in the pitted tracheæ. This is quite insoluble in water, while the substance which causes the fluorescence is freely soluble even in cold water, as already stated. It is somewhat less soluble in alcohol and scarcely at all so in chloroform and ether. Unfortunately the amount of material available was too small to obtain with certainty the fluorescent substance in crystalline form.

The fluorescing power of the wood is so great that an extract of one part of the wood in one hundred-thousand parts of water or alcohol, after having been made alkaline, showed a distinct fluorescence in diffused daylight, and when diluted to a ratio of one to one million a fluorescence could still be detected in the rays of a fluorescence lamp. In very attenuate solutions the fluorescence is bluish; in more concentrated solutions it is distinctly yellowish green.

Under a fluorescence microscope dry wood-sections showed a rather uniform fluorescence with some very minute bright spots. Sections

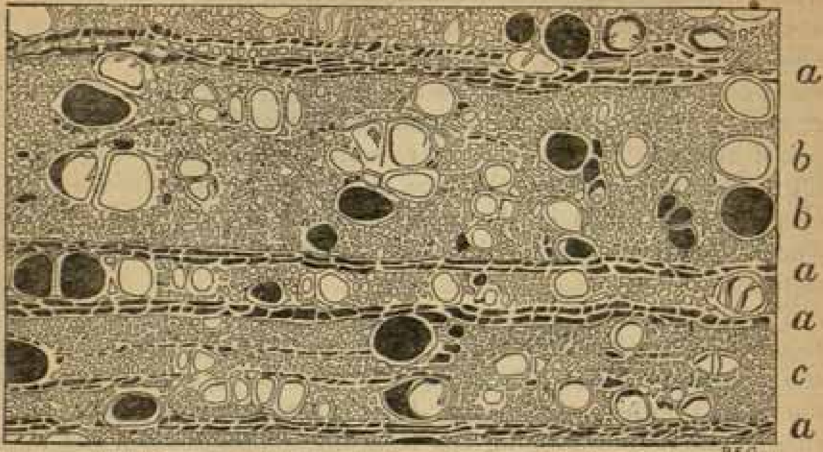

FIG. 4.—Cross section of wood of *Eysenhardtia polystachya*.
(See description, p. 287.)

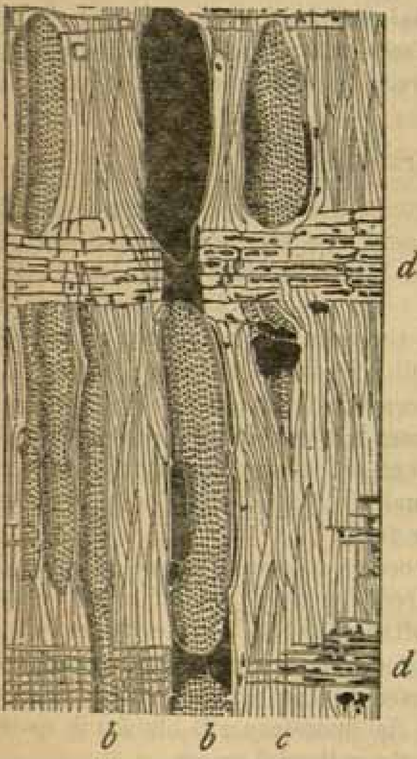

FIG. 5.—Radial section of wood of *Eysenhardtia polystachya*.

FIG. 6.—Tangential section of wood of *Eysenhardtia polystachya*.

mounted in borax-glycerine (one part to ten) showed a greenish veil of fluorescence due to diffusion, while sections from which the fluorescent substance had been completely extracted with boiling water had lost every vestige of fluorescence, though the resin-like masses remained undissolved in the pitted tracheæ. This substance proved to be remarkably resistant. Dr. Mann had already found that it would not break up in alcohol or xylol. Mr. Clevenger's experiments showed further that it was also insoluble under ordinary temperatures in chloral hydrate, benzol, petroleum ether, chloroform, 50 per cent potassium hydrate, 10 per cent sulphuric acid, 10 per cent hydrochloric acid, and carbon bisulphide.

II. Philippine Lignum Nephriticum.

Pterocarpus indicus.

The early history of the Philippine lignum nephriticum is closely associated with the Jesuits, who concerned themselves wherever they went not only with their religious duties, but with scientific investigation in many fields. The first written account of it (1701) was that of the Rev. George Joseph Kamel, or Camellus, in honor of whom the well-known genus Camellia was named. Although from a botanical point of view his description was inadequate, yet he established its identity beyond a doubt by giving its vernacular names: *narra*, *naga*, and *asana*. The wood itself he describes as "from brownish to reddish, turning water, in which it is soaked to a sea-blue color,"[1] and he calls attention to its medicinal virtues, especially as a remedy for renal calculus.

ORIGIN OF CUPS.

Another Jesuit, Father Delgado, speaks of the wood under the same common names and tells of cups made of it in southern Luzon, which he identifies with similar cups he had seen at Cadiz about the year 1700, when he was a child; and it was from the procurator of the Society of Jesus in Mexico that the Jesuit Kircher received the famous cup of lignum nephriticum, with which he performed his experiments already cited "on a certain wonderful wood, coloring water all kinds of colors."

Delgado tells of two kinds of naga, or narra, one rose colored, which he calls the male wood, and the other, much paler in color or white, which he calls female wood. He tells of trees of both the red and white wood of enormous dimensions, yielding boards of such

[1] "Lignum ex subfusco rufescens, aquam in qua maceratur colore, inficiens cymatili."—Camellus, G. J. Descr. Fruct. & Arb. Luzonis ad Jac. Petiverium, Pharmac. Londinens. missae, anno 1701, in Rallus, Joan., Hist. Plant., vol. 3, append. p. 79. 1704.

great width that a single one "sufficeth for making a door or a table." After praising the wood for its usefulness for construction purposes and for its durability when exposed to moisture, he speaks of its reputed medicinal virtues, and adds:

> The city called Nueva Caceres by the Spaniards bears among the natives the name Naga, on account of the abundance of this tree throughout those provinces of Camarines and Albay, where they carve very curious cups out of it for drinking water. Those made of female naga are much the better, for this wood tingeth the water very quickly to a celestial color, more quickly than the male. These cups are much esteemed in Europe and are regarded as a gift well worthy of any prince. Out of one of these cups they made me drink when I was a child, in Cadiz, as a remedy for hydropsy and oppilation, and I think that it might have helped me had I not drunk too much.[1]

This description of Delgado, written in 1754, but remaining unpublished until 1892, certainly connects the Philippine wooden cups with those of Kircher and Bauhin, which really were presented to an emperor and to a noble duke. Indeed, it is quite probable that the wood originally described by Monardes was of Philippine instead of Mexican origin; for it must be borne in mind that for a long time after the discovery of America the only trade route from the Philippines to Spain was by way of Mexico, and many products of the "Indies" attributed to New Spain (Mexico) were really of Philippine or East Indian origin. The "white" wood of which Kircher's cup was made might well have been the pale narra or "female" wood, which from long continued use yielded a very pale or even white infusion, and the variegated wood yielding red sawdust, described and figured by Bauhin, was without doubt the red or "male" narra of the Philippines.

These two kinds of wood were believed by Padre Blanco to come from distinct species of Pterocarpus. He described the tree yielding the pale wood as a new species, *Pterocarpus pallidus*, while he erroneously referred the red wood to the East Indian *Pterocarpus santalinus*, which is the source of the well-known "red-sanders wood" of commerce.[2] The vernacular names given by him for these trees are narra, naga, asana, daitanag, and apalit.

Padre Blanco's *Pterocarpus pallidus* has been identified with *Peterocarpus indicus*, a species previously described from the little island of Amboyna in the Malay Archipelago; and his so-called *P. santalinus*, quite distinct from the younger Linnaeus's species of that name, has been named by Mr. E. D. Merrill *Pterocarpus Blancoi;* but, as Mr. Merrill has already suggested,[3] it is so very close to the first species that it is perhaps not specifically distinct from it.

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[1] Delgado, J. J. Hist. gen. de las Islas del Poniente, llamadas Filipinas, p. 415. 1892.
[2] Blanco, Manuel. Flora de Filipinas, 560, 561. 1837.
[3] Merrill, E. D. Philippine Journ. of Science, Botany, 5: 100. 1910.

Specimens of narra wood from the Province of Cagayan, Island of Luzon, were obtained by the writer from the newly installed wood collection in the United States National Museum. The sapwood, beautifully flesh tinted, with pale, red lines of growth, and with large, conspicuous pores, bears little resemblance to that of Eysenhardtia but does resemble the *palum indianum* figured by Johan Bauhin. Moreover, it is almost as soft as cedar and its grain is more or less twisted, while the dark-colored heartwood of Eysenhardtia is hard, like lignum-vitæ, and its grain is close and straight. This wood had formed part of the Philippine collection at the St. Louis Exposition in 1904, where it had been exhibited as a valuable timber and cabinet wood. No notes on the fluorescence of its infusion accompanied the specimens, nor any indication that the wood is used medicinally. On placing a few chips of the wood in ordinary tap water the latter soon became tinged a yellow color, which deepened at length to orange, displaying a most beautiful fluorescence hardly to be distinguished from that of Eysenhardtia wood. At the request of the writer a cup was turned from this wood by Mr. James B. Conner, of the United States Department of Agriculture; and water, when allowed to stand in this cup, showed the same color effects as those described by Bauhin. Like the water in his cups the infusion assumed in a short time "a wonderful blue and yellow color, and when held up against the light beautifully resembled the varying color of the opal, giving forth reflections, as in that gem, of fiery yellow, bright red, glowing purple, and sea green most wonderful to behold." This infusion as seen in a glass flask, together with the cup described above, is shown on plate 1 (opp. p. 271), reproduced from a water-color drawing by Mrs. R. E. Gamble.

BOTANICAL DESCRIPTION.

The genus Pterocarpus, belonging to the Leguminosæ, bears little resemblance to Eysenhardtia, although, as in that genus, the fruit is an indehiscent one-seeded pod, and the leaves are pinnately compound with large leaflets alternate or opposite, but without stipels. The yellow, papilionaceous flowers are borne in panicled racemes and the pedicels are jointed at the apex. The turbinate, or top-shaped, calyx curved before opening, bears 5 short teeth, 2 above and 3 below. The exserted petals are narrowed at the base into long, slender claws, and the broad standard and wings are crisped, or frilled, around the margin, while the keel is linear. The androecium is diadelphous, consisting of 1 free stamen and 9 stamens united into a sheath which is slit either above and below or only above. The 2-ovuled ovary borne on a short stalk and bearing an incurved style

develops into a large 1-seeded orbicular indehiscent pod surrounded by a broad, rigid membranous wing with the point on one side or turned toward the base. The tree yielding the Philippine lignum nephriticum may be described as follows:

Pterocarpus indicus Willd. Sp. Pl. 3: 904. 1800; Prain, Indian Forestry **26**, Append. 9: 7. 1900.
Pterocarpus pallidus Blanco, Flora Filip. 560. 1837.

A large forest tree with a trunk often provided with broad buttresses with drooping branches. Leaves 8 to 10 inches long, composed of 5 to 9 usually alternate leaflets; these 2 to 4 inches long and 1½ to 2 inches wide, the terminal one usually the largest, ovate with rounded, rarely tapering base and rounded, abruptly and obtusely acuminate apex, the main nerves hardly more prominent than the secondary beneath. Inflorescence composed of lax panicles, little branched, all except the endmost one issuing from the axils of leaves, peduncle long, rachis and pedicels glabrescent; pedicels three-tenths of an inch long with two linear caducous bracteoles at the jointed apex. Flowers yellow, corolla papilionaceous, twice as long as the calyx, the standard and wings frilled on the margins. Pod orbicular broadly winged, borne on a stipe three-tenths of an inch long, the style on one side, some distance from the base, the margin of the wing between the stipe and the style convex.

Plate 6 is reproduced from a photograph of a specimen of *Pterocarpus indicus* in the United States National Herbarium, together with a piece of the wood from which the cup shown in plate 1 was turned.

This species, which is endemic in the Philippines and the Malay Archipelago, has been introduced as a shade tree in many localities in the tropics. According to Major Prain, it does not occur spontaneously either in India or Burma, but it has been confused with the well-known padouk (*Pterocarpus macrocarpus* Kurz) which is endemic in the vicinity of Mandalay and in other parts of Burma. It is interesting to note that the wood of the Burman padouk varies in color very much like that of the Philippine narra, and it is impossible in the forest to distinguish a tree yielding red padouk from one yielding yellow or pale-colored wood.

The genus Pterocarpus, as Prain has pointed out, is an exceedingly important one. In addition to the narra and padouk already mentioned, it includes the trees that yield the gum kino of commerce (*Pterocarpus marsupium* Roxb.), endemic in India and Ceylon; the red sanders (*Pterocarpus santalinus* L.), a much smaller tree of southern India, usually with 3-foliolate leaves; and the Andaman vermilion, or redwood (*Pterocarpus dalbergioides* Roxb.), which

LIGNUM NEPHRITICUM PHILIPPINENSE, PTEROCARPUS INDICUS WILLD. FROM THE ISLAND OF LUZON.

by many botanists has hitherto been confused with *Pterocarpus indicus*, but which Prain has shown to be quite distinct. Specimens of padouk and of Andaman redwood were obtained from the wood collection of the United States National Museum. Only one variety of the former was secured, a beautiful red wood with distinct dark annular lines of growth. Of the Andaman wood there was an abundance of material of several varieties, deep scarlet (from which its American trade name, "vermilion wood," is derived); brownish, tending to flesh-color; and with mixed red and brownish streaks. Chips of the deep-red Andaman wood when soaked in ordinary tap water scarcely colored it at all, and showed no fluorescence in ordinary sunlight. Chips of both padouk and of pale-colored Andaman wood, on the other hand, yielded a distinctly fluorescent infusion.

STRUCTURE OF THE WOOD.

Microscopic sections of the wood of *Pterocarpus indicus* and *P. dalbergioides* were studied by Dr. Arno Viehoever, pharmacognosist of the Bureau of Chemistry, and his assistant, Mr. J. F. Clevenger. They found that the resistant resinlike bodies occurring in the large pitted tracheæ of *Eysenhardtia polystachya* were absent in both species of Pterocarpus.

The color of the Pterocarpus wood is caused by certain colored bodies present in variable quantities in all parts of the wood. A study of distinct red masses, occurring chiefly in the medullary ray cells of the sapwood and heartwood (red and light colored streak) of *Pterocarpus dalbergioides*, shows a variation not only in the number of these masses but also in their solubility. Solubility tests were carried out with thin sections and observed under the microscope with the following reagents: Water, absolute alcohol, acetone, chloroform, ether, petroleum ether, concentrated hydrochloric acid, 50 per cent potassium hydroxide and ammonium, at room temperature, giving the following results: In the sapwood the colored bodies, which are relatively scarce, were not dissolved in any of the reagents. In the light-colored streak the colored bodies were soluble in 50 per cent potassium hydroxide and ammonium. In the red wood the colored bodies, being abundant, were readily soluble in absolute alcohol, acetone, 50 per cent potassium hydroxide and ammonium.

In *Pterocarpus indicus* yellowish brown bodies, found almost entirely in the medullary ray cells, occur somewhat diffused throughout the cells in minute granules and in somewhat larger masses near the end of the cells. These masses are less definitely outlined than the red bodies of *Pterocarpus dalbergioides* and were soluble in

water, 50 per cent potassium hydroxide, and 5 per cent hydrochloric acid.

To determine the fluorescing power in the wood of *Pterocarpus indicus* and *P. dalbergioides*, pieces of each of known weight were treated with hot absolute alcohol. On the addition of a few drops of alkali, fluorescence was shown in each extract. The process was continued until fluorescence could no longer be detected by means of the fluorescence lamp. After the alcohol extraction was completed, the same samples were boiled in water until no further fluorescence could be observed. The results demonstrated the fact that stronger fluorescence was displayed by the aqueous extracts, indicating either that the fluorescing substances are more easily soluble in water than in alcohol or that probably some of the fluorescing substances present are soluble only in water and not in alcohol.

In all cases fluorescence was observed, by means of the fluorescence lamp, in dilutions less than one to one hundred thousand parts, except in the sapwood of *Pterocarpus dalbergioides*, which yielded only a weak fluorescence in the aqueous extract. In the heartwood of this species the bright red portions show only slightly stronger fluorescence than the sapwood, while the paler streaks show the strongest fluorescence of all.

The Philippine narra, *Pterocarpus indicus*, shows a much stronger fluorescence than any part of the Andaman redwood, as the writer has already stated; but not so strong as the Mexican lignum nephriticum, *Eysenhardtia polystachya* of equal dilution.

Dry wood sections showed no fluoresage when observed in the fluorescence microscope. After mounting them in borax glycerine, a greenish veil of diffused light was observed. There was no evidence that the colored bodies showed a stronger fluorescence. In fact, the fluorescence could still be observed in sections where the colored bodies were almost entirely removed, as in the red heartwood, and where the color bodies are very scarce, as in the light sapwood. It is therefore believed that the red colored bodies are not the cause for the fluorescence.

FRUITS OF PHILIPPINE PTEROCARPUS.

Pterocarpus Blancoi is very closely related to *P. indicus*, as Mr. Merrill has already pointed out, differing from it chiefly in its larger pods and its relatively narrower leaflets. *Pterocarpus echinatus* Pers., which also occurs in the Philippines is distinguished by its prickly pods, and its leaflets are sometimes long-acuminate. It was mistaken by Vidal for *Pterocarpus erinaceus* Poir., an African

species, sometimes called rosewood, or African rosewood, and afterwards described as new by Rolfe, who named it *P. Vidalianus* in

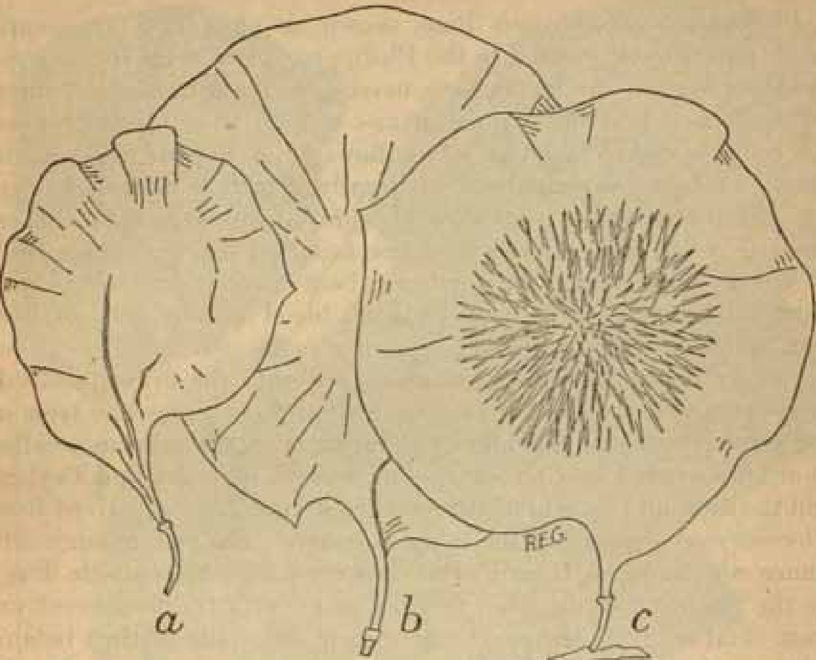


FIG. 7.—Fruits of Philippine Pterocarpus. *a*, *Pterocarpus indicus*; *b*, *P. Blancoi*; *c*, *P. echinatus*. Natural size.

Vidal's honor. Major Prain was the first to recognize its true identity. Figure 7 shows pods of the three Philippine species of Pterocarpus.

MEXICAN SPECIES OF PTEROCARPUS.

Owing to the marked fluorescence of infusions of Philippine Pterocarpus woods, Möller assumed that the Mexican species must yield similar infusions, but he had no opportunity of verifying this assumption. Of the wood of the tropical American *Pterocarpus officinalis* Jacq. (*P. draco* L.) very little is known. In Porto Rico it grows in swampy places to a height of 40 to 60 feet, with a trunk 14 to 18 inches in diameter. The wood is described as soft and of a dirty white color, used for fuel and sometimes for making fire screens, and is known locally as *palo de pollo* or "chicken wood."

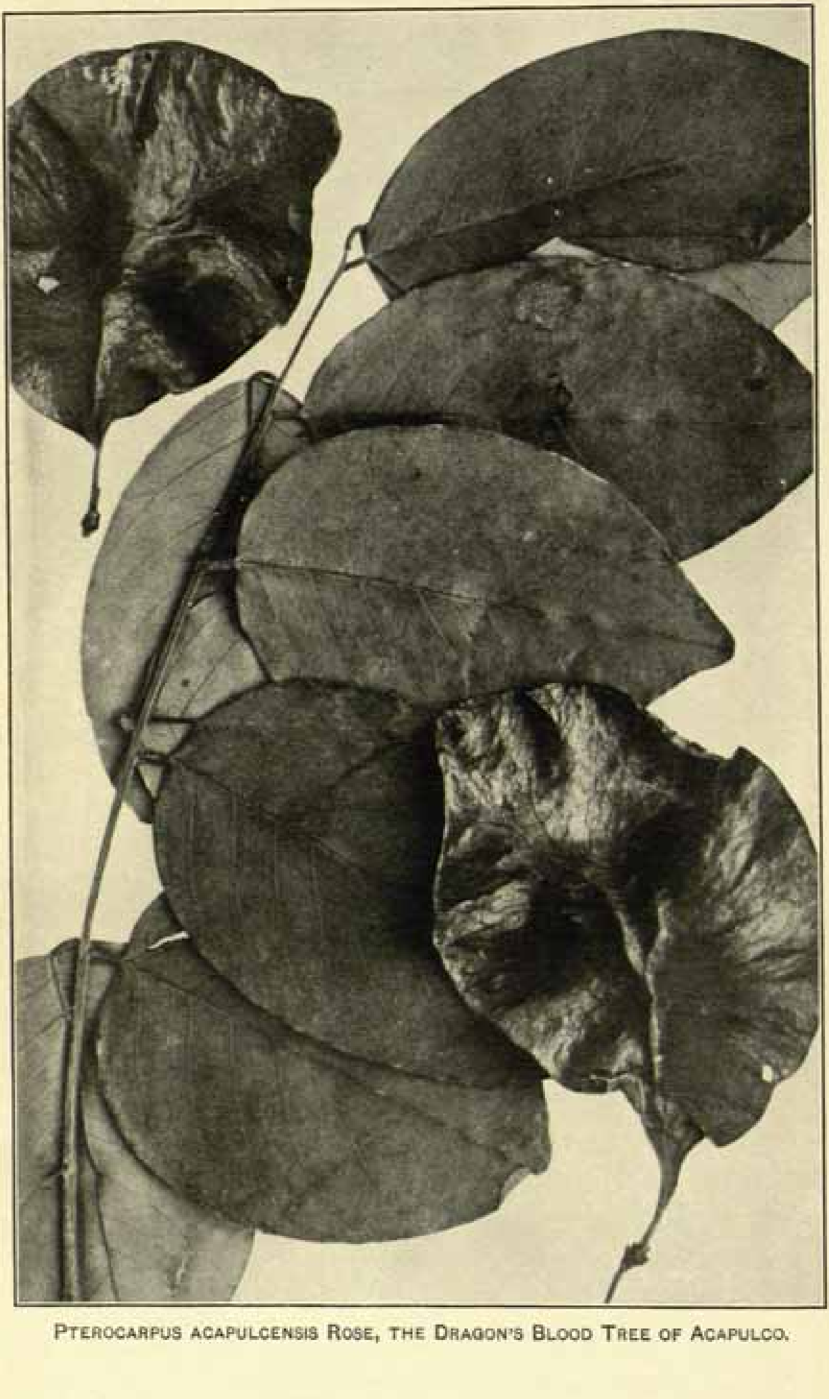
Pterocarpus pubescens (H. B. K.) Spr. (*Amphymenium pubescens* H. B. K., *Pterocarpus amphymenium* DC.), supposed by Möller to be the true lignum nephriticum Mexicanum, and *P. orbiculatus* DC. are likewise imperfectly known. Figure 1, page 279, shows a Humboldt and Bonpland's type, now in the Paris Museum (collected

in the Cañada de Zopilote, between Zumpanga and Mezcala, State of Guerrero) contrasted with a leaf of *Eysenhardtia adenostylis* Baill. from Guatemala.

Pterocarpus acapulcensis Rose, shown on plate 7, is apparently much more closely related to the Philippine narra. Of *Pterocarpus aphyllus* Micheli the leaves have never been described. It is interesting to note that the common names of both these species suggest the red, bloodlike exudation which flows from wounds made in the trees. *Pterocarpus acapulcensis* is locally known as *drago*, or dragon's blood tree, and *P. aphyllus* (possibly identical with *A. pubescens*) is called *llora-sangre*, from the fact that the tree weeps tears of blood. This substance, which has been called "dragon's blood," must not be confused with the dragon's blood of Sumatra and Borneo, which is derived from a climbing palm, *Daemonorops draco* (closely allied to the genus Calamus), nor with the dragon's bloods of Socotra and the Canary Islands derived from yucca-like trees of the genus Dracaena. Its affinity is rather with the substance called gum kino exuded by *Pterocarpus marsupium* of India and Ceylon; and the same may be said of the so-called dragon's blood derived from *Pterocarpus officinalis*. One thing is certain: The red, gummy substance which exudes from Pterocarpus trees, called sangre de drago by the Spanish colonists has nothing to do with the fluorescent extract obtained from the wood. Several plants, quite distinct botanically, are known in Mexico as sangre de drago, or sangregrado. In addition to species of the leguminous genus Pterocarpus may be mentioned *Jatropha spathulata* and *Croton draco*, belonging to the Euphorbiaceae. To the latter the ancient Mexicans applied the name *ezquahuitl* (from the Nahuatl *eztli*, blood, and *quahuitl*, tree). It is quite possible that the name *tlapalezpatli* (blood-red-tincture medicine) may have been applied to a species of Pterocarpus; but without a description of the tree or a figure, it is impossible to determine this definitely.

SUMMARY.

Lignum nephriticum, celebrated throughout Europe in the sixteenth and seventeenth centuries for its diuretic properties, but chiefly remarkable for the fluorescent properties of its infusion, comes from two distinct sources: (1) From a Mexican shrub or small tree, *Eysenhardtia polystachya*, the wood of which was used by the Hon. Robert Boyle (1663) in his well-known experiments on the fluorescence of light; (2) from a large tree of the Philippine Islands, *Pterocarpus indica* (*Pterocarpus pallida* Blanco), the wood of which, described by Kircher (1646) and Johan Bauhin (1650), was at one time commonly made into cups by the natives of southern Luzon. It is possible that cups were also made from allied species of Ptero-



PTEROCARPUS ACAPULCENSIS ROSE, THE DRAGON'S BLOOD TREE OF ACAPULCO.

carpus growing in Mexico, but there is no record of cups of known Mexican origin. That which Kircher received from the procurator of the Jesuits in Mexico had in all probability been brought as a curiosity to Mexico from the Philippines, for at that time the only trade route from the Philippines to Spain was by way of Mexico. It is also quite probable that Monardes's wood and the wood mentioned by Hernandez as being carried on shipboard in the form of large logs was Philippine lignum nephriticum.

The source of lignum nephriticum has remained uncertain for so long a time owing to the following causes: (1) Neither the Mexican nor the Philippine wood is known in its native country by the name lignum nephriticum; (2) from the beginning of its history the two woods bearing this name among pharmacologists were confused; (3) pharmaceutical material and cups were unaccompanied by botanical material; (4) botanical material in herbaria was lacking in wood and was usually unaccompanied by economic notes; (5) the original botanical descriptions of the species yielding lignum nephriticum were unaccompanied by references to the phenomenon of fluorescence; (6) the source of the wood described by Monardes was sought in Mexico, but was in all probability of Philippine origin; (7) attempts were made to identify the Mexican plant described by Hernandez with the wood described by Monardes and the cups described by Kircher and Bauhin, which only led to confusion.

The botanical identity of the Mexican lignum nephriticum was first indicated in 1854, by Dr. Leonardo Oliva, of the University of Guadalajara. It was established with certainty by the writer, January 6, 1915, through the exhibition of the wood and its fluorescent infusion accompanied by botanical material from the mother plant.[1]

The identity of the Philippine lignum nephriticum was clearly indicated, under its vernacular names, in 1701 by the Jesuit, George Joseph Kamel, and the origin of the cups carved from the wood was revealed in 1754 by another Jesuit, Padre Juan J. Delgado; but the work of the latter remained in manuscript until 1892. Its botanical classification was first established in 1837 by Padre Blanco, in his Flora de Filipinas, under the name *Pterocarpus pallidus*, which is now regarded as a synonym for *Pterocarpus indicus*.

Closely allied to the tree, which yields Philippine lignum nephriticum are the padouk of Burma (*Pterocarpus macrocarpus*) and the Andaman redwood (*Pterocarpus dalbergioides*), both of which produce red and pale colored varieties of wood. The padouk yields a fluorescent infusion very much like that of the Philippine narra. An infusion of the deep red variety of Andaman wood shows little

[1] See Safford, W. E. "Eysenhardtia polystachya, the source of the true lignum nephriticum mexicanum." Jour. Wash. Acad. 5: 503–517. 1915.

or no fluorescence, while that of the pale variety yields a distinct fluorescence.

Authors have hitherto tried to trace lignum nephriticum to some one source. Dr. Otto Stapf, after a careful study of the history of the wood and experiments upon a specimen of "cuatl" from the Mexican collection in the Paris exposition, was convinced that the mother plant of lignum nephriticum is *Eysenhardtia amorphoides*. Dr. Hans-Jacob Möller of Copenhagen after an equally exhaustive study was confident that the source of lignum nephriticum was not Eysenhardtia but a Mexican tree belonging to the genus Pterocarpus. It was assumed by Dr. Stapf that both the reddish *palum indianum* of which Johan Bauhin's historical cup was made and the "white" wood yielding an infusion like pure colorless spring water of which Kircher's cup was made were identical with the dark-colored wood used by Robert Boyle in his study of fluorescence. The erroneous conclusion would necessarily follow that the logs which Hernandez described as "larger than very large trees" were those of *Eysenhardtia*, although it is quite certain that this genus includes only shrubs and small trees. On the other hand Möller endeavors to make Hernandez's description of *coatli*, with its tiny leaflets suggesting the foliage of the chick-pea or common rue, apply to the genus Pterocarpus, of which all the known species have large leaflets in no way comparable to those of the plants mentioned.[1] In the present paper the two distinct sources of the woods called lignum nephriticum are for the first time definitely indicated, the fluorescence phenomena displayed by infusions of each described and illustrated, and the origin of the celebrated cups of Kircher and Bauhin traced to the country where they were made.

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[1] See Science, n. s. 43: 432, March 24, 1916.

IMPRESSIONS OF THE VOICES OF TROPICAL BIRDS.[1]

By Louis Agassiz Fuertes.[2]

[With 16 plates.]

I. THE WRENS.

Roughly speaking, wrens' songs improve in direct ratio with the humidity and darkness of their haunts. This, at least, is the vivid impression one gets from a field acquaintance with the tropical genera, *Heleodytes*, *Donacobius*, *Thryothorus*, *Henicorhina*, and *Pheugopedius*.

So far as I have been able to discover, all the cactus wrens except *Heleodytes bicolor* (which also differs in several other respects), are possessed of only a harsh, vigorous, and impertinent scold—a sort of angry, chattering noise, more or less closely imitated by pressing the tongue against the roof of the mouth and forcing the air out of a small opening behind the back teeth. All the speckle-breasted cactus wrens species have this note, and, so far as I know, no other that approaches a song, much less a wren song. Our own south-western species simply repeats a lazy, cross *rrrr*, *rrrr*, *rrrr*, while the Mexican bird, *Heleodytes zonatus*, seems to try to yell "brak-a-co-ax," rapidly repeated, but still in the unmistakable cactus wren burr. If song is of any value as a philogenetic character, *Heleodytes bicolor* certainly deserves to be lifted out of the prying and ill-natured group it now graces, and set down somewhere near the big wren-thrashers of the genus *Donacobius*,[3] for it shares with them a loud, liquid song, which is not given by the male alone, but by both sexes at the same time.

This countersinging by the female, so far as I am aware, is not generally known among birds, but it is certainly practiced by this species, as well as by all forms I know of *Pheugopedius*, *Henicorhina*,

[1] Reprinted by permission from Bird-Lore, vol. 15, no. 6, vol. 16, nos. 1, 2, 3, 5, 6.

[2] Illustrated by the author.

[3] *Donacobius* is a wren-like thrasher or thrasher-like wren which is usually placed in the family Mimidæ.

and *Donacobius*. In all these cases the birds sit close together, the male a little above the female, and his song is usually louder and more brilliant than hers. *Heleodytes bicolor* gurgles a loud, clear, oriole-like "Keep your feet wet." The female, 3 inches below and a little to one side, parallels this advice with an evenly timed "What d'you care?" in perfect unison, usually, with the reiterated phrases of her mate. *Donacobius* does it somewhat differently, as the female only says "wank, wank, wank," while the male sits just above and sings almost exactly like a cardinal, or a boy whistling loudly to his dog, *hui, hui, hui*. If the male gives only three phrases, so with the female; if, however, the male repeats his whistle a dozen times, the female begins and ends in exact time with him. This curious habit I verified a number of times. Still more interesting is the fact that both sexes of *Donacobius* possess an inflatable sac of bright yellow skin on the sides of the throat, which, when the bird sings, puffs out to the size of a cherry, and is a very queer and conspicuous character. When singing, they look down, hump up the shoulders, puff out the neck, and give their strange duet from the top of a marsh weed or dead bush, and then, wren-like, drop down into hiding.

All the Pheugopedius wrens are gifted with the most astonishingly loud and clear whistles. A wondrous thrushy quality is theirs, with an unbelievable range in the form and forte of their songs. Both sexes sing, usually close together, and when one is hushed in the deep silence of the fern-filled forest of the humid mountains, tense for the tiniest pip of a manikin or the mouselike run of an ant-thrush, it is enough to raise one's hair when right in one's ear explodes a loud, astonishingly clear "bloong-wheee-rip-wheeoo," rapidly repeated, frequently seconded by a less showy "We'll whip you yet" of the female.

It would be hard to describe a tangible difference between the songs of *Pheugopedius* and *Henicorhina*. Certainly there is no such difference in volume or range as the tiny size of the latter would lead one to suppose, for the diminutive wood wrens are by no means always distinguishable by their songs from their larger cousins, and the variety and timbre of the notes of one genus is as endless as in the other. While no description or literal syllabification can do much to bring up an "audital image" of a bird song, my notes, written only for my own recollection, have these cryptic bits as the framework upon which I hook my remembrance of *Henicorhina* songs: "Y'ought to see Jim, Y'ought to see Jim," "But Mary won't let you" (repeat four times), "Whip-wheéoo, correéoo."

Perhaps no songs heard in the Tropics are so characteristic or make such a strong impression on the mind and desire of a naturalist as these romantic and mysterious wren songs. They assail the ear

WOOD WREN.
Henicorhina leucosticta.

BLACK-CAPPED WREN—THRASHER.
Donacobius atricapillus.

JAMAICAN SOLITAIRE.

Myadestes solitarius.

while riding along the mountain trails, and are the unending goal of many a sweltering still hunt through the mosquito-full but otherwise Sabbath-still forest. For me, at least, a deep, humid mountain forest never ceases to have a hushing, even oppressive, effect. Awed and tense, I find myself a foreign and discordant note in the giant stillness. With this half-guilty feeling, and hushed by the stern green silence, hypnotized, as it were, into a sort of subjective identity with the Sunday-like vacuum of sound and keyed to a nervous expectancy in tune with the heavy odorous stillness, the sudden singing of any of these brilliant-voiced wood wrens is sufficiently startling to make one recoil, lumpy-throated, and it is often more than a mere second or two before the readjustment into the normal frame of mind can be made.

The wrens of the genus *Thryophilus*, which are closely allied to our Carolina wren, deserve a high place in the scale of singers. I think the Colombian species[1] are the most versatile and surprising singers in the entire family; and this is indeed high praise, for few, if any, birds of their size can surpass the wrens in volume and brilliancy of tone.

II. TINAMOUS, PARTRIDGES, AND SOLITAIRES.

In the Tropics, as in more familiar scenes, the bird songs of the fields are frank, pastoral, and prevalent. With us, the meadowlark, field sparrow, vesper, and song sparrows pipe often and openly, and from May to October their notes are almost constantly in the air. But the forest birds are more reluctant singers, and their rare notes are all mystery, romance, and reclusive shyness. The field sparrow will sit on a dock stalk and sing, looking you in the eyes; the veery will quietly fade away when your presence is discovered.

So it is, even to a more marked degree, in the Tropics. In the open pastures and on the bushy slopes of the Andes one hears the shrill piping of the "four-wing" cuckoo (*Diplopterus*), the insistent *kekking* of the spurwing plover, the dry, phœbelike fret of the spinetails (*Synallaxis*), the lisping insect songs of grassquits, and, from the bordering forest edge, the leisurely whistling of orioles. But enter the forest, and all is of another world. For a long time, perhaps, as you make your way through the heavy hush of its darkened ways, no sound strikes the ear but the drip of water from spongy moss clumps on broad leaves. You feel yourself to be the only animate thing in your universe. All at once, perhaps far off through the forest, perhaps close behind you, you hear the strangely moving whinny of a tinamou. I think no sound I have ever heard has more deeply reached into me and taken hold. Whether it is the

[1] *Thryophilus rufalbus*, *T. leucotis*, and *T. albipectus bogotensis*.

intensity of feeling that a deep, silent forest always imposes; the velvet smoothness of the wailing call; the dramatic crescendo and diminuendo that exactly parallels its minor cadence up and down a small scale; something, perhaps the combination of all these, makes one feel as if he had been caught with his soul naked in his hands, when, in the midst of his subdued and chastened revery, this spirit voice takes the words from his tongue and expresses so perfectly all the mystery, romance, and tragedy that the struggling, parasite-ridden forest diffuses through its damp shade. No vocal expression could more wonderfully convey this intangible, subduing, pervasive quality of silence; a paradox, perhaps, but not out of place with this bird of mystery.

Only less appealing are those other chaste singers in the cloud forest, the solitaires. It is, indeed, a strange sensation, in uncanny harmony with the unexpected familiarity one always feels in a Tropic forest, when, thinking vaguely of thrush songs, the silver note of a solitaire crystalizes the thought. There are many kinds, and they have varied song types beyond most similarly unified genera. The most typical is simply a lovely hermit thrush song, giving that effect of a private hearing so graciously done by our own thrushes. For some elusive reason, it seems as if these birds always sang as the shy perquisite of the favored few, and thus, perhaps, it is that their songs never become common.

Our own Townsend's solitaire has a very different melody, a blithe, grosbeak warble, frequently given in larklike flight, quite unlike any of the tropical species I have heard. These are all of the chaste, contemplative type, given from a perch part way up in the forest, and in frequent accompaniment of splashing water in mossy and fern-fringed ravines. *Myadestes ralloides*, of the Andes, sings almost exactly like a hermit thrush, as does *Myadestes unicolor*, of Mexico, while *Myadestes solitarius*, of Jamaica, singing from the tree ferns up on Blue Mountain, reminded me strongly of the varied thrush heard in the dark, cold spruce flats of the Alaskan coast. What a transposition! A vibrant, steadily crescendo note, as true as a violin, fading to nothing. Then another in a new key. A rich, descending broken scale followed, after a pause; then an exceedingly high trill, swelling and dying. These singers were common at about 5,000 feet, and their choral chanting was an experience to be long remembered. *Myadestes obscurus*, of southern Mexico, has a song more spontaneous and overflowing than the other tropical species; I thought of a bobolink when I first heard it. The song began high in the scale, and very loud; then through the rich progression of its bubbling cadences it gradually fell in pitch and lost volume till it died out, as with loss of breath. This is the "jilguero" of the natives, while

unicolor is known as "clarin." Distinguished from these as "jilguero de la tierra" are the wrens of the genus *Leucolchis*, which have a way of singing at your very feet, hidden under the ferns and low growing soft plants of earth. Theirs too, are violin tones, and, though the songs are not rare, the singer is seldom seen, however patiently you search or wait for him in the mosquito-ridden air of his dripping haunts. It has always seemed a mystery to me how these little birds of the cloud forest keep dry. They are, indeed, the only dry thing you would encounter in a week's hunt, for overhead all is oozing water, all the leaves are shiny wet, and underfoot is soaking, rotting vegetable mold or deep muddy ooze, that frequently lets you in over your boot tops.

In the same forests that shelter the tinamou and solitaire dwell the evasive and ventriloquistic wood partridges (*Odontophorus*). These are richly garbed in velvety, rotten-wood colors, with all the minute mothlike pattern of whippoorwills. But wonderful as is their coat, it is their vocal performance that gives them real distinction, for besides the familiar partridge clucking and pipping heard only at close range and therefore seldom, they possess a loud rollicking call that may be heard a mile or more across the forested course of a mountain river.

Once, while I was pussy-footing along a little water trail in the hope of again seeing a golden-headed trogon, I was congealed for the moment by a load, explosive alarm at the end of a fallen and rotting bole that lay just before me. "Kivelry, cavalry, kivelry, cavalry, pt′, pt′, pt′, t′ t′ t′ t," and up popped a brown velvet bird, called once more and dropped, already running, on the other side of the log. The call, at close range, had a roosterlike quality not noticeable in the distance, and I was surprised to see that the whole complicated and rapid performance was the work of one bird.

Perhaps it is a sort of statute of limitations that makes us constantly compare new bird songs with familiar ones at home. Perhaps it is the paucity of our language that renders description almost futile. But occasionally a resemblance is so striking that no alternative suggests itself. Sweltering in the heat and glare of the Andean foothills, veins throbbing with the exertion of the climbing hunt, exhaustion screaming for a let-up, and temper getting thin, something turns over inside one when, of a sudden, comes the cheery, old-home "bobwhite" of the little crested *Eupsychortyx* quail. Appearances would never suggest the close relationship, but this little fellow, 3,000 miles from home, says "bobwhite" without a trace of accent, striking a primitive chord that does queer things for the moment to the inner you, caught unawares.

III. ORIOLES, FLYCATCHERS, FINCHES, AND THRUSHES.

A comparative study of the notes and songs of the birds of the Tropics and their familiar northern representatives is certainly not less interesting than the study of their physical resemblances and differences. And here it may be suggested that resemblances, which are of greatest value as showing relationships, are even more elusive and hard to follow out than are more physical characters. Differences are of negative importance; resemblances alone count in tracing racial affinities.

In this respect the great family of tropical orioles hangs together as a unit and ties closely to its more familiar northern offshoots. From the tiny Mexican orchard oriole to the crow-sized oropendolas there is some subtle quirk of tone that makes them all recognizable to anyone having a single good acquaintance in the family.

I think no birds in tropical America have given me more pure fun with their vocal performances than the big yellowtails, or oropendolas; *Gymnostinops* in southern Mexico, and the various species of *Ostinops* in Colombia. I can not now remember any striking differences in their songs or calls, except that *Gymnostinops* combines more gymnastics with his effort than mere *Ostinops*. But everywhere in tropical America the loud rasps, chucks, and gurglings of these great orioles are as characteristic as the steady flashing of black and gold in the burning sky as they wing overhead from bank to bank of the great rivers.

They are all highly polygamous, and I have frequently seen them demonstrate a most watchful and efficient warden service in favor of the old males. After one shot you may stalk and stalk the big black Sultan, "quisking" from the bare dead spike above the forest roof, only to be defeated time after time by the party of six or eight silent and watchful females perching around him at lower points. Silent—that is, until you get within about twice gunshot of their lord—when they suddenly squawk and yell, and the old boss "yips" loudly and, with batting wings, leaves for foreign parts.

The calls of the male, given from a high perch with a commanding view, may be variously described: A loud, vigorous "quisk"; an equally carrying but very liquid "churg," ending inside an empty cask; a series of dry, ascending clicks or twig snaps, probably done with the enormously strong and hollowed bill. But his true song, to call it so, defies description or imitation without all the "traps" of the triangle man in the orchestra. Imagine a performance lasting only about 2 seconds, commenced by breaking off a handful of willow sticks, then running into a rising series of "choog-choog-choogs," to end in loud, explosive "keow," easily audible at a quarter of a mile. This is only the vocal part of the performance, and is accompanied

TINAMOU.
Crypturus.

MEXICAN OROPENDOLA—SINGING.
Gymnostinops montezuma.

ANDEAN WHITE-THROAT.
Brachyspiza capensis.

DERBY FLYCATCHER.
Pitangus sulphuratus derbianus.

BAHAMAN THRUSH.
Mimocichla bahamensis.

by a contortion of which the cowbird's spring effort gives a mild idea. The bird first looks down, ruffles the nape feathers and elevates the tail, and then, clattering the bill and emitting the other sounds that he alone is capable of, falls forward, clapping his wings lustily over his back, until he is under his perch with his bill pointing directly up. Now he delivers his last explosive yell, wings and glorious tail all outspread to their utmost, and by means of his first foothold, not relinquished in his effort, and with wings folded, he draws himself back to his first position, where he sits ruffled for a minute or two. Then, depressing his feathers, he repeats his acrobatic song. The males are a full half larger than the females and have enormously developed legs and feet, apparently for this performance, recalling a raven's foot; while the females have the usual slender, gracklelike feet of the family. One never need be bored when there is a colony of these striking and virile birds in the vicinity.

Some of the typical orioles and troupials have exceedingly brilliant, if monotonous, songs, and they are kept as pets in nearly every house in the towns or along the trails in Colombia. *Icterus mesomelas* nearly drove us insane with his piercing song in the hotel in Cali, repeating it incessantly from his cage at our door.

FIG. 1.

All orioles are great singers of little tunes, usually going just enough off key to get on your nerves, and this is only one of hundreds of such little phrases. The hooded oriole group have a deliciously naive way of singing little "earless" tunes, like a small boy on his reluctant way to school, whistling himself along the road. This is the most companionable bird song I know and has frequently been real company to me when hunting alone along the banks of tropical rivers and in the foothills.

It would be impossible here to take up more than a few of the striking types of this large family of brilliant singers, but it would certainly be doing the whole group an injustice not to mention the wonderful silver and golden songs of one of the black offshoots of the family, *Dives dives* of Yucatan. This glossy beauty was very common at Chichen-Itza, and was a source of constant marvel from the variety, richness, and volume of its notes. I can not describe them, nor even remember them concretely, but I was at once reminded of the pastor bird I had once heard in the Philadelphia zoo. It had all the deep-throated richness of the best oriole songs, combined

with a sweetness more thrushlike and of infinite variation. Among all the varied and rich songs about the place—wrens, orioles, and thrushes—on my first morning afield in the continental tropics, *Dives* made the one deep and lasting impression above all others, in the classic and thrilling surroundings of the ruined Maya city.

While orioles are always within hearing, I think that doubtless the most pervasive and ever-present sounds in the Tropics come from the even larger family of flycatchers. From the blue, lonesome, plaintive little "phew" of *Myiarchus l. platyrhynchus* and the equally despondent sighs of some of the *Elainias*, to the executive "yips" of the big-billed and derby flycatchers, these characteristic sounds are ever in the ear. So far as I know only one flycatcher can really be proclaimed as a singer with a real song different from his ordinary calls and scolds. This one exception is no less distinguished by his coat from the rest of the rather somber-colored family. The gorgeous little vermilion flycatcher has a simple but very sweet song; lispy and thin, but delivered with great devotion. Darting like a flame up into the flood of sunlight, he reaches a point about a hundred feet from earth, and then, with scarlet crest spread out like a hussar's hood and head thrown back, he floats lightly down on trembling wings, lisping in ecstacy his poor sweet little song, "Ciriví ciriví ciriví." It is hardly noticeable even among the little finch twitters along the roadside, but for a flycatcher it is remarkable; and surely no gifted thrush or lark ever went to his matins more devoutly. It is a strange contrast to the usual flycatcher utterances, which are loud, raspy, egotistic, and highly commandeering. Our kingbird is a fair example of the family, with the greatcrest as a good amplifier of the impression. It is the forest flycatchers, like the wood pewee and some of the *Elainias*, that have the lost-soul, hollow-hearted plaints; the sun-loving kinds are very kings of earth in their noisy self-confidence.

The finches and sparrows in general do not add much to the tropical mélange of bird music. They are frequently birds of great beauty, and all have some blithe little song, "finchy," and characteristic of each species. However, to a sparrow falls the distinction of being the most widely distributed singer we encountered in South America. It is safe to say that anywhere in the Andes above 2,000 feet, from the Pacific to the Orinoco slope, the little Andean white-throat, *Brachyspiza*, will cheer the traveler with his brief and pleasant piping. "It is sweet cheer, here," gives the phrase and accent. It is more like an abbreviated fox-sparrow song than anything I can recall. I shall always feel a personal debt to its cheery optimism, as it sang daily in the court of the hotel in Bogotá in the clammy chill of the damp days 9,000 feet above sea, while I was fighting through the fever contracted in the lowlands. He gave my scram-

bled and fevered brains the one tangible hold I had with the wonderful world outside, and it recalled nearly all of our associations in South America.

Some of the roadside finches and grassquits have curious and explosive little buzzy sounds. *Volatinia*, a raven-black mite living along the hedge-rows, has an amusing song-habit. Sitting on the top of a grass or weedstalk he suddenly rises in bee-like flight about a yard into the air; at the apex of his little spring he turns a rapid somersault, with a volatile "bzt," and drops back to his perch. The whole effort takes perhaps a second.

Most of the tanagers, which grade insensibly into the finches, are not much when it comes to singing. However, the larger *Saltators* have clear, whistled songs that are highly characteristic. They are leisurely soprano songs, usually heard from thickets of soft growth on the mountain sides. One song heard in the Eastern Andes that I ascribed to *S. atripennis*, though I could never quite satisfactorily prove the singer, was as loud, pure, and wide-ranged a song as I have heard. Though quite complicated it was always identically the same in form and range. Two long descending slurs, one ascending, a long descending trill, then a descending run in couplets (like a canyon wren), a rising slur, and a final short trill on a high note. In many songs, heard in several localities, this scheme was closely followed. The mountain forests of the Tropics furnish an endless and enchanting field for this kind of study, which our hasty survey and limited time unavoidably rendered all too superficial and fragmentary.

We found, as a rule, that the gemlike tanagers of *Calospiza*, *Chlorochrysa*, etc., were nearly devoid of song. Their drifting flocks, sifting along through the tree ferns and higher levels of the forest, were much like a flock of migrating warblers, always made up of several species, and their little lisping sounds were further reminders of our northern tree gleaners.

The cotingas, as a rule, were silent, though some of the more flycatcher-like, such as *Tytyra*, have loud, buzzy calls, and the big ones, like *Pyroderus* and *Querula*, have deep, pervasive vocal sounds hard to describe, but fairly easy to imitate. The tiny and gorgeous manikins all make loud, staccato "pips," out of all proportion to their diminutive size.

The thrushes, however, are quite as satisfactory singers in the Tropics as they are in New England. The robin group, *Planesticus*, is large and varied from Mexico south, and we had many chances to study and compare them in song and actions. *P. gigas*, of the Andes of Colombia, considerably bigger than a blue jay, and solid dusky but for his corn-colored bill, feet, and eyelids, had a dis-

appointingly weak and squealy song. Members of the *tristis* group, however, are to me the finest singers of the whole genus, trilling, piping, and warbling with the greatest abandon and purity of tone. They are shy singers, and rarely to be heard except after long silence in one spot. *P. jamaicensis*, heard with a divine accompaniment of solitaires, lost nothing of its beauty by the comparison. The related genus *Melanotis*, the "blue mockers," are accomplished and brilliant singers, with much of the well-known quality of all mockingbirds. But they rank very high, as do the members of the interesting Antillean group, *Mimocichla*. I shall never forget a concert I once heard on New Province, in the Bahamas. We were out in the "coppet," or woods, collecting, in the afternoon. About 4 o'clock a drenching thunderstorm broke, and for an hour we were subjected to as thorough a wetting as could be desired, and most of our efforts went toward keeping our specimens from getting soaked. After a time, however, it stopped almost as suddenly as it had begun, and through the breaking sky the level rays of a declining sun reddened the straight columns of the pines and glistened from the wet and shining foliage of the broad-leaved trees. Suddenly, and so robin-like that I was for a moment quite moved, there commenced a chorus of delicious and brilliant singing that I have no similar recollection of. It was from the "blue thrasher," *Mimocichla plumbea*, and for a few breathless moments we were carried into an enchanted realm that it is still a joy to remember. The music was no less scintillating than its clean and glistening setting.

It is perhaps too bad, and a sign of limitation that we should hesitate to admit, that the songs that please us most are apt to be those that perfect or glorify songs we already know at home. It may even not be true, but I think, nevertheless, that no bird songs have ever given me a more welcome turn of heart than some of these tropical thrushes, which carry farther the lovely qualities of intonation so richly present in our hermit thrush's song. The group known as *Catharus*, true thrushes, haunt the moist, ferny mountain forests, and from the quiet fragrance of these silent places come the exquisite silvery bell tones of their songs. They sing from the ground or very near it, and never have I heard them lift their voices high. But their tone is more pure, their delivery more perfect, and their chaste cadences more prismatic and rich than those of any other thrush I know, and I should find it hard to pick the slightest rift within the lute. It is upon these tender, ineffably sweet flutings that I base my concept of a perfect bird song.

IV.—ANT-THRUSHES AND THEIR ALLIES, AND WOODHEWERS.

To northern perceptions and training the ghostly, long-legged forest ground-runners, generally known as ant-thrushes, make an immediate and lasting appeal. The many species of *Grallaria*, *Formicarius*, and *Chamæza*, finding their most congenial surroundings among the tree ferns and moss-filled undergrowth of the wooded slopes, at once impress the student with their presence, but leave him, after however long an acquaintance, with little more knowledge of their lives and doings than he had on first hearing their invitation to the game of hide and seek they so skillfully and persistently play.

They are all strictly terrestrial and, on the rare occasions when they fly, they keep so close to the ground that their dangling feet almost touch. Indeed, I suspect that they fly only upon some special stimulus, ordinarily going about on foot.

The commonest and most generally distributed species in Colombia is *Grallaria ruficapilla*. It is about as big as a robin, but is almost round, stubby tailed, big eyed, and comically long legged. But while it was really a common bird, and its whistled *compra pan* was almost constantly in our ears in all three ranges of the Andes, not over six or seven were taken. Certainly nine out of every ten efforts to see the author ended blindly, even though they responded immediately to a whistled imitation of their notes. But so silent is their approach, and so densely are their ground haunts veiled by ferns, large fallen leaves, earth plants, and other visual obstructions, that they may call almost from between your feet with impunity, while with pounding heart and eager eyes you fail to penetrate the veil of intervening leafage. I have usually found that, while all these ground-running birds answer eagerly to a call, they are very easily satisfied on seeing its author, and usually the response, now almost under foot, suddenly fails, and the little feathered mouse that gave it swiftly and silently trots away after one quick look at the huge imposter. I think we all had certainly scores of these little ground ghosts within 15 to 20 feet, and not one-tenth of them gave us so much as a fleeting glance at them.

Grallaria's note can always be closely imitated by a whistle. The call of the common *compra pan*, whose name is the Spanish literation of his call, has a very "quaily" quality when heard near at hand. Three drawled notes—A, F, G, the first and second three tones apart, and the last between. We came to recognize this as an exact marker of the lower line of the second life zone, beginning at about 4,500 feet. This species goes up almost to the upper limit of trees, and adheres closely to the cloud forest. I never heard any variation in the song except, when the bird is near the limit of its curiosity, the

last note sometimes drops off in a throaty slur, instead of rising a tone: A, F, E.

On the west slope of the Eastern Andes we found another species, *G. hypoleuca*, whose song, though readily recognizable as a *Grallaria*, was radically different in form. One longish note on B; a rest; then about five ascending notes a scant semitone apart, and four to the second. This bore a striking resemblance to the first half of *Chamæza brevicauda's* song heard on the eastern slope of the Eastern Andes at Buena Vista, and is almost identical with that of *Grallaria rufula* from the highest timbered ridges of this chain, except that here the pause is omitted and the song is higher, beginning on E.

Little *Grallaria modesta*, from the eastern foot of the Andes at Villavicencio, has a most characteristic little song, all on E. It has seven sharply staccato notes, forming a perfect crescendo to the fourth, then diminishing to piano again at the end. The middle note is strongly accented. This little hermit lives in the sweltering weed thickets along the sun-baked beds of the lowland streams. I shall never forget an hour in a burr thicket, with nettle accompaniment, at a temperature of perhaps 115°, trying to find the elusive author of that queer little song. At least five times I had him within close range, but never could I see more than a ghost of a movement or the sudden wiggle of a fern rubbed against in his approach. Nearly discouraged, with hair, eyebrows, and clothes matted thick with little burrs, almost exhausted with the heat, I at last hit upon a very effective scheme. Deliberately clearing out a space of 10 or 15 feet and a tapering lane through which I could watch the opening, by gently approaching the sound I drove it to a point well beyond my clearing and retreated to my station. Waiting here a few minutes in silence, I repeated the call, in full loudness, until I got a response. Then, as the bird approached, I did the call more softly, to appear farther away and allay his wariness. My unfair subterfuge worked, and the little long-legged piper entered my trap unsuspecting, and I was able to identify it. We had not encountered this species before, and never saw it again after leaving the torrid lowlands about Villavicencio. I was never able to identify the song of the big slaty-blue breasted *G. ruficeps* in the uppermost forest zone above Bogotá. These were all the species of the genus that I personally encountered.

On the wooded slopes above Villavicencio we found another bird conspicuous in song, but spiritlike in actions. We at first thought it was a *Grallaria*, but it proved to be a closely allied bird, *Chamæza brevicauda*, very similar, but with shorter legs and more delicate bill. It had a curious song of about seven gradually ascending "toots," followed by four or five queer little falling yelps, "oot, oot, oot, oot,

COMPRA PAN.

Grallaria ruficapilla.

THE "NOON-WHISTLE."

Chamaza turdina.

oot, oot, oot—elp, elp', elp', ulp', ulp'." It was common, and, because the forest was much opener and almost like our woods, it was much easier to find and see. But, even so, many more were heard than we were ever able to discern, and we never got over a feeling of victory when we succeeded in seeing the singer. The color gradation was so perfectly adjusted to the lighting in the woods that only a motion was visible, and that scarcely.

In the dark, fog-steeped forest along the culm of the Central Andes a closely related species, darker in color, gave me one of the great song sensations of my life. I heard a sharp, loud, "wip-wip-wip," and ascribed it to one of the wood quail. I hunted it, unsuccessfully, until I was discouraged and exhausted. Also I became dully aware of a distant and long protracted whistle, which I vaguely attributed to a steam whistle in some neighboring village. So does our common sense become dulled when we are confronted by unfamiliar surroundings. On my tired way back to camp I realized that there were neither mills, steam, nor villages in these mountains, which are unbroken virgin forest for a hundred miles or more either way. Perhaps I had heard a cicada. I could scarcely credit a bird with such a prolonged sound as this.

The next day I went back to solve the thing. When, after two hours of steep ascent, I had reached the 8,000 foot level, I heard again my mysterious whistle. Listening carefully, and imitating it as well as I could, I was able to discern that the sound became definitely more loud and distinct. No insect, this. Soon I could analyze it quite closely, and found it to be a very gradually rising *crescendo*, beginning about on C, and a full though slightly throbbing or tremolo whistle. I was astonished at its duration, for I could detect no time at which a breath could be taken. Timing three successive songs, I found them to endure 47, 57, and 53 seconds! This was more than twice the length of any continuous song I have ever heard, the winter wren being second, with 28 seconds. But in this broken song there are surely many opportunities to catch the thimblefull of breath a wren can hold, while the *Chamæza* song was one long, unbroken, and constantly increasing sound.

Eventually my singer came so near that I was afraid of scaring it away by the imperfection of my imitation, which required a full breath out, an in-breath to full lung capacity, and then the last bit of breath I could expel to accomplish even a 40-second song. So I sat silent, tense, and eager, hoping almost against hope that the mystery bird would reveal himself. Suddenly, almost at my heels, a song began. Very soft and throaty at first, gradually rising and filling, the steady throbbing *crescendo* proceeded until I was so thrilled that I was afraid I couldn't stand it any longer. I dared not move, as I

was in plain sight, on the edge of a scar in the earth from a recently uprooted tree. Finally, though, the tension was relaxed; the song ceased. Where would it be next time? In front of me? Or would the singer see me and depart for good, still a mystery? Even as I was thinking these things a ghostly-silent little shadow sped dangling past me and came to a halt about 30 feet away, half lost in the dark fog, on the far side of the raw little clearing. In awful anxiety lest he become swallowed up in the mist and lost to me, and with a great effort not to lose the dim impression of the faintly seen bird, I moved slightly for a better view. My long watch was futile, for my spirit bird disappeared. I sat awhile and mourned, with a great deal of invective in my heart. But soon realizing that this was futile, I decided to practice the song I had learned. Imagine my surprise, after the first attempt, to hear, close by, the loud *wip-wip* of yesterday and to see it followed almost immediately by another ghost bird, which had the grace to alight or stop running (I couldn't be positive which) within range and in sight. This proved to be *C. turdina.* Although we often heard the curious protracted song later, when we went to the top of the range, we never again caught sight of this little-known bird, and this specimen remains unique in the whole South American collection.

The several species of true ant-thrush, *Formicarius*, all have characteristic notes, combined with the same skulking, rail-like habits of the foregoing. The recently described Colombian form of *F. rufipectus* has two sharp whistles, the last a semitone above the first. This, in our experience, was never varied. *F. analis connectens*, from the lower forest zone of the eastern foot above Villavicencio, had a song the exact reverse of that of *Grallaria hypoleuca;* a loud note on G, followed, after a rest, by a close descending scale of three or four semitones. *Formicarius*, like *Grallaria*, has a sort of clucking quality when heard near at hand.

Few brush birds have more distinctive notes than the ant-shrikes of *Thamnophilus* and their relatives. The commonest one we encountered, *T. multistriatus*, has the characteristic dry, woody, descending scale common to many species. It strongly suggests in quality the spring "rucking" of a nuthatch. It might be written ruk, ruk, ruk, uk, uk, k, k, k beginning lazily and gathering speed as it descends. All these birds put much effort into their calls and sing with head up and tail down. The latter moves noticeably at each note and, as with the trogons, we came to look for the vibrating tail when hunting them.

The many species have different notes, but most are readily recognizable as *Thamnophilus* when any one of them becomes thoroughly familiar. Until one has had real experience with tropical birds, it is

ANT THRUSH.

Formicarius rufipectus carrikeri.

ANT SHRIKE.

Thamnophilus multistriatus.

hard to work up much of an interest in the great mass of dull-colored brown and gray birds that form such a large proportion of the whole. In a case of South American birds the eye alights on the brilliant tanagers, callistes, trogons, cotingas, and hummingbirds, and ignores all the myriad flycatchers, ant-thrushes, furnarian birds, and other dullish and negative-colored things. But in the field the sense of sound enters and combines with the very interesting habits of the more obscure species. I can hardly subscribe to the popular idea that tropical birds are as a rule bright-colored and devoid of song after listening with an appreciative ear to the morning chorus in a Mexican or South American forest.

One of the most extensive and typical families is that of the Dendrocolaptidæ, or woodhewers. They are, in actions, overgrown brown creepers. There are many genera and almost endless species. As a family it is nearly as extensive and varied as the family of finches, though all have a single general type of coloring that is hardly departed from. The great, flicker-sized *Dendrocolaptes*, the tiny *Xenops*, and all between, are mainly wood-brown varying from rusty to olive, and streaked or not, but never boldly marked. They are also fairly unanimous in their songs, though of course there is considerable variation. Most that I have heard have a harsh, raspy note of alarm or displeasure, and many species sing a loud, ringing song that strongly recalls our canyon wren—"tee, twee, tui, tui, tooi, tooi," a descending series of whistles, which, pure and piercing in the lesser species, becomes coarse and "woodpeckery" in the larger. There are really no fine singers in this group, although several make pleasant sounds in the spicy-scented slashings, and all are interesting. They are rather silent birds, as a rule, and, as the family contains many rare and curious types, which are elusive and tricky, they are a never-ending source of interest and curiosity.

The woodpeckers may be dismissed in a sentence. Their calls and notes are all perfectly typical of the group as we know it in this country, and I recall no species that deviate noticeably from the well-known types of cries and calls by which we recognize our own species.

V.—TOUCANS, CUCKOOS, TROGONS, MOTMOTS, AND THEIR ALLIES.

The principal sensation one gets in the tropical forests is the mystery of the unknown voices. Many of these remain forever mysteries unless one stays long and seeks diligently. I am very sure that many sounds I now tentatively attribute to certain birds really belong to others, though several are among the striking sounds.

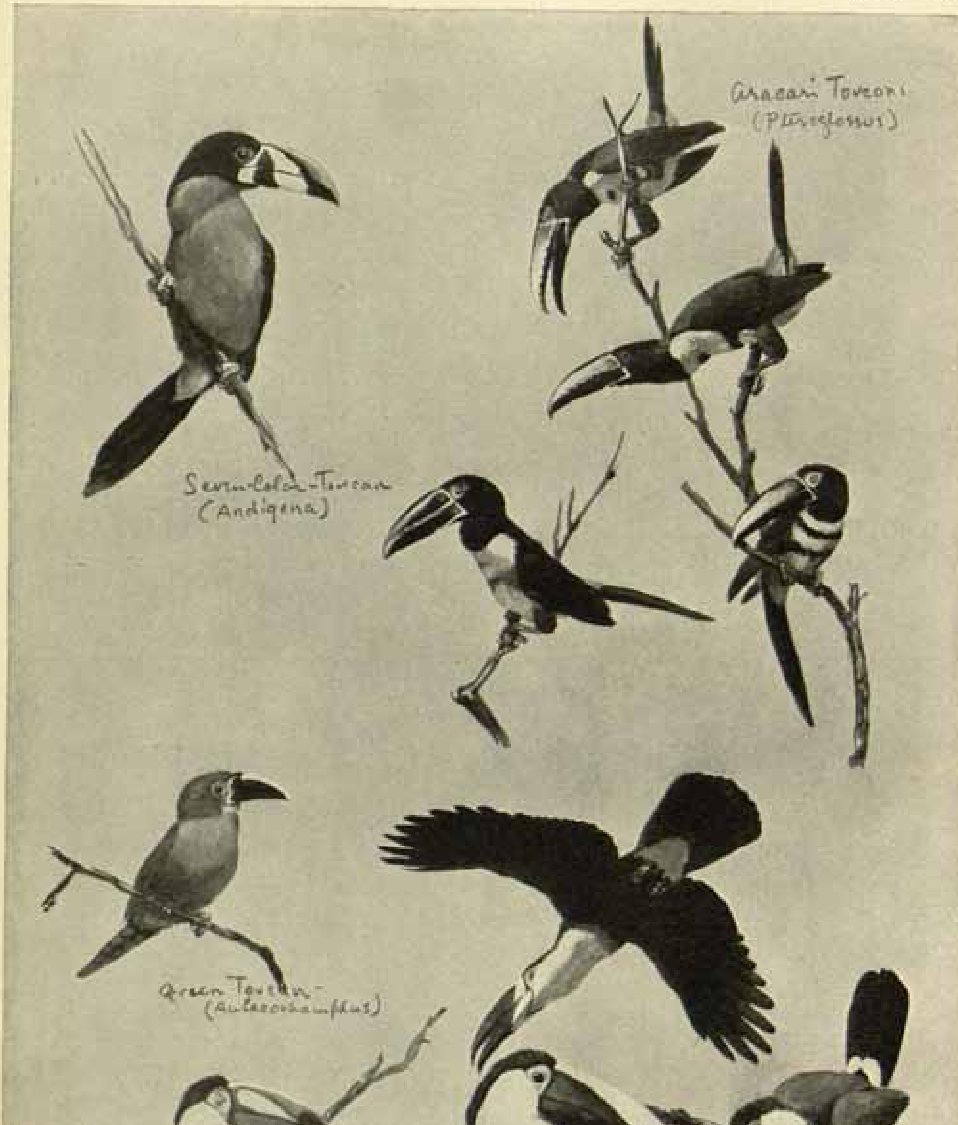
The toucans are all noisy birds, and for the most part they are all very boldly marked with strongly contrasting colors, all but the small green members of the genus *Aulacorhamphus* being brightly

dashed with black, yellow, red, white, or blue, with bills as bizarre as they are huge. *Andigena* is commonly called the "siete color" (seven color) from his Joseph's coat of black, blue, red, yellow, chestnut, green, and white. *Pteroglossus*, as an entire group, is garbed in the most strikingly contrasting patterns of black, yellow, red, and green, with bills of enormous relative size and painted like a barber's pole. *Rhamphastos*, containing the biggest of all toucans, with beaks like elongated lobster-claws, of all imaginable and many unimaginable designs in black and yellow, white, red, blue, green, or orange are themselves principally black, trimmed with a yellow or white throat and breast, and lesser patches of red and white or yellow at the base of the tail. One would naturally suppose that with these flashy colors and their noisy habits and large size, toucans would be among the easiest of birds to find; but this is far from the case. I think we all found them to be as hard to locate, after their calls had given us their general whereabouts, as any of the birds we encountered. The little green snarlers of the genus *Aulacorhamphus*, whose harsh voice seemed to me to sound like the slow tearing of a yard of oilcloth, were in many places quite common; but only those whose movements disclosed them ever fell into our hands, for it was about hopeless to discover them when they were sitting quiet among the leafage. The blue-breasted group, *Andigena*, we encountered only once or twice. The only one I saw I got from the steep trail in the Central Andes, and it was to the rattling accompaniment of horns of some 50 pack oxen we were passing on the narrow road. The excitement the shot caused among the startled beasts gave me other things to think of at the moment, and I do not now remember whether my "siete color" had a voice or not. When I finally retrieved him he was some 40 yards or more down the steep and tangled mountain side. In this connection it may not be out of place to offer one suggestion in explanation of the great difficulty of locating these large and apparently gaudily colored birds in the tropical woods and in retrieving them when shot.

To our northern eyes, used only to green leaves seldom larger than our hand, the extravagant wealth of size, form, and color in tropical vegetation offers quite as much wonderment and occupation as do the birds themselves; and here we have a diversion of the attention, however unconscious it may be, that certainly has its effect. Added to this, there are actual variations in the accustomed color of the foliage that repeat with greatest suggestiveness any red, yellow, blue, green, orange, or other color that may be present on a bird. No toucan's throat is yellower than the light shining through a thin leaf, and when leaf forms are further complicated, like those of the *Dendrophilum* creepers, by having great holes that let through

WOODHEWER.

Picolaptes lacrymiger.



TOUCANS.

Sketched from nature.

patches of the dark background or the blue sky, no black-patched toucan in the foreground looks more velvety than do these leaf interstices. As for the bizarre bills, they only serve to make it harder, for they bear no resemblance to bill or bird and simply merge their brilliancy with that of the whole picture they sit in. I don't know how many times I have searched and searched and scrutinized, to find the author of some raucous carping, only to see one of the large toucans burst away from a perch in plain sight, where he had been all the time. This has happened to me so frequently that I am sure other students must have had the same experience. Perched on a dead stub above the sky line, toucans, like everything else, are conspicuous in the extreme; sitting quietly within the shade of the forest cover, however varied their patchwork coat, they melt tantalizingly into their setting.

The big black toucans of *Rhamphastos* are generally called by the natives Dios te de or Dios te ve—meaning God will give to you, or God sees you. This is not a confession of faith on the part of the simple native, but a free and lilting transcription of the bird's call. It gives the rhythm and general shape of the sound fairly well. I could analyze it a little more closely by calling it a loud, hoarse whistle, with the words Tios-to-to or Tios, to, to, to. It has something of the queer quality of a yellow-billed cuckoo's song, only, of course, it is much larger and louder. *R. tocard* is the "Dios te de," but the name fairly well fits and is generally applied to the whole group of heavy billed toucans.

The only other group we encountered was *Pteroglossus*, the aracari toucans. These are small toucans, all joints and angles, much given to going around in noisy troops like jays. Skillful and jerky acrobats, they are the very extreme of bow-legged angularity. Curious as jays, they jerk and perk their way up into the branches of some dead tree, their great clumsy beaks and thin pointed tails complementing each other at odd angles. Toucans are all great tail jerkers, and the aracaris the most switchy of all. Their harsh mobbing cries recall some similar sounds made by jays, but are even louder and much more prolonged. Both are a great nuisance to the hunter, as they follow endlessly, their curious prying screeches and squawks effectually chasing out all the birds requiring more finesse in their approach. I should call their most characteristic noise a rattling, throaty squawk. In any case it will not take a green hunter long to identify these birds, as they are restless and their motion will soon catch the eye. I strongly suspect all the toucans of the habit and ability to slip noiselessly and rapidly away in case their curiosity is satisfied or their fear aroused. They are capable of making long leaps from branch to branch with their wings

closed, like jays and cuckoos, only more so. What with their looks, their noises, and their actions no group of birds has more amusing and interesting new sensations to offer than the toucans.

The family of cuckoos has some very interesting developments in the American Tropics. The little four-wing (*Diplopterus*), heard in the sunny river bottoms and lower brushy slopes—such places as a brown thrasher would affect—has perhaps the most insistent voice in his habitat. The commonest is an ascending couplet of notes a semitone apart—E, F. This is a sharp, piercing whistle that gets to be as much a part of the shimmering landscape as a hyla's notes do of a northern meadow bog in March. Indeed, the four wing's fuller song, which is a long, piercing note followed, after a short pause, by an ascending series of shorter notes, awoke a strangely familiar chord which I afterwards attached to the very similar pond toad call at home. The name four wing arises from the curious overdevelopment of the false wing or thumb plumes, which in this queer little bird form a sharply defined and separately distensible fan of black which the bird displays with a curious ducking motion.

The larger brown cuckoos of the genus *Piaya*, which the natives rather aptly call "squirrel birds" from their color and the slippery way they glide through the branches, I have never heard call but once, though they are fairly common throughout most of tropical America. This one sat in a bare cecropia tree, and did a loud rough kek, kek, kek, repeated 20 times or more, and I at first took it for a big woodpecker.

It is the little black, witchlike ani that is really the common cuckoo of the open savannas, and abounds over the cattle ranges and around the villages. There are a great many common native names for these conspicuous little black whiners, the commonest being "garrapatero," or tick eater. This name is almost universal, though in Cuba and Porto Rico it bears, from its obsequious manner and its great thin curved beak, the apt title of judio—or Jew. They are almost always in molt, and look shoddy and worn, and their peevishly whined "ooo-eek" gets to be a mildly annoying accompaniment to the day's work.

The barbets and puff birds (*Capito* and *Bucco*) fall naturally into this group, though they did not give us much to work on as to their notes. *Bucco* was usually found perching quietly on some twig halfway up in the trees along the roadside or pasture edges. All I remember of him is that he had a buzzing sort of scold, and could bite a piece out of my finger when caught in the hand.

The little spotted barbet, however (*C. auratus*), at Buena Vista, on the eastern foot of the Andes, had a curious little toot that was the despair of all of us till Mr. Chapman associated it with *Capito*.

PUFF BIRD.

Bucco ruficollis.

ANI.

Crotophaga ani.

TROGONS.

Trogon collaris and *Pharomacrus antisianus.*

Hoot-oot . . . hoot-oot in perfect time—hoot-oot (blank), hoot-oot (blank), almost indefinitely. It was a pervasive sound, about as loud as and very like the individual toots of a screech owl, and was given to the invariable accompaniment of the twitching tail, and with the neck humped up and the bill directed downward.

Every student in the Tropics hopes he may soon meet with trogons, at once the most beautiful and the most mysterious of all the varied tropical birds. Nothing could exceed the richness of their contrasting blood-red under parts, white and black tails, and resplendent emerald-green heads and backs. The large *Pharomacrus* trogons, of which the famed quetzal is a type, with their delicate yet richly gorgeous and pendulous mantle of feathers, are, for sheer beauty, among nature's truly great triumphs, and can not fail to force deep appreciation from the most calloused or mercenary collector. *P. antisianus* has a loud, rolling call, which I put in my notes as "whee oo, corre o," done in a round, velvety whistle. When, after quite a long time spent in imitating the unknown note, in the soggy tree-fern forest at the ridge of the coast Andes, this magnificent ruby and emerald creature came swinging toward me in deeply undulating waves and perched alertly in full sight not far away, I found it hard to breathe so great was my excitement and joy. We never found it a common bird and only three were seen in all our travel in Colombia.

A close congener of *antisianus*, the golden-headed trogon, fails in elegance before this distinguished beauty, though a marvel, nevertheless. Its notes are more commonplace, too, being merely booming hoots, not very loud but quite pervasive. The little banded trogons, with pink breasts, as well as the yellow-breasted ones, have very characteristic calls, so like each other that I never learned to distinguish the various species. They all sit quietly on some slender perch or vine stem, and do their rolling call ruk, ruk, uk, uk, uk, k, k, k, k, all on the same note. Here again the tail seems to be indispensable to the performance, and jerks sharply forward under the perch with each syllable. More than once this motion became the index to the authorship of the strangely pervasive and ventriloquistic sound.

One other group of birds has this quiet fashion of softly hooting from some low perch in the thicker and more watered parts of the forest. The curious racket-tailed motmots have what I call the most velvety of all bird notes. It is usually a single short "oot," pitched about five tones below where one can whistle. This note is very gentle, though fairly loud, and I think that some persons who do not hear low vibrations very well would often fail to notice it at a short distance. Most of the natives have sound names for motmots, and the Maya Indians of Yucatan call the brilliant little *Eumomota* "toh," and, as an appreciation of this interest, he has come to nest and

roost familiarly in the age-long deserted ruins of their former glory. Indeed, these mysterious, gentle, shy, little birds came to me, at least, to be the living symbol of this great lost magnificence: for the present-day Mayas know naught of the art and history of their great forefathers, whose temples and beautiful buildings are now in utter oblivion and disuse, except as the shelters and dwellings of little "toh," the motmot, and his soft hoot is the only sound that ever issues from their carved portals.

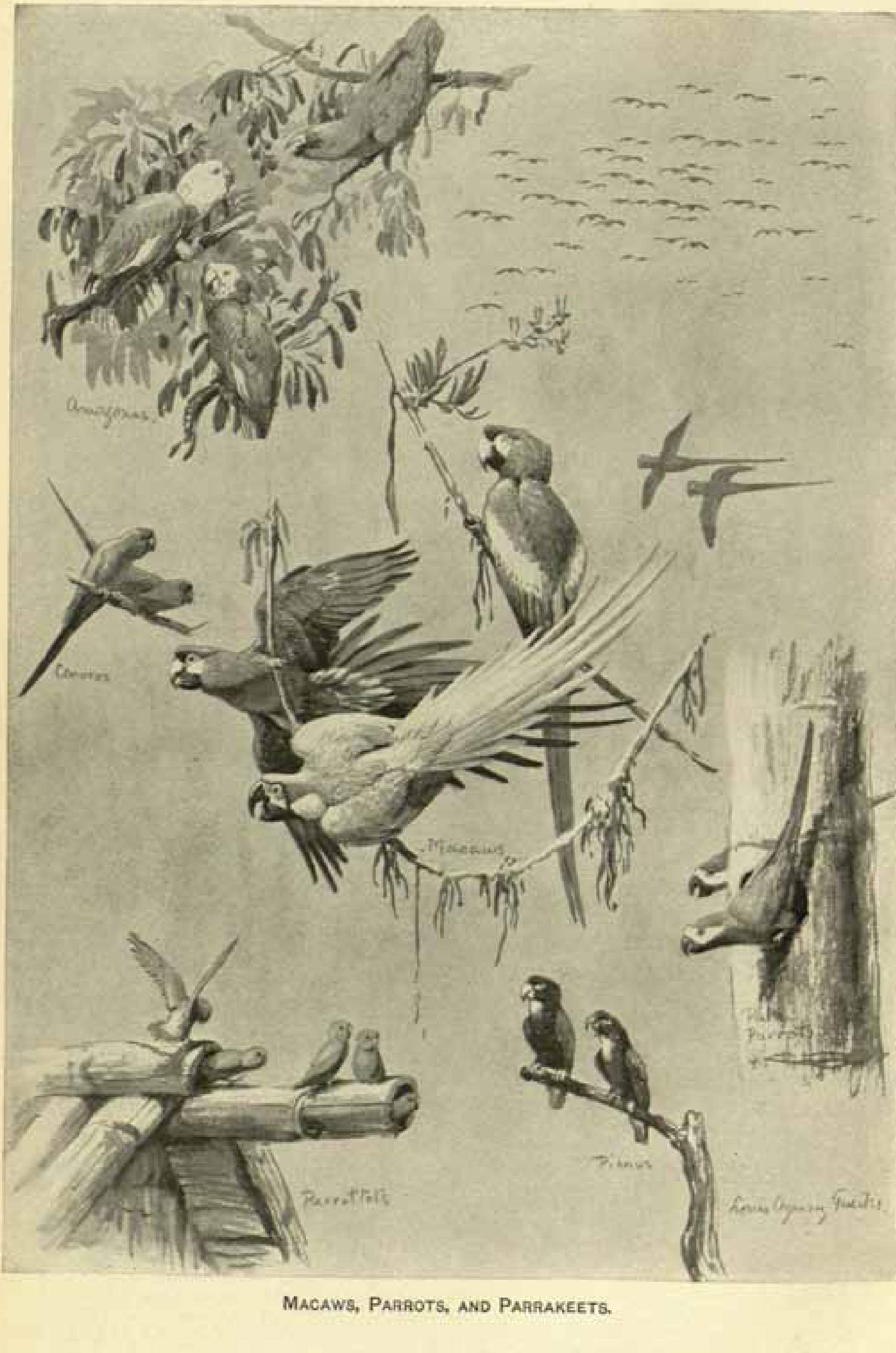
VI.—PARROTS, GUANS, AND PIGEONS; THE VOICES OF A TROPICAL MARSH.

When one meets with wild parrots for the first time he gets, undiluted, the pure breath of the Tropics. And when, after an acquaintance with the parrakeets and parrotlets, the larger and more thrilling kinds appear the sensations are even richer. About Cali, and indeed most of the other South American towns and villages, the little green and sky-blue parrotlets fill the place house sparrows occupy with us, nesting in the bamboo ridgepoles of the houses and adopting a familiar attitude toward man and his works. The native children almost universally tame them, and in the patio of the Cali Hotel, 17 of them lived in perfect familiarity among the roses and flowering vines. Their chirping and twittering reminded me of nothing more than the noises made by sparrows, though the fact that they were indigenous, coupled with their confiding friendliness and beautiful colors, removed the prejudice that the reminder might otherwise have engendered.

Wild parrots make the same raucous noises that tame ones do, and a feeding flock, unsuspicious of man's proximity, is constantly in low, chuckling conversation. But many and many a time I have heard them up the trail and, cautiously approaching, have become aware that I was observed, when all sound and motion ceased while I was still some distance from their feeding tree. With all their scarlet and saffron trimmings, the *Amazona* parrots, in my experience, take an easy palm over all others in the gentle art of ceasing to be where you know they are. I think we all had the experience of searching till our eyes ached where we knew parrots were working without being able to discern a single bird, even in the comparatively open leafage along the trails. Suddenly, without the slightest warning, as the entire flock took simultaneous alarm, the innocent air would be rent with the hellish screeching of 200 fiendish birds and gorgeous with the flashing scarlet and blue and gold of noisy wings as these capricious and thrilling birds would leave for another part of the forest. The tree would literally explode parrots.

MOTMOT.

Momotus lessoni.



MACAWS, PARROTS, AND PARRAKEETS.

After some experience with them we came to distinguish the three Mexican *Amazonas* by their cries when they were too far away to tell by sight. *A. oratrix*, the "double yellow head" of fanciers, cried quite plainly "cut it out, cut it out," while *A. viridigenalis* called "poll poll parrot, poll poll parrot," and *A. autumnalis*, from southern Vera Cruz, had a sufficiently distinct screech to immediately stamp it as something new, although I made no transcription of its yell.

Conures all make regular parrot noises, though shriller and "lighter" than those of the larger kinds. But the "real noise" in parrotdom is the great, gorgeous and ear-splitting macaw. Along the lower Magdalena River the red-and-blue and the blue-and-yellow macaws were both quite common, and it is hard to say whether their greatest attack was on our eyes or our ears. Their heavy, rasping yell was clearly audible above the churning racket of the engines, even when the birds were some distance away in the forest. We were frequently apprised of their flights, high, high over the valley as they passed from one great Andean chain to another, perhaps 3,000 feet above us, by the penetrating, though distance-mellowed, cries that filtered down to us from the scarcely discernible line. When heard near at hand there is a heavy, hammering quality in a macaw's scream that makes it the most deafening noise that I have ever heard from a bird, while their fiery beauty affords the greatest sensation a naturalist gets in their country. Not only are their exposed surfaces brilliant, but their wing and tail linings are as gorgeous. I shall never forget a flock of blue-and-yellow macaws we passed one evening just before sunset as we were descending the Magdalena. We were between them and the low sun. They were near, and about level with our eyes, relieving against the velvety green of the forest wall directly where our shadows fell. The astonishing glory of their turquoise upper surfaces, alternating as they flew with intense cadmium yellow as the sun got under their wings, kindled a flashing riot of color that made us gasp.

So far as I know, parrots all pair for life, and every large flock we saw, whether of macaws, parrots, or parrakeets, was made up of pairs, each bird of which bore the same relation to the other all through the flock. They looked as if made with a paired stencil, or seen through a double-refracting glass. Invariably, if one bird was lost out of a passing flock, another would soon drop out, circle, and come back to see what had happened to its mate. If, rarely, there were unpaired birds in a flock, they were usually apart from the main body, and conspicuously "out of it." In flight parrots present a singular resemblance to ducks, particularly from ahead or behind. Flying "across the quarter," their heavy blunt heads are, of course, unmistakable.

We were kept constantly interested in the varied voices of the doves and pigeons. The gentle little ground doves, hardly bigger than sparrows, give a single, soft, questioning "coo," invariably with a rising inflection. I could distinguish no material variation in their calls in Florida, Yucatan, or South America, and even the rufous species presented no differences appreciable to my ear. The ground pigeons of the genus *Geotrygon* all have gentle, velvety voices which, heard in the damp gloom of the cloud forest, impart something of the mystery and romance of the tinamou's tremulous plaint. They have the same uncanny way of gliding silently into view and melting away, and when, rarely, they fall into our hands, their subdued but rich beauty compels an admiration that does not dim with repetition.

But not all pigeons have these soft owllike voices. *Columba speciosa* has a harsh, raw-voiced single "toot," audible at a considerable distance. *C. bogotensis*, in the eastern Andes, in addition to the regular pigeon clucks and cooing, has a loud, rough call, with a strong roll or "burr" in it, suggesting a "Klaxon" automobile horn. The white-winged doves of *Melopelia* are among the noisiest of the pigeons. Indeed, a flock calling from a feeding tree, with their loud rollicking "Hoo-too-coo-roooo, hoo-too-coo-roooo," reiterated interminably, recalls a group of victory-crazed undergraduates "rooting" for their football team. I found that I could quite closely imitate this and several other pigeon calls by whistling through my hands.

I heard only one of the big guans of the genus *Crax*. What I took to be the fine black curassow, at Buena Vista, sat one evening for half an hour before sunset in the dense top of a great forest tree and gave his exciting cry at intervals of half a minute until the sun was well down and the hurrying dusk began to deepen. I cautiously crept nearer and nearer and finally gazed up from directly below. Here I searched until my neck ached, but though the cries came regularly and I constantly changed my position, the bird was so well hidden that I never saw him, and at last I left him there, to hurry out of the deepening gloom of the forest before it should get fully dark. As it was, I had to "foot feel" my way for the last part of the trail, as night caught me before I reached the clearing. This call is hard to describe. It was not at all "gobbly," like a turkey's voice, but was a loud siren call, which the natives interpret by their name for the bird "Aburria," with the r's strongly thrilled. It rolls up a full octave, sustains a second, and rolls down again. I think it would carry across the shadowed valleys in the still sunset forests for a mile at least, and is fully as loud as any answer a strong-lunged boy could yell back.

The little guans of the genus *Ortalis*, the Chachalacas, have also a fine sensation saved up for the eager naturalist who has not heard

them before. The male, with his elongated and convoluted windpipe, has the louder and rougher cry, which, by virtue of the longer instrument to trumpet through, is an exact octave lower than that of his normally equipped mate. *O. vetula*, from Mexico, says quite plainly "Cha-cha-lac′-ca. Cha-cha-lac′-ca," or, as the Mexicans more phonetically spell it, "Guacharra′ca." It has a very human quality of voice and sounds nearly as loud at a quarter of a mile as it does at a hundred yards. The Colombian species heard in the Magdalena Valley seemed to my ear to screech "Aqua-dock." The various members of a calling flock keep time, roughly, according to sex. They are apt to call from up on the mountain sides or in ravines, when the rebounding echoes complicate and augment the chorus immensely.

Another noteworthy voice is the rolling cry of *Aramides*, the big rusty-colored wood-rail. As dusk was falling around me on a forested mountain side, while working my way out to the trail, I was suddenly congealed by a loud, rolling cry, hastily repeated three or four times. It sounded in front of me, behind me, over me, and under me. I began to think it was all around me. A loud hoot, then a rising, rolling trill—"Oot- roo-ee-e-e-e- oot- roo-ee-e-e-." I found I could do it by "pigeon tooting" through my hands, so that the bird came quite near and thrilled me deeply. But it was too dark, and I knew not where to look for it. After a few responses it slipped away, still a mystery; but when I reached camp and imitated it for Mr. Cherrie he at once recognized it as *Aramides;* and this diagnosis is his, not mine, for I never had another opportunity to identify it.

Among the lasting impressions that I have brought out of the Tropics certainly one of the most vivid is of the great, sultry, odorous, and soundful marshes of the Magdalena and Cauca Valleys. These treacherous reaches have a fascination and exert a call upon the novice naturalist that is indeed likely to get him into trouble. Everything that charms the senses in a northern water field is here multiplied. Plant life is riot, insects accordingly swarm, and many species of birds avail themselves of the easy food they furnish. The allurements of a fragrant, shimmering sheet of placid water, with beds of floating plants made gay with the delicately lovely Jacanas, fighting their innocent battles and displaying their lemon butterfly wings; the dignified spurwinged plover that trot on the margins or fly in noisy flocks, like Dutch lapwings, low over the surrounding pasture lands; perhaps a bare snag far out in the deep marsh, all in glowing blossom with roseate spoonbills and snowy herons; the loud clatter of the giant kingfisher and the dry rasping of his tiny "Texas" cousin; statuesque screamers posing on an exposed bar; the squealing whistles of the tree ducks dabbling and sunning

themselves at the edge of the hyacinth beds—all these and a hundred other charms lure him deeper and deeper into the marsh or into the lush reeds and papyrus beds that form some of their margins. I shall not soon forget an hour spent in retrieving an everglade kite in the great marsh at Calamar. Here the one pervasive sound was the constant, irritating hum of the myriads of ravenous mosquitoes. Things were not helped by the discovery that I was soon on a false bottom, made only of the suspended roots of the vegetation that rose 10 feet above me, so that I went through and had to go the rest of the way on my knees, up to my armpits in tepid water. As I had a gun and a glass to keep dry, this was no joke, and I think that was the most miserable hour I ever went through. At the end I was absolutely spent and could only crawl out and lie down—easy meat for the mosquitoes—for another hour. But it had its recompenses. Into the willow-like shrubbery over me came the beautiful little yellow-headed blackbird of the Tropics and sang his orchard-oriole song. Nearby great-tailed grackles squealed, piped, and pointed their bills aloft in their nuptial attitudinizing. The red-breasted meadowlark, *Leistes*, also came to close quarters, though it did not sing, and I watched the lovely and delicate little black and white marsh flycatchers almost at arm's length.

There is a creature in the South American forests which, though not a bird, ranks easily first as a maker of weird noises. I have read many descriptions of his performance, but was not in the least prepared for the reality when I actually heard it, nor did I even recognize it. This is the roaring of the so-called howling monkey. To my mind howling is a sort of eerie, rising and falling noise, far different from the deep-voiced, businesslike, bellowing roar that is the predominant feature of this little animal's performance. It is at least a hundred times more thunderous and terrible than would seem possible from a creature somewhat larger than a big tomcat. I had heard them in the distance a number of times, but it was at Rio Frio, on the Cauca River, where our little sternwheeler was taking wood, that I first got close to them in "action." As I left the boat for a short walk in the virgin bottom-forest I heard howlers a little distance in. I knew they were small animals (our biggest male weighed 17 pounds) and could do me no harm. Yet here I confess to a greater triumph of mind over matter than I have elsewhere ever been called on to effect in order to overcome the fierce desire to be somewhere else. In spite of the intellectual certainty that it was perfectly safe, it took all my nerve that first time to move up under the tree whence came that courage-killing, menacing bellow. There were only four of them—an old male, a female, and two half-grown

SPURWINGS, JACANAS, AND CRESTED SCREAMER.

BOUCIER'S FOREST DOVE.

Geotrygon bourcieri.

RED HOWLER.

CRESTED CURASSOW.
Crax sp.?

young; probably a family. Yet the terrible noise that issued principally from the bearded and swollen throat of the old male seemed really to make the atmosphere quake. As I stood below he would rush down toward me, bellowing outrageously, and I thought it took some fortitude at first to stand by till he retreated again. The noise, as I analyzed it at the time, was a deep, throaty, bass roar, with something of the quality of grunting pigs, or the barking bellow of a bull alligator, or an ostrich. Accompanying this major sound was a weird, crooning sort of wail, probably the contribution of the female or young, or both. The noise was fully as loud as the full-throated roaring of lions, and that it has marvelous carrying power was frequently attested when we heard it from the far side of some of the great Andean valleys as we wound our tortuous way across the Central Cordillera. This is, of course, in no sense a bird voice, yet it is by far the most striking sound in the American tropics, and I should feel that I had done the subject slight justice if I did not at least try to make it recognizable to those who may read these papers and some day hear for themselves this astonishing sound.

In bringing to a close this series of impressions it must not be thought that they cover the field of tropical-bird music. They form, indeed, the merest nucleus on which to build.

THE ESKIMO CURLEW AND ITS DISAPPEARANCE.[1]

By Myron H. Swenk.

[With 1 plate.]

It is now the consensus of opinion of all informed ornithologists that the Eskimo curlew (*Numenius borealis*) is at the verge of extinction, and by many the belief is entertained that the few scattered birds which may still exist will never enable the species to recoup its numbers, but that it is even now practically a bird of the past. And, judging from all analogous cases, it must be confessed that this hopeless belief would seem to be justified, and the history of the Eskimo curlew, like that of the passenger pigeon, may simply be another of those ornithological tragedies enacted during the last half of the nineteenth century, when because of a wholly unreasonable and uncontrolled slaughter of our North American bird life several species passed from an abundance manifested by flocks of enormous size to a state of practical or complete annihilation. In this deadly work the people of Nebraska, as well as those of our neighboring States, to our lasting discredit played a conspicuous and all too effective part each spring, while in the fall the equally profligate gunners of New England and the Atlantic States poured leaden death into southbound flocks of these unfortunate birds whenever an opportunity presented itself.

Nothing was known concerning this interesting bird until after the middle of the eighteenth century. It was originally described by Forster[2] in 1772 as *Scolopax borealis*, from a specimen taken at Albany Fort, Hudson Bay. Pennant[3] in 1785 and Hearne[4] in 1795 both erroneously referred to the larger congener of this bird, the Hudsonian curlew (*Numenius hudsonicus*) as the "Eskimaux

[1] Reprinted by permission, after revision by the author, from the Proceedings of the Nebraska Ornithologists' Union, vol. 6, pt. 2, Feb. 27, 1915.

[2] Forster, J. R. Phil. Trans. Royal Soc. London, 62, pp. 411 and 431, 1772.

[3] Pennant, T. Arctic Zoology, 2, 1785.

[4] Hearne, S. A journey from Prince of Wales' Fort in Hudson's Bay to the Northern Ocean, 1795.

curlew," though the latter author recognized two species of curlew as abundant about Hudson Bay from 1769 to 1772, the smaller of which was undoubtedly the present species. In 1790 Latham[1] formally described the Hudsonian curlew and referred the Eskimo curlew to the same genus, but confusion between the two species continued up to the earlier years of the nineteenth century, and the bird described by Wilson[2] in 1813 as the "Esquimaux curlew" was in reality the Hudsonian, the species rightfully entitled to the name he used being unknown to him. The Hudsonian curlew is a large bird, about 17 inches long, with a bill about 4 inches long, a whitish stripe in the middle of the top of the head and the long flight feathers of the wing barred with buffy; the Eskimo curlew is 2 to 5 inches shorter, with a bill only slightly over 2 inches long, the crown unstriped and the flight feathers of the wing unbarred.

In the spring migration this curlew passed through the interior of the United States, in the Mississippi Valley, rarely if ever occurring on the Atlantic Ocean or its coasts. It first appeared in the United States in Texas and Louisiana during early to middle March. In central Texas Brown[3] noted it at Boerne, Kendall County, March 9, 1880, as a rather common migrant, while in northern Texas at Gainesville, Cooke County, it arrived on the average March 17, according to Ragsdale, while its earliest date was March 7, 1884.[4] In the adjacent county, Wise, it was noted as late as April 2, 1884, while at Caddo, Okla., a short distance across the Red River from Gainesville, in 1884 it was noted March 25 and was abundant on April 2.[5] In Louisiana, where it was a common migrant,[6] the last records are for March 17 and 23, 1889,[7] while for Arkansas the last record is from Fayetteville, March 31, 1883, on the authority of Prof. F. L. Harvey.[8]

The quadrangle of States to the north—Kansas, Missouri, Iowa, and Nebraska—saw the passing through of these curlews during the last few days in March and during April. By the last of March the vanguard of the birds had reached central Missouri (St. Louis, Mar. 25, 1884,[5] and southern Nebraska (Waco, Mar. 31, 1911)[9] Curlews were on the St. Louis market April 6, 1885,[5] a flock of a hundred birds was seen in Vernon County, southwestern Missouri, April 16, 1894, and a flock of 10 was noted in the neighboring county of Jasper as late as May 2, 1902.[10] In central Kansas, according

[1] Latham, J. Index Ornithologicus, 2, p. 712, 1790.
[2] Wilson, A. American Ornithology, 7, 1813.
[3] Brown, N. C. Bull. Nuttall Ornith. Club, 7, p. 42, 1882.
[4] Cooke, W. W. Bull. 35, Bureau of Biological Survey, pp. 74–76, 1910.
[5] Cooke, W. W. Bull. 2, Division of Economic Ornithology, p. 98, 1888.
[6] Beyer, G. E., Allison, A., and Kopman, H. H. Auk, 25, p. 179, 1908.
[7] Forbush, E. H. Game birds, Wildfowl and Shorebirds, pp. 416–432, 1912.
[8] Howell, A. H. Bull. 38, Bureau of Biological Survey, p. 32, 1911.
[9] Eiche, A. Proc. N. O. U., v, p. 31, 1911.
[10] Widmann, O. Trans. Acad. Science, St. Louis, p. 75, 1907.

to the observations of Kellogg, they reached Emporia April 14, 1884, and April 13, 1885.[1,2] In Iowa, the last recorded specimen was taken at Burlington in the extreme southeastern part of the State, April 5, 1893, by Paul Bartsch.[3] The bulk of the birds reached southern Nebraska about April 2 to 25 and remained until the 15th to 25th of May; in northern Nebraska they were apparently most numerous in early May. The van reached Heron Lake, Jackson County, in southwestern Minnesota, April 3, 1884, and the next year (1885) were noted at this place on April 24.[2] In southeastern South Dakota, the bulk arrived at Vermilion, Clay County, May 3, 1884,[2] while Coues reported them present in large flocks between Fort Randall and Yankton during the second week in May, 1873.[4]

By latter May the curlews had reached their breeding range in the far north, on the Barren Grounds of Mackenzie, within the shadow of the Arctic Circle or even within the circle itself. They reached Fort Resolution, near the south shore of Great Slave Lake, May 26, 1860, Kennicott mentioning in his journal the taking of a specimen there on that date.[5] At Fort Anderson, Mackenzie, near the arctic coast, they were noted May 27, 1865, by MacFarlane.[6] In this latter locality the birds bred abundantly, MacFarlane collecting some 30 sets of eggs on the Barren Grounds east of Fort Anderson on June 13, 1863, June 16, 1864, and June 16, 1865.[7] Previously Richardson had found "one of these curlews hatching on three eggs on the shore of Point Lake," Mackenzie, on June 13, 1822.[8] He also found these birds at Fort Franklin, on the west shore of Great Bear Lake, Mackenzie, late in May, 1849, but this was probably too early for nests.[9] The breeding range probably extended from Alaska to Labrador, as these curlews penetrated even as far to the northwest as Point Barrow, at the apex of the north Alaska coast, where, though "rare and irregular," it was first seen by Murdock May 20, 1882, and last seen July 6 of that year, thus probably being present through the breeding season.[10] Also, eastwardly it was recorded by Kumlien as passing in small flocks northward in June, 1878, at Cumberland Bay, and a specimen was taken.[11] It was

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[1] Cooke, W. W. Bull. 35, Bureau of Biological Survey, pp. 74–76, 1910.

[2] Cooke, W. W. Bull. 2, Division of Economic Ornithology, p. 98, 1888.

[3] Anderson, R. M. Proc. Davenport Acad. Sciences, 11, p. 227, 1907.

[4] Coues, E. Birds of the Northwest, pp. 510–512, 1874.

[5] Biography of Robert Kennicott; Committee, Chicago Acad. Sciences, in: Trans. Chicago Acad. Sciences, 1, p. 172, 1869.

[6] Preble, North American Fauna, No. 27, p. 332, 1908.

[7] McFarlane, R. Proc. U. S. Nat. Mus., 14, p. 429, 1891.

[8] Swainson, W., and Richardson, J. Fauna Boreali-Americana. London, 2, p. 378, 1831.

[9] Richardson, J. Arctic Searching Expedition: A Journal of a Boat-Voyage through Rupert's Land and the Arctic Sea, in search of the Discovery Ships under command of Sir John Franklin, London, 2, p. 108, 1851.

[10] Murdock, J. Auk, 2, p. 63 and p. 201, 1885.

[11] Kumlien, L. Bull. 15, U. S. Nat. Mus., p. 88, 1879.

not known, however, to have actually nested either west or east of the Mackenzie Barren Grounds.

The nest of the Eskimo curlew was a mere hole in the ground on the open plain lined with a few decayed leaves with a thin sprinkling of dried grass in the center. The eggs were laid by the third week in June. As the setting bird would glide off before the nest was closely approached it was a very difficult thing to find. After leaving the nest the female usually soon ascended into the air in a straight line. The eggs, usually four in number, were oblong oval, slightly pear shaped, varying in size from 1.90 by 1.40 to 2.12 by 1.33, and also exceedingly variable in color, a pale green or greenish gray to clay colored or olivaceous drab heavily marked on the larger end with shades of sepia to umber brown. The young began hatching about July 12, leaving the nest as soon as hatched and hiding away in the grass if alarmed.[1 2]

Late in July and early in August the curlews had completed their domestic duties, and began congregating in flocks preparatory for their long southward migration. Their first movement was from the Barren Grounds southeastward to the eastern shores of Labrador, where they massed in immense swarms. July 29, 1833, while Audubon was near the harbor of Bras d'Or, Labrador, he found these curlews coming in from the north in such dense flocks as to remind him of the flights of the passenger pigeon.[3] In 1838 Tucker recorded these birds as exceedingly abundant, occurring in vast flocks on the Labrador coast.[4] In 1860 Dr. Packard noted a flock which was perhaps a mile long and nearly as broad, and the sum total of their distant notes resembled the wind whistling through the rigging of a ship, or at times sounding like the jingling of many sleigh bells.[5] Dr. Coues in the same year noted their arrival at Indian Tickle Harbor, Labrador, August 16, 1860.[6] Norton recorded their arrival at Houlton Harbor, Labrador, August 20, 1891.[6] Here they found an abundance of food and gorged themselves until they became extremely fat. During latter August the bulk of the curlews crossed the Gulf of St. Lawrence to Newfoundland and Nova Scotia, and from there struck out to sea, heading toward their South American winter home. The records at Cartwright, Labrador, cover the period from July 28 to October 24.[7]

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[1] Coues, E. Birds of the Northwest, p. 510–512, 1874.

[2] Baird, S. F., Brewer, T., and Ridgway, R. Water Birds of North America, 1, p. 318, 1884.

[3] Audubon, J. J. Birds of America, 6, p. 45, 1843; Orn. Biog., 3, p. 69, and 5, p. 590, 1835.

[4] Tucker, E. W. Five months in Labrador and Newfoundland in 1838, p. 110, 1839.

[5] Forbush, E. H. Game Birds, Wildfowl and Shorebirds, pp. 416–432, 1912.

[6] Cooke, W. W. Bull. 35, Bureau of Biological Survey, pp. 74–76, 1910.

[7] Townsend, C. W., and Allen, G. M. Proc. Boston Soc. Nat. Hist., 33, pp. 356–357, 1906–7.

During this long flight, if the weather was fair and fine, little was seen of the curlews from the time they left the Newfoundland and Nova Scotia shores until they reached the Lesser Antilles, nearly 2,000 miles away. A few flocks would land for a few days on the Bermuda Islands, according to Jardine,[1] and if southerly storms prevailed great numbers of them would land, but usually the bulk passed on, and, flying both day and night, probably without landing, did not land until the Lesser Antilles had been reached. Passing through these islands, they continued along the eastern portion of Brazil to Argentina, their winter home.[1] Barrows reports them arriving at Conception del Uruguay, in large flocks, September 9, 1880, and remaining until the middle of October. At Bahia Blanca they were seen every day until late in February, but after March they had disappeared.[2] Most of the birds arrived in Argentina about the middle of September and wintered in the campos region of that country, mostly south of Buenos Aires.[1] They occurred south of the Chabut Valley, Patagonia, according to Durnford, and according to Abbott a specimen was taken on the Falkland Islands.[1] On the west coast they were rare, but occurred in Chile south to Chiloe.[1]

But if easterly storms occurred, the birds would be driven out of their line of flight, and great flocks would occur on the coast of New England, and, less commonly, the shores of the middle and southern States; or, if westerly storms prevailed, they might be driven far out to sea or even across the Atlantic, as there are several records of the occurrence of the species on the British Isles in the fall. On September 6, 1885, one was recorded from Cairn Moncarn, near Stonehaven, Kincardineshire,[3] two others were also taken on unknown dates on the Alde at Aldeburgh, and at Woodbridge, both in Suffolk;[4] a fourth was purchased in Dublin, in the flesh, October 21, 1870;[5] another individual at Slains, Aberdeenshire, September 28, 1878;[6] and a sixth bird, a male, at Forest of Birse, Kincardineshire, September 21, 1880.[7] On May 26, 1906, an Eskimo curlew came on shipboard about halfway between Ireland and Newfoundland (lat. 49° 06′ N., long. 27° 28′ W.) in a fatigued condition.[8]

On the Pacific coast south of Alaska this bird was always very rare. A lone specimen was shot over decoys at San Diego, Cal., September, 1883, and was the only one seen.[9] Mr. P. I. Hoagland, who is well acquainted with this bird in Nebraska, states that a number

[1] Cooke, W. W. Bull. 35, Bureau of Biological Survey, pp. 74–76, 1910.
[2] Barrows, W. B. Auk, 1, p. 316, 1884.
[3] Longmuir, Naturalist, p. 265, 1855, and Yarrell, British Birds, 2, p. 620.
[4] Hele, Notes about Aldeburgh, p. 177, and Harting, Handbook of British Birds, p. 145.
[5] Blake, Knox, Zoologist, p. 2408, 1870.
[6] Sim, Scottish Naturalist, p. 36, 1879.
[7] Harvie-Brown, Zoologist, p. 485, 1880.
[8] Barbour, R. Auk, 23, p. 459, 1906.
[9] Holterhoff, G. Auk, 1, p. 393, 1884.

of years ago he saw a flock of about a dozen birds at Coronado Beach, near Tia Juana, Cal., and that he shot a few birds from this bunch.

In Labrador the Eskimo curlews were abundant until about 1876, according to observations reported to Townsend and Allen,[1] but there was a great and sudden falling off in numbers about 1886. Other observers place the sudden decline in 1891[2] or 1892.[3] Bigelow states that after 1892 the birds appeared no more in numbers, and while in Labrador in September, 1900, he heard of only about a dozen being seen on the coast, and of these he personally saw five.[3] According to Dr. W. T. Grenfell the birds became scarce in the eighties in Labrador, and in 1892 he saw only two flocks of any size. In 1906 he heard of a few dozen being killed but did not see one.[1] During the years 1908–1911 the birds were not noted in Labrador,[2] but in August and September, 1912, eight Eskimo curlews were seen on the beach at West Bay, north of Cartwright, Labrador, and seven of these were shot, while the skins of five were saved and sent to Cambridge, Mass., by Dr. Grenfell, where they were seen and identified by Mr. William Brewster.[4]

During the period of abundance in Labrador these birds were continually and heavily slaughtered. One hunter states that the fishermen killed them by thousands, and he had personally shot a hundred before breakfast.[1] Another hunter, quoted by Carroll,[5] said that he did not remember having secured less than 30 or 40 brace in a two-hours' shoot, and in a day's shooting by 25 or 30 men as many as 2,000 birds would be killed for the Hudson Bay Co.'s store at Cartwright.

Concerning the shooting in Labrador, Coues[6] says:

> The most successful method of obtaining them is to take such a position as they will probably fly over in passing from one feeding ground to another. They may then be shot with ease, as they rarely fly high at such times. The pertinacity with which they cling to certain feeding grounds, even when much molested, I saw strikingly illustrated on one occasion. The tide was rising and about to flood a muddy flat of perhaps an acre in extent, where their favorite snails were in great quantities. Although six or eight gunners were stationed upon the spot and kept up a continual round of firing upon the poor birds, they continued to fly distractedly about over our heads, notwithstanding the numbers that every moment fell. They seemed in terror lest they should lose their accustomed fare of snails that day. On another occasion, when the birds had been so harrassed for several hours as to deprive them of all opportunity of feeding, great numbers of them retired to a very small island, or rather a large pile of rocks, a few hundred yards from the shore, covered with seaweed and, of course, with snails. Flock after flock alighted on it till it was completely

[1] Townsend, C. W., and Allen, G. M. Proc. Boston Soc. Nat. Hist., 33, pp. 356–357, 1906–7.

[2] Forbush, E. H. Game Birds, Wildfowl and Shorebirds, pp. 416–432, 1912.

[3] Bigelow, H. B. Auk, 19, p. 29, 1902.

[4] Townsend, C. W. Auk, 30, p. 10, 1913.

[5] Carroll, W. J. Forest and Stream, 74, p. 372 (1910).

[6] Coues, E. Proc. Philadelphia Acad. Nat. Sciences, p. 236, 1861.

covered with the birds, which there, in perfect safety, obtained their morning meal.

In Newfoundland and on the Magdalen Islands in the Gulf of St. Lawrence, for many years after the middle of the nineteenth century, the Eskimo curlews arrived in August and September in millions that darkened the sky.[1] As late as 1890 a "cloud" of these birds was seen on the Magdalen Islands, perhaps the last large flocking of these birds that was seen anywhere in the east.[2] In 1900 one was killed on an island in the Gulf of St. Lawrence, in 1901 one was killed on Prince Edward Island, in 1902 it is believed one was taken on Sable Island, and in 1906 a male was killed, September 6, on the Magdalen Islands.[3] In Nova Scotia, since 1888, there is but one record of this bird, a specimen in the Halifax market, September 11, 1897.[3]

The fishermen of Newfoundland, as well as those of Labrador, made a practice of salting down these birds in barrels. At night when the birds were roosting in large masses on the high beach a man armed with a lantern to dazzle and confuse the birds could approach them in the darkness and kill them in enormous numbers by striking them down with a stick.[1]

In New England, and especially in Massachusetts, the Eskimo curlew was known as the "dough bird" or "doe bird," and the existing accounts would indicate that these birds occurred on Cape Cod, Nantucket, and other points on the coast in tremendous numbers in August and September during northeast storms in the early part of the nineteenth century. During these storms the birds sometimes landed in a state of great exhaustion, and they could be chased and easily knocked down with clubs when they attempted to fly. These immense flights continued to appear on the Massachusetts coast up to the middle of the nineteenth century or even later. In the thirties and forties these birds alighted on Nantucket in such numbers that the shot supply of the island would become exhausted and the slaughter would have to stop until more could be secured from the mainland.[3] By 1858 Sumner[4] wrote for the vicinity of Boston: "None are now to be seen where once they were so abundant, and even the market offers but few at 50 cents apiece." In other less frequented parts of the coast, however, the bird continued common for 25 years or more. Up to 1861 there were some birds each year on the Massachusetts coast, but there were none in 1862.[5] A great flight occurred there August 29, 1863. A few days later, on Septem-

[1] Hapgood, W. Forest and Stream series No. 1, Shore Birds, pp. 17 and 22–23, 1885.

[2] Sanford, L. C., Bishop, L. B., and Van Dyke, T. S. The Water-fowl Family, pp. 445–446, 1903.

[3] Forbush, E. H. Game Birds, Wildfowl and Shorebirds, pp. 416–432, 1912.

[4] Sumner, W. H. History of East Boston, p. 53, 1858.

[5] Mackay, G. H. Auk, 9, pp. 16–21, 1892; 10, p. 79, 1893; 11, pp. 75–76, 1894; 14, p. 214, 1897; 15, pp. 52–53, 1898; and 16, p. 180, 1899.

ber 3, 1863, on Cape Cod, several gunners killed 281 Eskimo curlew and golden plover in one day.[1]

A few birds occurred on the Massachusetts coast in 1866, 1867, 1868, 1869, and 1870, but none in 1864, 1865, and 1871.[2] In 1872 there were two flights, and the birds were killed in such numbers that two market gunners sold $300 worth and boys offered the birds for sale at 6 cents apiece.[3] There were some birds in 1873, 1875, and 1876, but none in 1874, while in 1877 there was a flight and in 1878 a smaller flight.[2] In 1879 there were no birds, but the next three years there were some; in 1882 two hunters on Nantucket shot 87 Eskimo curlew in one morning, while at about the same time another hunter on Marthas Vineyard killed about 70 of them.[3] In 1883 there was a large flight August 26,[2] while on August 30 of that year the last great flight of Eskimo curlew and golden plover occurred on Cape Cod.[4] There were a few birds in 1884, 1885, 1886, and 1887, a number in 1888 and 1889, again a few birds in 1890, 1891, and 1892, while in 1893 a single bird was shot[2] and another seen.[5] One bird was seen in the Boston market in 1894,[2] two were killed at Chatham in 1895,[2] none were seen in 1896, eight in 1897, and two in 1898.[2] At Chatham Beach one was killed in 1897, four in 1899, and the last one on September 13, 1900.[3] In 1898 one was seen at Dennis, in 1900 one was killed at Eastham[3] and in 1901 birds were killed at Ipswich[5] and on Prince Edward Island.[2] In October, 1902, two were obtained in the Boston market and one of them came from Massachusetts.[3] In 1908 two were shot at Newburyport, Massachusetts, August 27, and one of them was saved.[6]

In New York State the Eskimo curlew was seen or taken on Long Island every year except 1888 from 1885 to 1891; the last record for that State being about 1896.[7] In early days there were flights of many thousands of these birds on Long Island, where they were known as "Futes," at long intervals during heavy easterly storms, but not in recent years.[8] In 12 years this bird was met with only four times by N. T. Lawrence, viz, September 12, 1875, September 10, 1876, and September 26, 1884, two on the latter date.[9] In Maine a female was shot at Pine Point September 23, 1901, and two were shot at Hog Island, Hancock County, in September, 1909—one on the 2d and one on the 14th—both specimens being preserved.[10, 3]

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[1] Hapgood, W. Forest and Stream series No. 1, Shore Birds, pp. 17 and 22–23, 1885.
[2] Mackay, G. H. Auk, 9, pp. 16–21, 1892; 10, p. 79, 1893; 11, pp. 75–76, 1894; 14, p. 214, 1897; 15, pp. 52–53, 1898; and 16, p. 180, 1899.
[3] Forbush, E. H. Game Birds, Wildfowl and Shorebirds, pp. 416–432, 1912.
[4] Job, H. K. Wild Wings, pp. 207–208, 1905.
[5] Townsend, C. W. Birds of Essex County.
[6] Mayer, J. E. Auk, 26, p. 77, 1909.
[7] Eaton, E. H. Birds of New York, 1, p. 342, 1910.
[8] Braislin, W. C. Proc. Linnaean Soc. New York, p. 64, 1907.
[9] Lawrence, N. T. Auk, 2, p. 273, 1885.
[10] Knight, O. W. Auk, 27, p. 79, 1910.

As to the destruction in Massachusetts, Forbush[1] says:

> The decrease of the dough-birds in Massachusetts during the last century may be explained in part by the continual persecution they suffered here. The arrival of these birds was the signal for every gunner and market hunter on the coast to get to work. The birds were rarely given any rest. Nearly all that remained on our shores were shot, and only those that kept moving had any chance for their lives. As a consequence of this continual persecution the birds probably learned to avoid the New England coast, and most of those that were driven to land by storms left the moment the weather was favorable for a continuance of their flight. Often they came in at night and went in the morning.

In Texas the Eskimo curlew came in immense flocks on the prairies from 1856 to 1875, after which year the large flocks disappeared.[1] Small flocks were seen in 1886 and 1890.[1] The last records of the species for Texas were 1902 and 1905, one and three individuals respectively.[1] The species were first definitely recorded for Kansas from Russell County in 1874.[2] In that State these curlews were abundant as late as 1878, but in 1879 their numbers were much reduced and the birds decreased rapidly.[1] There were still a few in the Kansas markets in the early nineties. The last record is for 1902.[1]

Eastwardly in the interior the birds were always uncommon and disappeared early. The last Michigan record is in 1883.[3] The last Ohio record is in 1878.[1] The last Wisconsin records are April 27, 1899,[4] and September 10, 1912, the latter specimen a male taken at Fox Lake, Dodge County, Wis.[5] The last Indiana record is, with some doubt, April 19, 1890.[6]

We have no definite records of the Eskimo curlew in Nebraska during the territorial days, aside from the recollections of the few survivors among our earliest settlers of enormous flights of "prairie pigeons" which passed through the territory each spring. As to the abundance of these birds in Nebraska during the early years of its statehood the observations of Prof. Lawrence Bruner, who distinctly remembers the flights which occurred in the vicinity of Omaha during the years 1866–1868, when he was a boy 10 or 12 years old, are indicative. The birds would arrive about the time the later willows began to bloom (latter April), being present in force for a week or 10 days only, for by the time all of the wild plum blossoms had fallen (middle May) the birds were gone. Usually the heaviest flights occurred coincident with the beginning of corn-planting time, and enormous flocks of these birds would settle on the newly plowed

[1] Forbush, E. H. Game Birds, Wildfowl and Shorebirds, pp. 416–432, 1912.
[2] Benson, F. S. Forest and Stream, 2, p. 341, 1874.
[3] Barrows, W. B. Birds of Michigan.
[4] Schoenbeck, A. J. Birds of Oconto County, pp. 1–51, 1902.
[5] Snyder, W. E. Auk, 30, pp. 269–270, 1913.
[6] Butler, A. W. Auk, 23, p. 274, 1906.

fields and on the dry burnt-off prairies, where they searched industriously for insects.

These flocks reminded the settlers of the flights of passenger pigeons and the curlews were given the name of "prairie pigeons." They contained thousands of individuals and would often form dense masses of birds extending for a quarter to a half mile in length and a hundred yards or more in width. When the flock would alight the birds would cover 40 or 50 acres of ground. During such flights the slaughter of these poor birds was appalling and almost unbelievable. Hunters would drive out from Omaha and shoot the birds without mercy until they had literally slaughtered a wagonload of them, the wagons being actually filled, and often with the sideboards on at that. Sometimes when the flight was unusually heavy and the hunters were well supplied with ammunition their wagons were too quickly and easily filled, so whole loads of the birds would be dumped on the prairie, their bodies forming piles as large as a couple of tons of coal, where they would be allowed to rot while the hunters proceeded to refill their wagons with fresh victims, and thus further gratify their lust of killing. The compact flocks and tameness of the birds made this slaughter possible, and at each shot usually dozens of the birds would fall. In one specific instance a single shot from an old muzzle-loading shotgun into a flock of these curlews, as they veered by the hunter, brought down 28 birds at once, while for the next half mile every now and then a fatally wounded bird would drop to the ground dead. So dense were the flocks when the birds were turning in their flight that one could scarcely throw a brick or missile into it without striking a bird.

The decade 1870–1880 witnessed the beginning of the diminution of these great flocks of Eskimo curlew. In addition to the numerous gunners who shot these birds for local consumption or simply for the love of killing, there developed a class of professional market hunters, who made it a business to follow the "flight birds" as they made their annual journey across the State each spring. Mr. Mont Wheeler, living near Norfolk, pursued this business during the latter seventies, and his observations, transmitted to me by Mr. L. Sessions of that place, describe graphically the status of the bird at this period, and also the typical methods of the market hunter in securing these birds.

The chief feeding grounds of these curlews at the time Mr. Wheeler came to Nebraska (1877) was in York, Fillmore, and Hamilton Counties, and their heaviest lines of northward migration across the State were between the ninety-seventh and ninety-eighth meridians. The birds were much less numerous north of the Platte River than on the South Platte feeding grounds, although they were noted there, but not in large flocks. One spring, about 1879, while working on the

Marshall Field ranch in Madison County, following a heavy south wind, birds which seemed to have been driven past their feeding grounds by the wind were seen flying southwardly, very close to the ground, apparently going back to this South Platte feeding ground. The birds used to come in about the 18th to the 25th of April, all arriving between these dates, and would remain until about the 15th to the 25th of May. Early in the season, when they first arrived, they would frequent the burnt-over prairies, where they would occur in flocks of from a dozen to 300 or 400. As the season advanced the different smaller flocks would bunch up until as many as a thousand birds had assembled, but this assemblage was obviously made up of many small flocks. In later years, when these prairies commenced to be extensively broken up and farmed, the curlews used to feed a great deal in the open wheat fields, and toward the last they were found very frequently in tame meadows.

In hunting these curlew the field glass was used by the hunters to follow their flights. The fields where they were prone to gather were patroled many times during the day, and carefully scanned with the glass to discover the flocks on the ground. When the birds came in they would be up quite high, perhaps from 200 or 300 yards to a quarter of a mile, and in preparing to alight they would turn and wheel, towering in the air while they whistled softly, would hover a while, and then all drop and come down, flying along over the ground for a short distance before alighting. The birds would always alight all at once and very close together, and if the day were warm they would sit down very close together on the ground, forming bunches, when they could be readily discovered with the field glass and approached close enough to get a shot.

There was no difficulty in getting quite close to the sitting birds, perhaps within 25 or 35 yards, and when at about this distance the hunters would wait for them to arise on their feet, which was the signal for the first volley of shots. The startled birds would rise and circle about the field a few times, affording ample opportunity for further murderous discharge of the guns, and sometimes would re-alight on the same field, when the attack would be repeated. Mr. Wheeler has killed as many as 37 birds with a pump gun at one rise. They weighed just about 1 pound each when they were fat. Sometimes the bunch would be seen with the glass alighting in a field 2 or 3 miles away, when the hunters would at once drive to that field with a horse and buggy as rapidly as they could, relocate the birds, get out, and resume the fusillade and slaughter. On rainy days the birds would fly restlessly from one field to another, moving about in this way most of the day, and seeming unusually plentiful because of being so much in the air.

Other observers in the North Platte country corroborate the observations of Mr. Wheeler as to the comparative infrequency of this bird north of the Platte River during these flights of the seventies, as compared with the enormous flocks found in the South Platte region. Removing from Omaha to West Point in 1869, Prof. Bruner recalls that though he noted the birds each spring the flocks were usually much smaller than the enormous flights seen at Omaha, usually consisting of 50 to 100 birds, though occasionally of considerable size. Year by year the birds decreased in numbers, until by 1878, in which year Prof. Bruner entered the services of the Government, they were seen only in small flocks or individually here and there. During these eight or nine years he mounted several of these curlews, three or four for the university museum (all of which have since disappeared), a pair for the Omaha Deaf and Dumb Institute, and a pair for the Union Pacific Railroad Co.

Mr. L. Sessions moved to Madison County in May, 1871, and his acquaintance with the Eskimo curlew began at that time. The birds were then very abundant and could be found moving about over the burnt prairie or an occasional plowed field, in search of food. The flocks were not large, about 30 or 40 birds in a flock, on the average, and the banding together of numerous flocks such as occurred in the South Platte feeding grounds was not observed in Madison County, which furnished no special attraction as to feeding grounds. During these days food was somewhat scarce in Nebraska, and many of the settlers were led to look forward to this spring flight of the curlews as a helpful source of food supply. Mr. Sessions possesses a specimen of this curlew which was secured in these early days, for he has not seen a living bird for many years now, nor has he had any sent him to be mounted.

Mr. W. A. Elwood, who as a boy hunter in the seventies shot quite a number of these birds in Antelope County, states that they were numerous in flocks of 30 or 40 birds, appearing about the first week in May and remaining only a very short time, just long enough to feed. He has not seen the bird for the past 20 years or more. Mr. A. J. Leach, of Oakdale, remembers these birds passing northward in the spring during the seventies while he was plowing for corn, probably from the middle to the last of April. These flocks consisted of from 20 to 40 birds, and they used to alight on the plowed ground and stubble lands to feed. He also has not seen an Eskimo curlew for a quarter of a century past. Mr. Sanders, a guide and old hunter, of Clarks, who lived at Silver Creek up to the early nineties, told Mr. P. I. Hoagland that in the early days the birds were very abundant there, as much so as the passenger pigeon in the East, and that hundreds would be shot in a single day.

In the eighties the Eskimo curlew began decreasing rapidly. Apparently many of the birds moved their line of migration to the westward. Gunners reported flights passing through Grand Island, Kearney, and North Platte after they had practically disappeared from eastern Nebraska, but no specimens are extant to verify these reports. April 2, 1884, the species was reported from Alda, Nebraska.[1] Rev. J. M. Bates informs me that Warden D. A. Piercy, of All Saints' Church, at Kennedy, Cherry County, states that during the first years of his residence there, 1885–1887, the Eskimo curlew was as common as its congener, the long-billed curlew. In 1889 Rev. Bates saw a mounted specimen of this bird in a store near Wood Lake, Cherry County, which had been taken near that place. In 1889 Mr. Charles E. Holmes, now of Providence, Rhode Island, reported the Eskimo curlew as common locally in the hills about 40 miles south of Ainsworth, Brown County, though they were decreasing and many were killed by cowboys.[2]

By the nineties the Eskimo curlew was so reduced in numbers that hunters rarely met with it, and there are no records of specimens taken during the next 20 years, though it was repeatedly reported as seen by competent observers. In 1896 Mr. I. S. Trostler reported the Eskimo curlew as still a "common" migrant at Omaha, giving its dates as April 1 to 20 in the spring and October 1 to 15 in the fall. On April 12, 1896, Mr. J. S. Hunter saw a pair of Eskimo curlews near Stevens Creek, several miles east of Lincoln. It might also be mentioned here that about 1897 Mr. P. I. Hoagland saw a flock of these birds near Laramie, Wyoming, so late in the spring that he wondered if the birds could be expecting to nest there.

About the middle of April, 1900, Mr. Paul I. Hoagland and his father, of Omaha, were hunting near Clarks, Nebraska, when a large flock containing 70 or 75 birds flew across the road and disappeared over the hill. Mr. Hoagland, sr., recognized the birds as the Eskimo curlew, and both men started toward the place where the birds were last seen. They saw a newly plowed field and made toward it and found the entire flock on the freshly plowed land busily engaged in picking up grubs and insects turned up by the plow. The birds were entirely unsuspicious and permitted the hunters to approach as close as desired. The flock was flushed, and each hunter made four shots, obtaining in all about 34 of the birds. None of them was saved as a specimen. This was written up by Mr. Sandy Griswold in the Omaha World-Herald at the time, but he called the birds "golden plover," which they are not.

Mr. C. W. Tinker, a hardware merchant, of Waco, who used to

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[1] Cooke, W. W. Bull. 2, Division of Economic Ornithology, p. 98, 1888.
[2] Forbush, E. H. Game Birds, Wildfowl and Shorebirds, pp. 416–432, 1912.

hunt these birds with Mr. Wheeler in the seventies, saw his last Eskimo curlews in 1904 or 1905 on the old York County feeding grounds. Mr. Wheeler himself saw a flock of nine of these curlews in the spring of 1909 or 1910 near Norfolk, Madison County. He was very close to them, and positively identified the birds.

The last records of collected birds for Nebraska were made in the spring of 1911 and of 1915. On March 22, 1911, while Mr. Fred Geiger was shooting ducks near Waco, York County, two of these birds came flying by within gun range, and both were shot by him. The birds were identified by an old-time hunter, and were then brought to Lincoln and mounted by Mr. August Eiche, in whose collection they are at present. Both birds were females, with well-developed ovaries.

On April 20, 1911, while hunting at Clarks, within a mile of the field where the large flock had been seen 11 years before, Mr. Hoagland saw a flock of 8 Eskimo curlews. With little difficulty the entire flock were killed except one bird, which made its escape. The birds were brought to Omaha, and Mr. Hoagland, remembering that in spite of almost continual hunting during the open season he had not seen the bird since the large flock 11 years before, or even heard of its being seen, took one of the birds to Mr. Allabaugh, a taxidermist of Omaha, for mounting. Mr. Fred Goodrich, also of Omaha, saw the birds, and when he noted that Mr. Hoagland was about to have one of them mounted said he would like one mounted also. Two birds were put aside for this purpose. Later, on considering the matter, Mr. Hoagland decided to save all of the birds and gave orders to that effect, but they had already been picked by the cook. Both birds were mounted by Mr. Allabaugh April 24, 1911, and one is now in the possession of Mr. Fred Goodrich, of Omaha, the other in the N. O. U. collection, a gift of Mr. Hoagland, through the writer.

In April 1913, Mr. Mont Wheeler, of Norfolk, and Mr. Paul Hoagland, of Omaha, were hunting snipe near Norfolk when a flock of six or seven of these birds, flying northwest, passed over their heads. When the birds passed over they were not over a hundred yards high, and the hunters observed them until they disappeared from view. Both Mr. Wheeler and Mr. Hoagland are positive that the birds were the Eskimo curlew, and, considering the extended first-hand experience that both of these men have had with the species, there can hardly be any question of correct identifications. Although no Eskimo curlews were noted in 1914, a single bird was killed about 10 miles due south of Norfolk, Nebraska, on the morning of April 17, 1915. The bird was alone when taken. It came into the possession of Mr. Hoagland, who had it mounted by Allabaugh, a taxidermist of Omaha, in whose shop I saw it in May. The taxidermist stated that

ONE OF 7 ESKIMO CURLEWS SHOT FROM A FLOCK OF 8 AT CLARKS, MERRICK COUNTY, NEBR., APRIL 20, 1911, BY MR. P. I. HOAGLAND, OF OMAHA.

Specimen in N. O. U. collection.

the bird was a male and that it had been hit with a single shot only, so it has made a handsome specimen, which Mr. Hoagland will retain in his possession. About the same day that this specimen was killed, a brother of Mr. Mont Wheeler, of Norfolk, reported seeing five Eskimo curlews at about the same spot. These birds were not disturbed, but their occurrence was reported to Mr. Hoagland and, through him, to me.

Even in these latter captures and observations, when the birds were nearing extinction from incessant persecutions, they were very unsuspicious and apparently fearless. They flew away leisurely in close, compact flocks, so that they could scarcely be missed when shot at, and a single discharge would bring down many of the birds.

The occurrence of eight and the killing of seven of these birds near Cartwright, Labrador, in August and September, 1912, and the collecting of a male specimen on September 10 of that same autumn while flying alone over decoys along the shore of Fox Lake, Dodge County, Wisconsin, have already been mentioned. A specimen was observed on the Bermuda Islands, according to Kennedy, on January 20, 1913.[1] On September 5, 1913, a specimen was collected at East Orleans, Massachusetts, it being alone when taken.[2] These recent records for the Eskimo curlew would indicate that it is probably not yet wholly extinct.

In the spring flight these curlews arrived at the same time as the golden plover, though they did not always frequent the same localities. The Eskimo curlew was always uncommon in the fall migration in Nebraska. Most of the observers who have furnished me data on this bird (Messrs. Bruner, Wheeler, Hoagland) have never seen it at that season, but Mr. Elwood thinks he remembers having seen the birds some time in October, and Mr. A. J. Leach thinks he remembers their passing through southwardly about October 1. Aughey[3] records a specimen sent him from Bellevue for identification in October, 1874, and states that he had observed the species in northeastern Nebraska in that month.

The Eskimo curlew had several notes. During flight they uttered a fluttering "tr-tr-tr" note, which was given by many individuals at once, and described by Coues as a "low conversational chatter" and by Mackay as "a soft, melodious whistle, 'bee, bee.'" Mr. W. A. Elwood describes this note as "a short, low whistle" continually repeated by many of the birds simultaneously while in flight. Mr. A. J. Leach recalls the notes as resembling quite closely the note of the bluebird when in flight, only perhaps shorter and more of a twittering whistle, and, as it was given by a large number, perhaps

[1] Kennedy, J. N. Ibis, ser. 10, 2, 1914.
[2] Lamb, C. R. Auk, 30, p 581, 1913.
[3] Aughey, S. 1st Rept. U. S. Entomological Comm., Appendix, p. 55, 1878.

all, of the flock as they took wing and while flying, it was difficult to catch the individual note. This note was constantly uttered while the birds were flying and was often audible before the birds could be seen. Before alighting, as they descended and sailed, they gave a soft whistle, somewhat like the note of the upland plover, according to Prof. Bruner, while as they walked over the ground when feeding they uttered a chirruping whistle, as if calling to each other.

The Eskimo curlew was a bird of such food habits that it is a distinct loss to our agriculture that it should have disappeared. During the invasion of the Rocky Mountain grasshopper (*Melanoplus spretus*) it did splendid work in the destruction of grasshoppers and their eggs. Mr. Wheeler states that in the latter seventies these birds would congregate on pieces of land which had not been plowed and where the grasshopper eggs were laid, reach down into the soil with their long bills, and drag out the egg capsules, which they would then devour with their contents of eggs or young 'hoppers until the land had been cleared of the pests. A specimen examined by Aughey in 1874 had 31 grasshoppers in its stomach, together with a large number of small berries of some kind.[1] The bird in its migrations often alighted on plowed ground to feed on the white grubs and cutworms turned up by the plow, or in meadow lands, probably feeding on ants in the latter situation. Richardson records finding them feeding on large ants at Fort Franklin in late May, 1849.[2] The curlews were rarely seen near water, but were upland birds almost exclusively during the spring migration over the Great Plains region.

The flesh of the Eskimo curlew is said by all who have eaten it to have been exceedingly well flavored, and, according to Mr. Hoagland, the equal if not the superior of any of our large shore birds.

Although the Eskimo curlew is reduced to the point of extinction, it is probably not yet absolutely extinct; and if the pitiful remnant of the species could be absolutely protected there is still a chance that it might be enabled to recover and be saved. A campaign of education as to the present desperate status of this bird by all ornithologists and true sportsmen, together with absolute legal protection under high penalties everywhere, and a complete cessation of killing these birds, even for specimens, might actually accomplish this result. The recently enacted Federal law giving the control of migratory birds to the General Government should be a large help in such a campaign.

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[1] Aughey, S. 1st Rept. U. S. Entomological Comm., Appendix, p. 55, 1878.
[2] Blake, Knox. Zoologist, p. 2408, 1870.

CONSTRUCTION OF INSECT NESTS.[1]

By Prof. Dr. Y. Sjöstedt,
Royal Museum of Natural History, Stockholm.

[With 3 plates.]

Among both the higher and lower animals are found types which can build protective shelters for themselves and for their young by widely varying methods, in some cases with a high degree of art, in others in the simplest manner. In the insect world this art takes the most widely diversified forms, but we can give here only a few examples selected from among thousands.

I.

The nesting material is of various origins; it may be taken from the vegetable kingdom or from the mineral kingdom, such as earth, clay, etc., or the entire nest may be composed of a secretion of the insect, as is the case with the cells of bees, which are made entirely of wax.

With the European social bees all the cells, whether intended to contain young larvæ or only the pollen, are of the same shape, the cells of the bumblebee being simply larger. In North America other bees are found which make their cells in such a way that remarkable results are obtained with the least possible work. These bees (Meliponas) have no stings. As with many other wild bees, they make their nests in the hollow trunks of trees, where they store up wax and honey in great quantities. The cells intended for the larvæ, placed in the middle of these masses of wax, are hexagonal and of nearly the same shape as those of the common bees, but differ from the latter, which are constructed back to back in two rows with horizontal openings, in being made in a single row with the openings always directed toward the top. All around these hexagonal cells there are large cells of very different shape with large openings, intended exclusively to receive the pollen. The

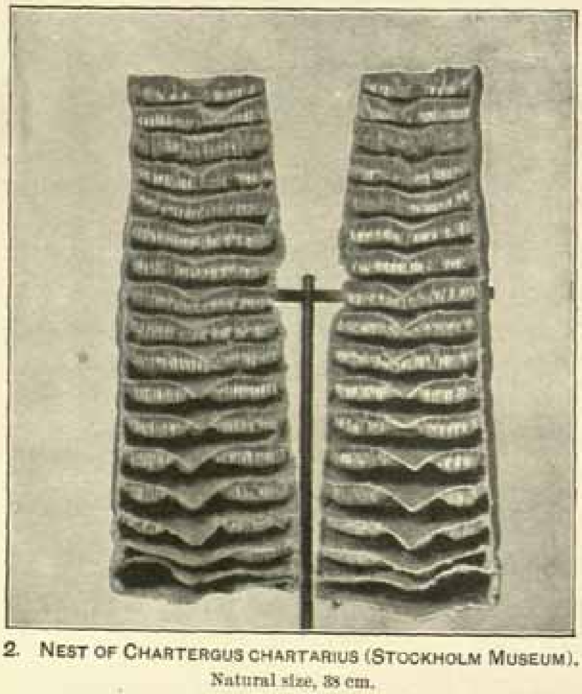
[1] Translated by permission from the Revue générale des Sciences, Feb. 15, 1915.

Meliponas and the Trigonas have achieved great economy in construction; instead of using for all purposes the hexagonal cells, made with great labor and with mathematical precision, they reserve these for the larvæ only, constructing simpler cells for provisions. The nests of Meliponas built in hollow trees are sometimes over a meter long. If the hollow of the tree is too large, they limit it at one end or the other by making a wall, but instead of using the wax for this purpose, since this is made only with great labor, they utilize earth agglutinated with a liquid which they secrete. This same mixture is used to reduce the size of the entrance to a simple little hole, allowing the passage of only one bee at a time, and at night this opening is closed. These precautions are justified by the absence of a sting, which renders them defenseless. The cells of the larvæ, in the middle of the nest, always opposite each entrance, are specially protected by lamellæ of fine wax, and, as we have just said, are surrounded by provision cells shaped like pots. Where the Meliponas can not find hollow trees they build by the aid of the mixture just mentioned—earth and the special secretion (propolis)—a true nest, with irregular branching galleries, which has some resemblance to a white ant's nest.

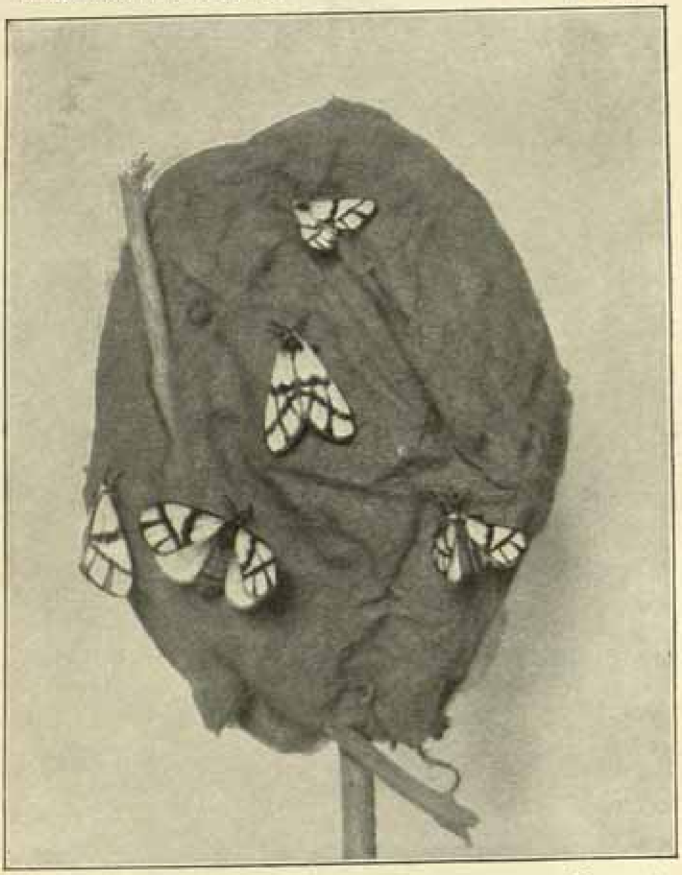
A peculiar habit is found among the Xylocopas, a species related to the Meliponas. These creatures, the largest of the big bees, are found in the warmer portions of Africa, Asia, and America. They make their nests in old trunks of trees and in dead wood which they bore with their strong jaws. In the gallery made in this way, the female brings together a mass of honey and pollen intended for larval food. On this mass an egg is laid, and then the chamber is closed by a wooden partition which becomes the bottom of the next chamber. In this way she builds a column consisting of a series of superposed cells. After about three weeks the larva becomes full grown and transforms into a pupa in the interior of a cocoon. The larva in the lowest cell, the oldest, is from that fact the first to be ready to issue as an adult bee. But how can it get out? Must it wait until the younger larvæ has transformed, or does it eat its way out through the upper cells at the risk of killing all of its brothers and sisters? Here the insect shows a very special adaptation, as though it appreciated the danger to which such a passage would expose the other larvæ, and adopts another road. With its strong mandibles it opens a passage at right angles to the floor, and the others follow by the same road, each one eating through the partition of its own cell, and thus the whole colony finds itself liberated through the industry of the first one.

Even more than the bees, the social wasps astonish us by their artistically constructed nests, and it is rare to find insects with such bellicose habits devoting themselves so conscientiously and peacefully

1. NEST OF HYPSOIDES FROM MADAGASCAR (STOCKHOLM MUSEUM).
Natural size, 17 cm.



2. NEST OF CHARTERGUS CHARTARIUS (STOCKHOLM MUSEUM).
Natural size, 38 cm.



NEST OF ANAPHE INFRACTA FROM CAMEROUN (STOCKHOLM MUSEUM).

Natural size, 17 cm.

to work. We find among them simple combs with openings directed downward, which are not made of wax but of vegetable material finely pulverized and macerated by the secretions of the insect's mouth. If we examine different wasps' nests carefully, we note that some are elastic and resistant, while others are tender and fragile, depending upon the material used by the insect. In the second case, the substance consists of long wood fibers, and in the other, of a different kind of vegetation. The fragile paper of the nests of certain species is taken from the bark of various trees and has the appearance of ribbons.

The simplest form of nest is made by the Belonogaster wasps. These large, somber, silent-flying wasps are found in the hot regions of Africa. Their nests generally are made simply of cells fastened together on top of a twig, without any envelope, although some species are not contented with such rudimentary nests and have added to them different methods of protection. We may cite the *Chartergus chartarius*, a species found in tropical America. Its nests (pl. 1, fig. 2) are sometimes as much as half a meter long, and are composed of a great number of stories connecting by a central opening. As the colony grows a new story is built on the preceding one, the surrounding wall being torn down and reconstructed to inclose the new story.

II.

In all the cases that we have mentioned the nests have been built by the adult insects to insure the protection of their young. But certain larvæ, which live a free and vagabond life, know how themselves to prepare a shell for the chrysalis, which is, of course, defenseless. I once had occasion to study the larvæ of one of the processionary caterpillars, Anaphe, in West Africa. They marched in a column up the trunk of a tree to a branch where they constructed a great common cocoon (pl. 2), consisting in part of the long hairs from their bodies; inside this great envelope each larva surrounded itself with a cocoon of silk, and in the silken cocoon it made a capsule of parchment-like tissue which served as the last protection for the chrysalis. Although in case of Anaphe the insects leave the nests without showing any trace of their leaving, with Hypsoides the exit is effected through a series of individual holes which make the abandoned nest look like a sieve (pl. 1, fig. 1).

In tropical regions one meets upon walls and stones, earthy nests 60 to 100 millimeters long, of an irregular, oval form, made by the wasp, Sceliphron. Other nests of a rounder form are built on the branches and trunks of trees by another wasp, Eumenes. These nests are found in Africa, chiefly in inhabited regions. If we closely examine these earthy structures which are apparently com-

pact, we shall find that they are made up of a number of parallel cells connected by the inner surface, which, after being filled by the wasp with spiders for the nourishment of the larvæ, are closed so carefully with bits of earth that they become invisible.

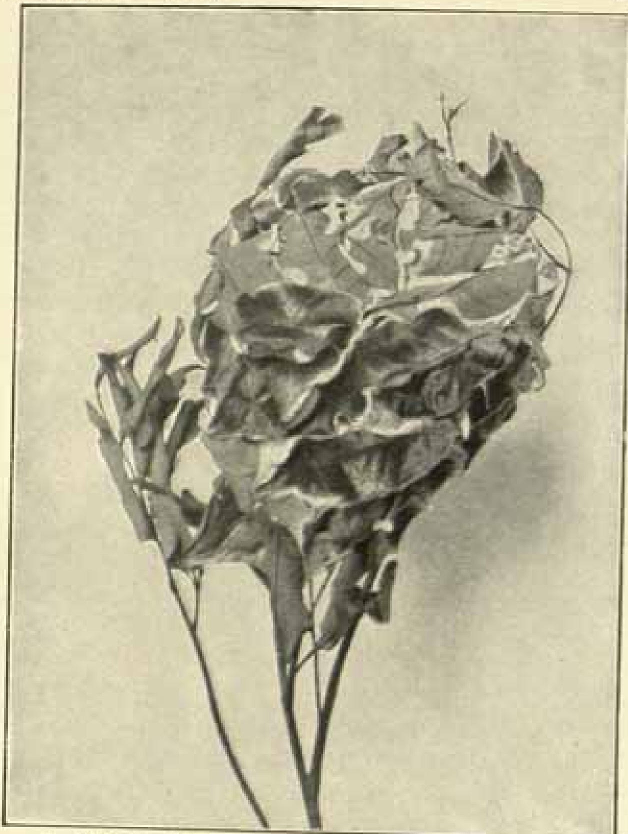
To capture the spider the wasp often has to undertake a desperate struggle armed with its formidable sting; if the insect succeeds in stinging its prey, the conquest is easy, but the spider is not defenseless. With astonishing rapidity the spider spins a sticky thread and the struggle between the two adversaries begins. With great care the wasp approaches the spider's web, and by a skillful maneuver often succeeds in stinging its enemy. But the threads are sticky; an imprudence, and the wings are caught. Immediately the spider renders the wasp helpless in a network of threads and devours it. When the wasp succeeds in touching the spider its sting does not cause immediate death, but produces a state of paralysis. If the spider were killed outright it could not be kept as reserve nourishment, while, merely paralyzed, it lives and keeps fresh, though it can not harm the larvæ which are at this stage entirely defenseless. Usually about 15 spiders are found in each cell. The lower part of the cell is occupied by the larva of the wasp, which, after having consumed the last spider, is transformed into a chrysalis in the interior of a capsule of reddish-brown parchment.

III.

While some insects build their nests above the ground, others try to find security underground for their offspring. Among these we may mention the sacred *Ateuchus*, belonging to the group of Coprophagids. The Coprophagids are represented by many species, of which several are characterized by brilliantly colored and metallic-looking elytra. Their ball of provisions, of known origin, serves either for their own nourishment or for that of their larvæ. In the first case the ball is pushed into a hiding place, where it is gradually consumed; in the other case the Coprophagid introduces an egg into the ball and buries it.

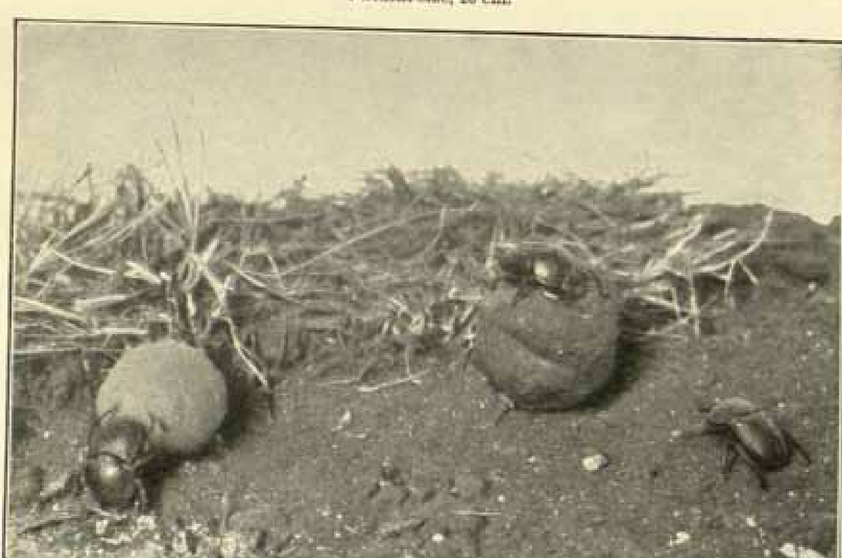
On the plains of eastern Africa, at the end of September and during the month of October, these insects, especially the great black scarab, *Scarabaeus pustulatus*, may be seen making and rolling these balls (pl. 3, fig. 2). Their ability to discover the necessary material is remarkable. If not a single one of these insects has been noticed all day, great numbers of them will be found running around antelopes which have been recently shot down by hunters.

It is extremely interesting to watch a scarab make one of these food balls, during which process it is often necessary for the insect to fight with its own kind. With the anterior edge of its head, which



1. NEST OF ŒCOPHYLLA FROM AUSTRALIA (STOCKHOLM MUSEUM).

Natural size, 20 cm.



2. THE SCARABÆUS PUSTULATUS ROLLING ITS BALLS (STOCKHOLM MUSEUM).

is flattened and notched, it loosens a fragment large enough to make up the future ball; then with a rapid movement the ball is freed and rounded off. Then standing on its front feet the scarab with his back feet rolls the ball thus made. During this operation the insect displays great activity, but at this stage others of its kind endeavor to get possession of the fruit of its toil. A struggle ensues, during which the ball changes owners several times, and the final victor endeavors then to get the ball away in safety either for its own use or for that of its larvæ.

In the case just cited the parents provide shelter and reserve nourishment for the evolution of the larvæ, while among other species the larvæ themselves provide their own nourishment and a way of release when the transformation is complete.

Among the cicadas, which live in the Tropics and contribute their song to the perpetual concert heard there during the dry season, the larvæ at the time of being transformed into perfect insects bury themselves about 40 centimeters deep in the earth. In digging the hole they secrete a liquid which assures the permanence of the passage by hardening the sides. The quantity of liquid required to coat this tube nearly half a meter long is considerable, and the insect would not have enough unless while digging it encountered new material to supply the secreting organs. A close examination of the nest shows the presence of roots laid bare, from which the insect draws the sap by means of his proboscis. This nest, consisting of a shaft sunk in the ground with solid walls, permits the insect to come to the surface during the warm hours, and to bury itself to escape the cold.

IV.

An unusual method of making nests is encountered among certain ants—those which build their nests in galls. On the plains of eastern Africa attention is often attracted to small acacias with long thorns appearing from a distance to be covered with a great number of black balls resembling apples but which in reality are hollow galls inhabited by a species of small ants, *Cremastogaster tricolor*. If one of these galls is touched, all the inhabitants come out through a series of small orifices, and from the extremity of their abdomens, raised vertically, flows a white, ill-smelling liquid, with which the galls, leaves, and branches become saturated.

The young galls are green in color, with a solid interior, attaining sometimes the size of a walnut. The ants remove little by little the medullary substance in such a way that the interior of the gall becomes a chamber with smooth and polished walls. The gall then takes on the color of soot and has a ligneous texture. When the wind

blows on the plains the hollow balls, pierced with holes, give out strange, low sounds recalling the whistling of wind in the rigging of a ship, or the tones of an aeolian harp—hence the name, acacia-flutes.

If the eggs, larvæ, or chrysalises of the ant were placed in the hollow of the gall without precautions, at every puff of wind they would be thrown against each other and injured. To avoid this danger the ants build from the interior substance of the gall, which has the appearance of an agaric fungus, a series of combs and cases in which the larvæ and chrysalises are placed.

So there really exists a kind of symbiosis between the ants and the acacias; but who profits by this symbiosis? In the galls the ants find protection for themselves and their larvæ; on the other hand, the ants cause no damage to the acacias and give them protection against numerous enemies. Giraffes, antelopes, and gazelles are kept away by the presence of these ants with such nauseous secretions.

V.

There are also cases in the insect world in which the adult uses the larvæ in the construction of the nest. This singular habit occurs among certain tissued ants, Œcophylla, Camponotus, and Polyrhachis. The Œcophylla, inhabiting Asia, Africa, and Australia, build their nests among the leaves of certain trees by binding the leaves together with the aid of silk threads (pl. 3, fig. 1).

Among these ants there is observed one of the most curious phenomena of all biology. If the nest be torn in any way so that the leaves are separated from each other, the ants are immediately seen hurrying out. While some are defending the nest against the presumed enemy, the others hasten to repair the damage done. From one edge of the tear the workers try with their mandibles to reach the edge of the neighboring leaf and draw the two edges together to close the break, but the distance is often too great and they are forced to form a living chain. One ant with its mandibles seizes one of its comrades by the body, so that the second one may be able to reach the edge of the neighboring leaf. If the distance is still too great, a third comes to join the others, and sometimes the chain is made up of five or six ants. This work is very fatiguing, sometimes taking several hours to make sure the contact of the two leaves. The ants then clean up and polish the edges of the leaves, but how can they secure the necessary adherence to make the connection permanent, since the adult ants do not have setiferous glands? This difficulty is overcome by a method so astonishing that the first observations made in Singapore in 1890 were doubted by naturalists. When the edges of the leaves are perfectly clean several workers emerge from the nest, each

bearing a larva between its mandibles. The larva is held by the body, with the head upward. Thus their own larvæ serve to make a silken net to join the leaves. Due to the pressure of the mandibles, doubtless, the larva excretes from its mouth a liquid which in solidifying forms a silk thread, and by carrying the head of the larva from the edge of one leaf to the edge of the other the ant obtains a web which assures the adherence of the two leaves. In the same way the interior walls of the nest are formed, the larva thus functioning as spinning wheel and as bobbin. An anatomical examination of these larvæ shows that the setiferous glands in them attain dimensions not found in any other of the Hymenoptera.

VI.

From a scientific point of view, in the light of these complex manifestations, the question arises as to whether or not they are expressions of intelligence—whether the insects at work are conscious of the procedure and of the importance of the end to be attained, or whether their actions are merely the result of instinct, the insects being incapable of reasoning.

If the animals were simply mechanisms with no spontaneity, a strict identity ought to be observed in their methods of work and construction. But with certain species at least a remarkable adaptability to variations in the surrounding conditions is shown, these adaptations being transformed, if the causes persist, into hereditary characters.

Forel, the eminent myrmecologist and psychologist, thus sums up the observations made during more than 20 years on the psychology of insects:

> All the characteristics of man might be derived from the characteristics of the higher animals, and all the characteristics of the higher animals might be derived from those of the lower animals. In other words, the evolutionary formula applies equally in the realm of psychology as in the physiological domain.

[illegible] a larva between its mandibles. The larva is held by its [illegible] with the head [illegible]. Thus the [illegible] [illegible] which [illegible] to [illegible] the larva. Due to the [illegible] of the [illegible] [illegible] the larva [illegible] [illegible] [illegible] and by [illegible] of the larva [illegible] of one [illegible] to the [illegible] of the other [illegible] [illegible] which [illegible] the adhesion of the [illegible] [illegible] [illegible] of the [illegible], [illegible] the larva [illegible] [illegible] wheel and [illegible]. The anatomical examination of these larvae shows that the [illegible] glands in these [illegible] are not [illegible] than those of the Hymenoptera.

VI.

[illegible] animals [illegible] of view, in the light of [illegible] can [illegible] [illegible], the question arises as to whether or not they are [illegible] of intelligence — whether the insects at work are conscious of the [illegible] and of the importance of the end to be attained, or whether their actions are merely the result of instinct, the insects being incapable of reasoning.

If the animals were simply [illegible] [illegible] ought to be observed in their methods of work and construction. [illegible] [illegible] species of [illegible] [illegible] to [illegible] the [illegible] [illegible] [illegible] being [illegible] [illegible] [illegible] into [illegible] [illegible].

[illegible], the [illegible] and [illegible] have [illegible] during [illegible] years on the [illegible] of [illegible].

[illegible]

OLDEN TIME KNOWLEDGE OF HIPPOCAMPUS.

By Charles R. Eastman,

American Museum of Natural History, New York.

[With 4 plates.]

From time immemorial the interesting little fishes known as sea horses (Hippocampids) have attracted attention on account of their curious form and no less peculiar habits. Occurring plentifully in the Mediterranean, the typical species (*Hippocampus hippocampus* or *antiquorum*) was well known to the ancients; and owing to the wide distribution of the remaining thirty-odd species composing the genus, sea horses have become familiar objects in most of the large aquaria of the world.

We owe to the late Dr. Theodore N. Gill an interesting account of the life history of Hippocampines, published in volume 38 (1905) of the Proceedings of the United States National Museum. More recently a number of pictorial representations of the common Mediterranean species, taken from old authors, have been reproduced in a short popular article by Prof. R. C. Osburn (Zoological Bulletin, March, 1915).

The movements, feeding, and breeding habits of these creatures are all extremely curious, and have been so well described by Dr. Gill that we can not forbear quoting a few paragraphs from the article referred to, before turning to the accounts given by two or three old writers not mentioned by Prof. Osburn.

Concerning the attitudes and movements of sea horses, Dr. Gill remarks that the "the most frequent position is a state of rest, with the tail wound around the stem of a plant or some other substance, and the body carried nearly or quite erect." Continuing, this distinguished observer writes:

> Such is the most frequent position, but notwithstanding the apparent rigidity of the cuirass almost every other attitude consistent with such a form may be assumed. The body may be thrown outward at various angles and even downward and the tail wound around a plant in a double coil. Once in a while one eye may roll toward you while another may be passive or look backward or in an opposite direction. It becomes obvious that the little fish can move its eyes independently of each other and in entirely different ways.

A comical effect is produced by the way in which the little fishes peer at some object, reminding one of the actions of a very near-sighted person.

Releasing itself at length from its support one may slowly progress still in a vertical position, its tail curved inward, its dorsal fin rapidly undulating, and reminding one of a screw propeller, its pectorals vibrating in harmony. The rapidity of the undulatory or vibratory movements of the dorsal and pectorals is especially noteworthy.

Incased as it is in an almost inflexible coat of mail, progression can not be effected by lateral flexion of the body as in ordinary fishes, and flexion in a vertical direction is limited.

With such limited powers of progression a nice adjustment of organs is called for, and Dufossé has explained one method. The air bladder is comparatively large and always distended by a quantity of gas so exactly in harmony with the specific gravity of the body that this entire body is a hydrostatic apparatus of extreme sensibility. A proof of this is that if a single bubble of gas no larger than the head of a very small pin be extracted the fish immediately loses its equilibrium and falls to the ground on which it must crawl till its wound has been cicatrized and a new supply of gas secreted by the internal membrane of the bladder.

As is well known, the eggs of Hippocampus are taken care of by the male in an abdominal sac or pouch open forward opposite the dorsal fin. The same authority described a peculiar phase connected with the breeding habits in these words:

As the season for reproduction approaches the sexes become prepared for it. * * * The receptive male's pouch becomes thickened and vascular and thus prepares for the reception of the eggs and the nutriment of the embryos. The males, as usual in fishes, are somewhat smaller than the females.

Curiosity is naturally excited as to the manner in which the eggs are transferred into the narrow-mouthed ovigerous sac of the male. Many have watched, but so far as known the only one who has caught the female and male in the act of transfer was Dr. Filipo Fanzago. In May, 1874, the doctor observed the approach of the two in an aquarium at Naples. The approach was not once for all, but oft repeated and very short each time. The male remained passive and the egg-burdened female advanced toward him and pressed the aperture for the extrusion of the eggs against the mouth of the male's pouch. At the most a few eggs—perhaps not more than a single one—were passed from the female to the male and then she retreated. After a not very long interval (it varied) she again approached and another transfer was made. Five times Fanzago observed this strange kind of copulation in a short space of time (in breve spazio di tempo), but exactly how long is not stated. He hoped to be able to make further observations, but has left no other records. The eggs are doubtless fertilized during the act of transfer.

The ovigerous pouch is especially adapted not only for the reception of the eggs but for the sustenance of the newly hatched offspring. Dufossé (1874) found that there was a lining mucous membrane which had the faculty of secreting an aëriform fluid. Further, this function is liable to pathologic deviation, in which case the bladder may become stopped up and the fish be unable to control itself and carried to the surface of the water, where it remains helpless till death follows.

The earliest figures of Hippocampus in a printed book, so far as known to the present writer, are those given in Pietro Matthioli's Commentaries on the "Materia Medica" of Dioscorides, which

passed through a number of editions and translations beginning with the Italian editio princeps of 1544. This work appears to be the source of the illustrations given by Thomas Mouffet in his "Theatrum Insectorum" (London, 1634), which are copied by Prof. Osburn; and the description therein given of the Hippocampus is by far the best found among sixteenth century writers.

Next in order of time after the woodcuts of Matthioli, shown in our plate 1, figure 1 is the figure of Hippocampus given by Pierre Belon in his small folio entitled "De Aquatilibus," published at Paris in Latin in 1553, and in French two years later under the title of "La Nature et Diversité des Poissons." A copy of Belon's illustration is reproduced in our plate 1, figure 2, and his description of the creature may be rendered into English as follows:

The name Hippocampus is derived from the Greek words *hippus*, signifying horse, and *campus*, a caterpillar. And in verity the head and neck are shaped like those of a horse, and the body (i. e., tail) like that of a caterpillar. The term *hippus* is employed by Pliny, *hippidium* by Athenaeus to designate this animal. Venetian fisherfolk call it "falopa," and among those of Marseilles and Genoa it is known as the "caballo marino."

Its size does not exceed a finger's length; it has a tough and rugose skin, and neither men nor fish of other kind esteem it as food. In color it is sometimes dark; in other cases white. The gills are laterally situated, and the neck is arched like that of a horse. [This sentence follows the Latin version. The French of 1555 reads: "The gills are uncovered as in other fishes, notwithstanding it is a bloodless creature."] It bears a small fin, a little elevated, along the back, and another small one on the neck where it joins the head. The mouth is small and tubiform. Dead or dried specimens have the tail coiled inward, like that of a chameleon; it is furnished with small, blunt prickles, and is of quadrangular section. The spinous projections arise from transverse folds which cross the tail.

Certain authors profess that the ashes of Hippocampus, when commingled with liquid pitch, tallow, or oil of sweet marjoram, cure baldness and pain in the sides. Partaken of when roasted, it prevents retention of urine. An application of oil of roses into which the live animal has been dipped and killed is an efficacious remedy for chills and fever.

The alleged medicinal properties of Hippocampus, which are gravely set forth by Matthioli, Belon, Rondelet, Gesner, and others, are traceable to a number of late Greek and Roman writers, the more important of whom are Menander, Strabo, Philostratus, Dioscorides, Ælian (N. A. 14; 20) and Pliny (N. H. 32 and 36). Aristotle does not mention the Hippocampus, and this word was used by the poets of classical antiquity as the name of a sea monster, half horse and half fish, on which sea divinities rode.[1] It is probably in this character that conventionalized representations of the creature appear in

[1] See Hoffman, H. A., and Jordan, D. S., "A Catalogue of the Fishes of Greece." Proc. Acad. Nat. Sci., Phila., 1892, vol. 44, p. 250. It is there stated that "as the name of a fish it seems to occur only in late writings, * * * and the references in Pliny refer to the use of the Hippocampus and its ashes in medicine."

Etruscan and other ancient works of art. Our plate 2 is from a photograph of an Etruscan vase, which is preserved in the Boston Art Museum, and has the ears beautifully fashioned in the form of sea-horses with the tails conjoined. Similar figures are seen in an Etruscan frieze belonging to the Metropolitan Museum of Art, New York, and the same design is occasionally found in ancient Greek coins.

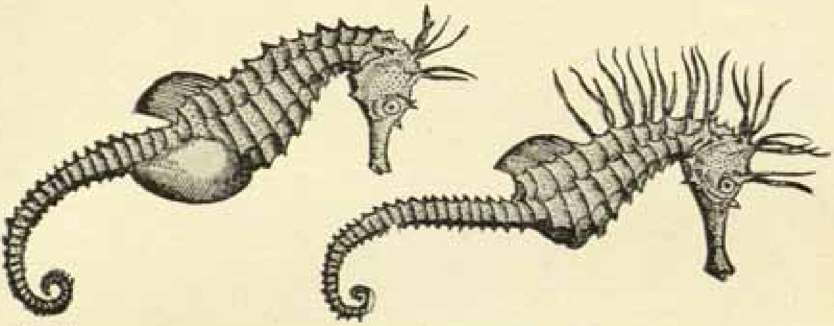
From the time of Pliny onward the sea horse does not reappear in literature until the close of the middle ages, when the great thirteenth century encyclopedists, Vincent de Beauvis (?1190–1264) and Albertus Magnus (?1206–1280), both mention Hippocampines under the term of "sea dragon." Vincent, or Vincentius, was an extraordinarily industrious and painstaking compiler. One of his works, the "Speculum Naturali," is a bulky volume, divided into 32 books and 3,718 chapters; it seems to have been given to the world about the year 1250, and was first printed at Nüremberg in 1472. For us it represents, as has been well said, "a vast summary of all the natural history known to western Europe toward the middle of the thirteenth century." Books XVI and XVII treat of fowls and fishes, mainly in alphabetical order, and with frequent references to their medicinal qualities. In book XVI, chapter 138, we find the following description of the "sea dragon" ("Zidrach"), quoted from the unknown Gallic author of "Liber de Naturis Rerum":[1]

> Caput habet ut equus, sed forma minori. Corpus autem ex omni parte draconi simillum est; totumque diversimode coloratum. Caudam habet longam secundum quantitatem corporis sui; gracilem et tortuosam, ut anguis, pinnas quoque habet sicut piscis aliquis.

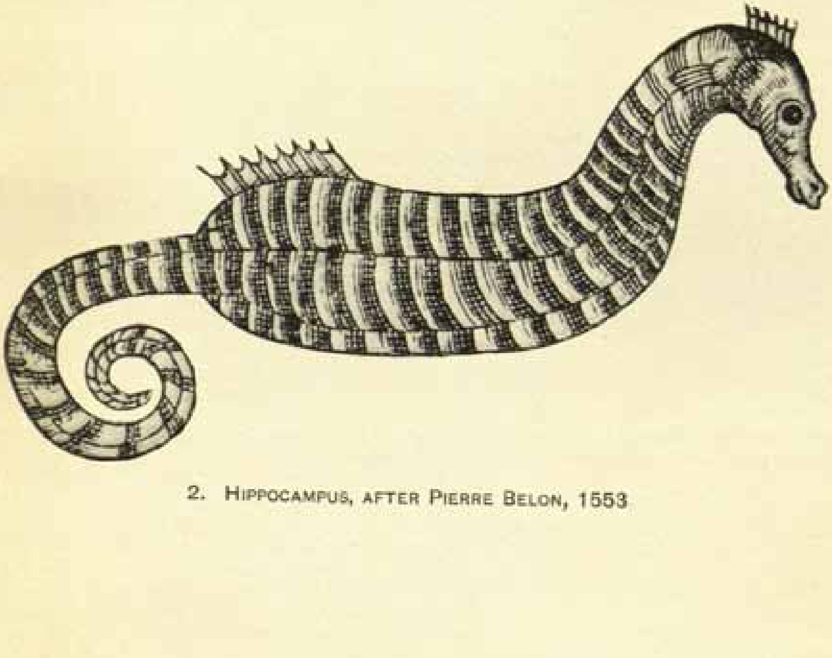
Albert of Bollstadt, bishop of Ratisbon, the most erudite scholar and most widely read author of his time, gives, in book XXV of "De Animalibus" (Mantua, 1479), practically the same account as Vincentius, only the vernacular name for sea dragon is either misprinted or corrupted into "Zydeath," and a slightly different description of the same creature is found on another page under the caption of "Equus maris," as if it were another kind of fish. One of the attributes accredited by Albertus to the sea horse is that it expires on being brought out of water into contact with the air. "Extra aqua nihil potest: statim enim moritur ab aqua extractum," one reads at page 654 of the Lyons edition.

Important to note is the fact that the characteristic here reported as holding true of Hippocampines was transferred at the hands of later encyclopedists so as to apply to the Remora, or sucking-fish. The fifteenth-century physician who styles himself Johannes von

[1] A widely read medieval work having the same title was written about 1180 by the English schoolman, Alexander Neckham, foster brother of King Richard I. This work is an important manual of the scientific knowledge of the twelfth century. Several kinds of fishes are mentioned.



1. HIPPOCAMPINES, THE COMMON MEDITERRANEAN SPECIES, AFTER MATTHIOLI (ED. OF 1568, P. 319).



2. HIPPOCAMPUS, AFTER PIERRE BELON, 1553

ARCHAIC ETRUSCAN REPRESENTATION OF SEA HORSES. ORIGINAL IN THE BOSTON MUSEUM OF FINE ARTS.

Cube,[1] compiler of "Hortus Sanitatis," and also Conrad Gesner, in the middle of the sixteenth century, both of whom quote Albertus, fall into the same error of treating the "Zidrach," "Equus marinis," and Hippocampus as separate and distinct kinds of fishes.

Both Vincentius and Albertus Magnus, and also the English Franciscan scholar, Bartholomew, whose work on "The Properties of Things" was written some years prior to 1260, take a number of their descriptions of fishes from "De Animalibus" of Jorath (or Jorach), an eastern, perhaps Persian, Christian writer of whom little is known. Bartholomew's encyclopedia, composed originally in Latin and translated into English by John Trevisa in 1397, contains rich materials for the study of the history of science and of literature. We become acquainted through it with popular medieval theories in the circle of sciences that are scarcely attainable otherwise, and modern students regard it as "one of the most important documents, by the help of which we rebuild for ourselves the fabric of medieval life."[2]

In view of the fact that popular beliefs concerning the sea horse and "ship stayer," or Remora, run a parallel course from the thirteenth century onward, it may be instructive to offer at this point the account given by Bartholomew of the Remora. In Trevisa's version the name Echeneis is either misprinted or corrupted into "Enchirius," just as Albertus Magnus and his copyists employ the erroneous term of "Zydeath" for Zidrach, meaning "sea dragon." The account reads:

> *Enchirius* is a little fish unneth [only] half a foot long: for though he be full little of body, nathless he is most of virtue. For he cleaveth to the ship, and holdeth it still stedfastly in the sea, as though the ship were on ground therein. Though winds blow, and waves arise strongly, and wood [violent] storms, that ship may not move nother [neither] pass. And that fish holdeth not still the ship by no craft, but only cleaving to the ship. It is said of the same fish that when he knoweth and feeleth that tempests of wind and weather be great, he cometh and taketh a great stone, and holdeth him fast thereby, as it were by an anchor, lest he be smitten away and thrown about by waves of the sea. And shipmen see this and beware that they be not overset unwarily with tempest and with storms.

After the time of these medieval encyclopedists no important additions to the literature of ichthyology were made until the third decade of the sixteenth century, and such notices of fishes as ap-

[1] The first edition of the *Hortus*, or "*Ortus*," *Sanitatis* appeared at Metz in 1475 and was a number of times reprinted. It is one of the earliest printed books containing illustrations of fish and fishing scenes. The next oldest work containing similar figures is "Dialogues of Creatures Moralysed," of which an English reprint, edited by Joseph Haslewood, was published in 1816. For an account of von Cube's compilation one may consult an article by H. S. C. Everard in the New Illustrated Magazine for July, 1898, p. 263–271.

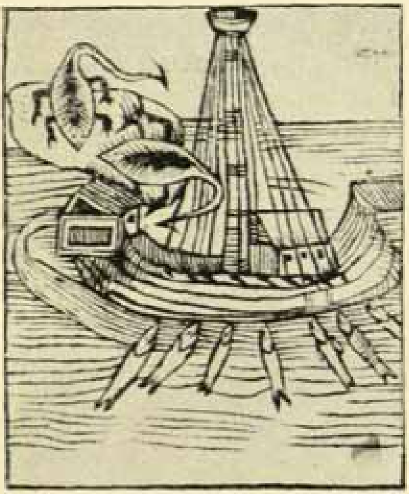
[2] Robert Steele, in his epitome of Bartholomew's Encyclopedia entitled "Medieval Lore." London, 1893.

pear in handbooks of medicine and herbals like the "Hortus Sanitatis" or "Margarita Philosophica" consist chiefly of oft-repeated excerpts from ancient writers on natural history. To the same class of popular handbooks belongs the so-called "Kräuterbuch" of Adam Lonicer, a work which was frequently reedited and translated, and which contains a rough sketch of Hippocampus. The illustrations shown in plate 3, figures 1 and 2, are reproduced from woodcuts in the 1536 edition of the Frankfort physician's "Hortus Sanitatis," intended to illustrate the sea horse and Remora (*Echeneis naucrates*).

New interest in the plants and animals of distant lands was awakened by the voyages of discovery that were made toward the close of the fifteenth century and in the early decades of the sixteenth century, and consequently a new era in natural science may be said to begin at about the year 1500. Columbus brought back with him from the New World in 1493 not only six Indians, but live parrots, many plants, and a few stuffed animals, among which latter was a fish from Hispaniola, the peculiar characters of which are recorded in his Journal (entry for Nov. 16, 1492). In all probability this was either the trunkfish or a specimen of *Diodon histrix*, a species which figures prominently in sixteenth and seventeenth century ichthyological writings under the name of "*Reversus*, var. *squammosus*." The other variety, called the "*Reversus Indicus anguilliformis*," is clearly the Remora; and both forms are associated with the original eye-witness account given by Columbus of having been employed by native West Indians for the capture of other fish. Like other fish stories, the tale lost nothing in repeating. Oviedo (1535) "lifted" his account from the writings of Peter Martyr (Libretto of 1504 and De Rebus Oceanis, 1511), and added considerable embroidery of his own. Rondelet passed the story along to Gesner, Aldrovandi, and John Jonston, all of whom give illustrations of the two "species" of Reversus, and the first-named even portrays a fishing scene in which the anguilliform variety is seen in the act of capturing its prey (pl. 3, fig. 3). Nieremberg (1635) also gives a similar figure.

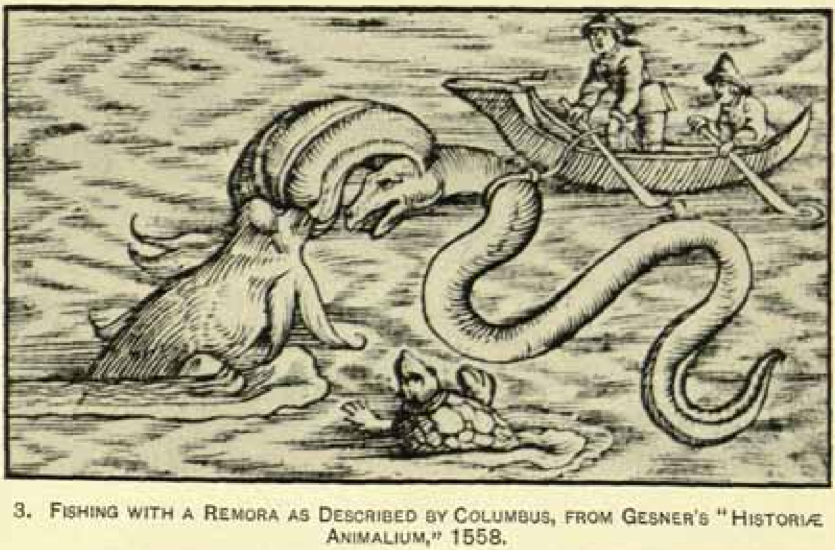
The attentive reader will not fail to note in these various accounts of the "Reversus," or, more properly speaking, the Remora, that a peculiar property is still ascribed to it which in medieval times was transferred to this genus from the Hippocampus; that is, its extraordinary aversion to the air. All of the authors just named mention this characteristic. Thus, Jonston, in his "Natural Wonders," speaks in following manner:

The Indian Reversus like an Eel, is a Fish of an unusual figure, like to a great Eel in body, and it hath on the hinder part of the head a capacious skin, like to a great purse. The inhabitants hold this fish bound at the side of the

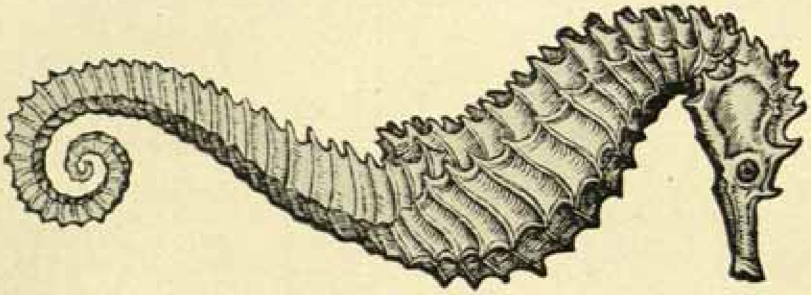


1. ECHENEIS, THE REMORA OR "SHIP-STAYER," FROM THE 1536 EDITION OF VON CUBE'S "ORTUS SANITATIS."

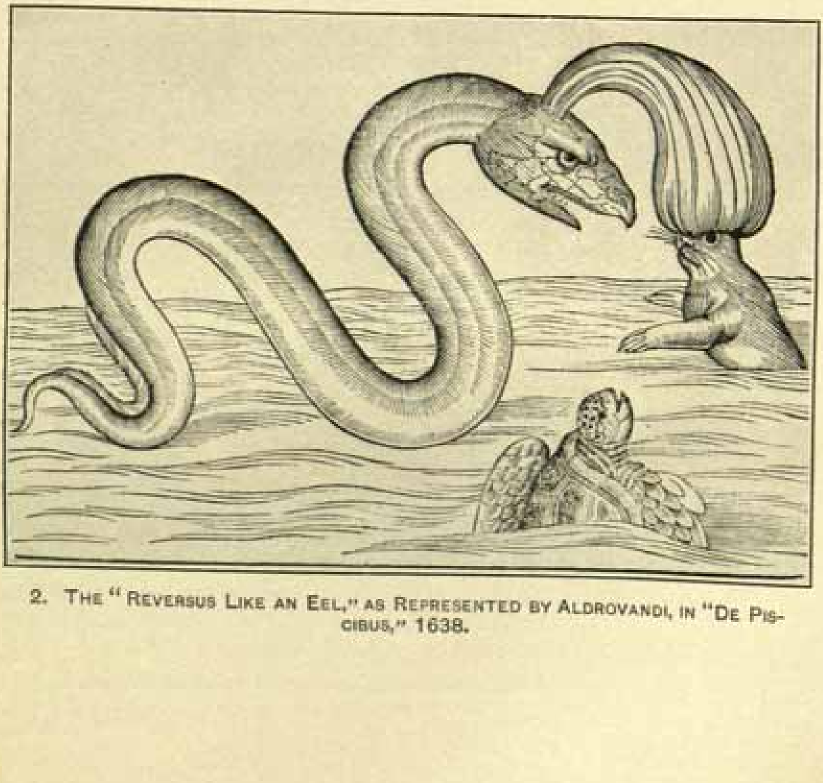
2. "EQUUS MARINIS," FROM THE 1536 EDITION OF VON CUBE'S "ORTUS SANITATIS."



3. FISHING WITH A REMORA AS DESCRIBED BY COLUMBUS, FROM GESNER'S "HISTORIÆ ANIMALIUM," 1558.



1. HIPPOCAMPUS HIPPOCAMPUS L. FROM CONRAD GESNER'S "FISCHBUCH," 1575.



2. THE "REVERSUS LIKE AN EEL," AS REPRESENTED BY ALDROVANDI, IN "DE PISCIBUS," 1638.

ship, with a cord, and onely let it down, so far as the fish may stick by the keel of the ship, for it cannot anywayes endure the ayr; and when it sees any fish or Tortoise, which are there greater than a great Target, they let loose the fish; he so soon as he is loose, flies swifter than an arrow on the other fish or Tortoise, and casting that skin purse upon them, layes hold of his prey so fast, that no force can unloose it, unlesse they draw up the cord a little and pull him to the brink of the water. For so soon as he sees the light of the ayr he forsakes his prey. *Martyr. Rondeletius* ascribes to him the understanding of an Elephant, for he will be tame, and know what is said to him. (P. 301.)

In the early collection of voyages known as "Libretto de Tutta la Navigatione," etc., and "Paesi novamente Retrovati," published in 1504 and 1507, an account is given by Peter Martyr of fishing with the "anguilliform Reversus" (probably *Echeneis naucrates*), which appears to have been derived from personal conversations with Columbus and his companions after their return from the second voyage, in 1494. The narrative reads:

Afterwards they found further onward [among the Queen's Gardens, off the southern coast of Cuba] some fishermen in certain of their boats of wood excavated like *zopoli*, who were fishing. In this manner they had a fish of a form unknown to us, which has the body of an eel and larger, and upon the head it has a peculiar, very tender skin, which appears like a large pouch or purse. And this fish they drag, tied with a noose to the edge of the boat, because it can not endure a breath of air. And when they see any large fish or reptile they loosen the noose and this fish at once darts like an arrow at the other fish or reptile, throwing over it this skin which he has upon his head, which he holds so firmly that they are not able to escape, and he does not leave them if they are not taken from the water; but as soon as he feels the air he leaves his prey and the fisherman quickly seize it. And in the presence of our people they took four large tortoises, which they gave our people for a very delicate food.

It would be apart from our main topic to pursue the subsequent history of the Remora beyond calling attention to Aldrovandi's and Jonston's portrayals of its form, as shown in our plate 4, figure 2, and to Dr. Günther's article on the genus (Ann. Mag. Nat. Hist., 1860, 3. ser., vol. 5), in which the more important literary references are collected. At this point we may say with Jonston, at the conclusion of his "Wonders concerning fishes," "so much then for [this] fish."

Paul Giovio (in Latin Jovius, 1483–1552), whose work on fishes was first published in 1524 and passed through three editions, makes no mention of Hippocampus; and in the handsomely illustrated folio of the Roman physician Salviani, published in 1557, one finds only the bare references to its mention by earlier authors.

We come now to the great encyclopedic writer, Conrad Gesner (1516–1565), apostrophized by Cuvier as "le plus savant naturaliste du seizeième siècle." The account of Hippocampus given by this compiler in his "Fischbuch" (1556), and also in his "Historiæ Ani-

malium" (Book IV, 1558), follows pretty closely that which is found in Matthioli's commentaries on Dioscorides (1554), but the figures are of inferior merit. Our plate 4, figure 1, is reproduced from the woodcut introduced at page 156 of the "Fischbuch," at which point we find the following passage:

Hippocampus. Ein Meerross; Ein Meerpfärdt. Von seiner Gestalt und Grösse.

Die grosse wunderwerck Gottes von geschickligkeit der natur erzeigend sich in vil wunderbarlichen geschöpffen, insonderheit in disem gägenwirtigen Meerthier oder fisch, welcher mit kopff hals, maul brust, halshaar[1] so an den schwümmenden allein gesähen wirt, sich genzlich eine irdischen pfärdt vergleycht, ausgenommen der hindertheil oder schwanz so ein andere gestalt hat, als dann aus gägenwirtigen figur wol mag sähen werden. Sein lenge ist nit ganz einer spang lang, die dicke eines daumes oder grossen fingers, an der farb voraus oben auff dem ruggen braun mit weyssen punckten, unden am bauch weysslächt; der so unser etlich zu Montpelier am gestad dess Meers gesähen habend war bleich one zweyfel dass er todt was. Keine fischoun hat er sonder ob den augen zwey kleine löchle. Ist ein sonderlicher schöner wunderlicher sälzamer fisch, wirt auch nit vil von den fischeren gefangen. * * *

Dise thier angehenckt söllend bewegen zu unküschheit. Item gederret gepülvert und eyngenommen sol wunderbarlich denen hälffen so von wütenden hunden gebissen sind. Dergleychen aus starckem essich gestossen auff den bis gelegt.

Dises thier zu äschen gebrant mit altem schmär und Salniter, oder mit starckem essich aufgeschmiert, erfült die kalköpff oder abgeflossen haar.

Das pulver der gederten Meerpfärden genossen milteret das seyten wee oder den stich, und in der speyss genommen hilfft denen so den harn nit verhalten mögend.

Die gall der thieren sol ein sonderbare artzney seyn wider vil prästen der augen.

It is evident that the famous sixteenth-century naturalist was quite unaware of having introduced into his work two other descriptions of the same creature, under different names, as if there were in reality as many different kinds of fish. Thus, the "Equus marinis" is described at page 432 in book IV of the Natural History and the "Zidrach" (sea dragon) at page 1254. Far better illustrations of Hippocampus are found in the "Historia Piscium" (1686) of Willughby and Ray. On the other hand, those given in the "Theatrum Animalium" (1718) of Jonston, edited by Ruysch, and in the colored plates of East Indian fishes published by Louis Renard in 1754 are scarcely recognizable.[2]

Other colored figures of both the Hippocampus and "Reversus Indicus" (*i. e., Diodon histrix*) are shown in the plates accompany-

[1] The so-called "halshaar" of Gesner's description is not shown in his woodcuts, but is represented in exaggerated and fantastic form in Thomas Mouffet's "Theatrum" of 1634.

[2] Renard's work has for title: "Poissons, écrivisses et crabes de diverses couleurs et figures extraordinaires, que l'on trouve autour des Moluques et sur les côtes des terres australes," etc. Amsterdam, 1754. For an account of these colored drawings see Cuvier and Valenciennes, Hist. Nat. des Poissons, 1828, vol. I, p. 86.

ing Theodor van Brussel's "Dieren, Visschen," etc., published at Amsterdam in 1798. Adam Lonicer's Natural History, remarkable for its numerous editions and great longevity, preserved a fanciful figure of Hippocampus until the work finally disappeared from the book market in the eighteenth century. And with this we approach the modern period, ushered in, as regards Hippocampus, by Pietro Andrea Matthioli.

The first mention of New World Hippocampines (*H. hudsonius?*) would appear to be found in John Josselyn's "New England's Rarities Discovered" (1672), from which we may quote in conclusion the following passage:

> Of fish, we are best acquainted with Sturgeon, Grampus, Porpus, Seales, Stingraies, whose tailes are very dangerous, Bretts, Mullets, white Salmonds, Trowts, Soles, Plaice, Herrings, Conyfish, Rockfish, Eels, Lampreys, Catfish, Shades, Perch of three sorts, Crabs, Shrimps, Creuises, Oysters, Cocles and Muscles. But the most strange Fish is a small one, so like the picture of Saint *George* his Dragon, as possible can be, except his legges and wings, and the Todefish, which will swell till it be like to burst, when it cometh into the aire.

HEREDITY.[1]

By Prof. William Bateson, M. A., F. R. S.

As the subject of the addresses which I am to deliver here and in Sydney I take "Heredity." I shall attempt to give the essence of the discoveries made by Mendelian or analytical methods of study, and I shall ask you to contemplate the deductions which these physiological facts suggest in application both to evolutionary theory at large and to the special case of the natural history of human society.

Recognition of the significance of heredity is modern. The term itself in its scientific sense is no older than Herbert Spencer. Animals and plants are formed as pieces of living material split from the body of the parent organisms. Their powers and faculties are fixed in their physiological origin. They are the consequence of a genetic process, and yet it is only lately that this genetic process has become the subject of systematic research and experiment. The curiosity of naturalists has, of course, always been attracted to such problems; but that accurate knowledge of genetics is of paramount importance in any attempt to understand the nature of living things has only been realized quite lately even by naturalists, and with casual exceptions the laity still know nothing of the matter. Historians debate the past of the human species, and statesmen order its present or profess to guide its future as if the animal man, the unit of their calculations, with his vast diversity of powers, were a homogeneous material, which can be multiplied like shot.

The reason for this neglect lies in ignorance and misunderstanding of the nature of variation; for not until the fact of congenital diversity is grasped, with all that it imports, does knowledge of the system of hereditary transmission stand out as a primary necessity in the construction of any theory of evolution, or any scheme of human polity.

The first full perception of the significance of variation we owe to Darwin. The present generation of evolutionists realizes perhaps more fully than did the scientific world in the last century that the

[1] Two addresses delivered, August 14 and 20, 1914, at the Australia meeting of the British Association for the Advancement of Science. Reprinted by permission from author's pamphlet copy, London, 1914.

theory of evolution had occupied the thoughts of many and found acceptance with not a few before ever the "Origin" appeared. We have come also to the conviction that the principle of natural selection can not have been the chief factor in delimiting the species of animals and plants, such as we now with fuller knowledge see them actually to be. We are even more skeptical as to the validity of that appeal to changes in the conditions of life as direct causes of modification, upon which latterly at all events Darwin laid much emphasis. But that he was the first to provide a body of fact demonstrating the variability of living things, whatever be its causation, can never be questioned.

There are some older collections of evidence, chiefly the work of the French school, especially of Godron[1] (and I would mention also the almost forgotten essay of Wollaston[2]). These, however, are only fragments in comparison. Darwin regarded variability as a property inherent in living things, and eventually we must consider whether this conception is well founded; but postponing that inquiry for the present, we may declare that with him began a general recognition of variation as a phenomenon widely occurring in nature.

If a population consists of members which are not alike but differentiated, how will their characteristics be distributed among their offspring? This is the problem which the modern student of heredity sets out to investigate. Formerly it was hoped that by the simple inspection of embryological processes the modes of heredity might be ascertained, the actual mechanism by which the offspring is formed from the body of the parent. In that endeavor a noble pile of evidence has been accumulated. All that can be made visible by existing methods has been seen, but we come little if at all nearer to the central mystery. We see nothing that we can analyze further—nothing that can be translated into terms less inscrutable than the physiological events themselves. Not only does embryology give no direct aid, but the failure of cytology is, so far as I can judge, equally complete. The chromosomes of nearly related creatures may be utterly different both in number, size, and form. Only one piece of evidence encourages the old hope that a connection might be traceable between the visible characteristics of the body and those of the chromosomes. I refer of course to the accessory chromosome, which in many animals distinguishes the spermatozoon about to form a female in fertilization. Even it, however, can not be claimed as the cause of sexual differentiation, for it may be paired in forms closely allied to those in which it is unpaired or accessory. The distinction may be present or wanting, like any other secondary sexual character. Indeed, so long as no one can show consistent distinctions

[1] *De l'Espèce et des Races dans les Êtres Organisés*, 1859.
[2] *On the Variation of Species*, 1856.

between the cytological characters of somatic tissues in the same individual we can scarcely expect to perceive such distinctions between the chromosomes of the various types.

For these methods of attack we now substitute another, less ambitious, perhaps, because less comprehensive, but not less direct. If we can not see how a fowl by its egg and its sperm gives rise to a chicken or how a sweet pea from its ovule and its pollen grain produces another sweet pea, we at least can watch the system by which the differences between the various kinds of fowls or between the various kinds of sweet peas are distributed among the offspring. By thus breaking the main problem up into its parts we give ourselves fresh chances. This analytical study we call Mendelian because Mendel was the first to apply it. To be sure, he did not approach the problem by any such line of reasoning as I have sketched. His object was to determine the genetic definiteness of species; but though in his writings he makes no mention of inheritance it is clear that he had the extension in view. By cross breeding he combined the characters of varieties in mongrel individuals and set himself to see how these characters would be distributed among the individuals of subsequent generations. Until he began this analysis nothing but the vaguest answers to such a question had been attempted. The existence of any orderly system of descent was never even suspected. In their manifold complexity human characteristics seemed to follow no obvious system, and the fact was taken as a fair sample of the working of heredity.

Misconception was especially brought in by describing descent in terms of "blood." The common speech uses expressions such as consanguinity, pure-blooded, half-blood, and the like, which call up a misleading picture to the mind. Blood is in some respects a fluid, and thus it is supposed that this fluid can be both quantitatively and qualitatively diluted with other bloods, just as treacle can be diluted with water. Blood in primitive physiology being the peculiar vehicle of life, at once its essence and its corporeal abode, these ideas of dilution and compounding of characters in the commingling of bloods inevitably suggest that the ingredients of the mixture once combined are inseparable, that they can be brought together in any relative amounts, and in short that in heredity we are concerned mainly with a quantitative problem. Truer notions of genetic physiology are given by the Hebrew expression "seed." If we speak of a man as "of the blood royal" we think at once of plebeian dilution, and we wonder how much of the royal fluid is likely to be "in his veins"; but if we say he is "of the seed of Abraham" we feel something of the permanence and indestructibility of that germ which can be divided and scattered among all nations, but remains recognizable in type and characteristics after 4,000 years.

I knew a breeder who had a chest containing bottles of colored liquids by which he used to illustrate the relationships of his dogs, pouring from one to another and titrating them quantitatively to illustrate their pedigrees. Galton was beset by the same kind of mistake when he promulgated his "Law of Ancestral Heredity." With modern research all this has been cleared away. The allotment of characteristics among offspring is not accomplished by the exudation of drops of a tincture representing the sum of the characteristics of the parent organism, but by a process of cell division, in which numbers of these characters, or rather the elements upon which they depend, are sorted out among the resulting germ cells in an orderly fashion. What these elements, or factors as we call them, are we do not know. That they are in some way directly 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 rather that their properties depend on some phenomenon of arrangement. However that may be, analytical breeding proves that it is according to the distribution of these genetic factors, to use a noncommittal term, that the characters of the offspring are decided. The first business of experimental genetics is to determine their number and interactions, and then to make an analysis of the various types of life.

Now the ordinary genealogical trees, such as those which the studbooks provide in the case of the domestic animals, or the Heralds' College provides in the case of man, tell nothing of all this. Such methods of depicting descent can not even show the one thing they are devised to show—purity of "blood." For at last we know the physiological meaning of that expression. An organism is pure bred when it has been formed by the union in fertilization of two germ cells which are alike in the factors they bear; and since the factors for the several characteristics are independent of each other, this question of purity must be separately considered for each of them. A man, for example, may be pure bred in respect of his musical ability and crossbred in respect of the color of his eyes or the shape of his mouth. Though we know nothing of the essential nature of these factors, we know a good deal of their powers. They may confer height, color, shape, instincts, powers both of mind and body; indeed, so many of the attributes which animals and plants possess that we feel justified in the expectation that with continued analysis they will be proved to be responsible for most if not all of the differences by which the varying individuals of any species are distinguished from each other. I will not assert that the greater differences which characterize distinct species are due generally to such independent factors, but that is the conclusion to which the available evidence points. All this is now so well understood, and has been so often demonstrated and expounded, that details of evidence are now superfluous.

But for the benefit of those who are unfamiliar with such work let me briefly epitomize its main features and consequences. Since genetic factors are definite things, either present in or absent from any germ cell, the individual may be either "pure bred" for any particular factor, or its absence, if he is constituted by the union of two germ cells both possessing or both destitute of that factor. If the individual is thus pure, all his germ cells will in that respect be identical, for they are simply bits of the similar germ cells which united in fertilization to produce the parent organism. We thus reach the essential principle, that an organism can not pass onto offspring a factor which it did not itself receive in fertilization. Parents, therefore, which are both destitute of a given factor can only produce offspring equally destitute of it; and, on the contrary, parents both pure bred for the presence of a factor produce offspring equally pure bred for its presence. Whereas the germ cells of the pure bred are all alike, those of the crossbred, which results from the union of dissimilar germ cells, are mixed in character. Each positive factor segregates from its negative opposite, so that some germ cells carry the factor and some do not. Once the factors have been identified by their effects, the average composition of the several kinds of families formed from the various matings can be predicted.

Only those who have themselves witnessed the fixed operations of these simple rules can feel their full significance. We come to look behind the simulacrum of the individual body and we endeavor to disintegrate its features into the genetic elements by whose union the body was formed. Set out in cold general phrases such discoveries may seem remote from ordinary life. Become familiar with them and you will find your outlook on the world has changed. Watch the effects of segregation among the living things with which you have to do—plants, fowls, dogs, horses, that mixed concourse of humanity we call the English race, your friends' children, your own children, yourself—and, however firmly imagination be restrained to the bonds of the known and the proved, you will feel something of that range of insight into nature which Mendelism has begun to give. The question is often asked whether there are not also in operation systems of descent quite other than those contemplated by the Mendelian rules. I myself have expected such discoveries, but hitherto none have been plainly demonstrated. It is true we are often puzzled by the failure of a parental type to reappear in its completeness after a cross—the merino sheep or the fantail pigeon, for example. These exceptions may still be plausibly ascribed to the interference of a multitude of factors, a suggestion not easy to disprove; though it seems to me equally likely that segregation has been in reality imperfect. Of the descent of quantitative characters we still know practically nothing.

These and hosts of difficult cases remain almost untouched. In particular the discovery of E. Baur, and the evidence of Winkler in regard to his "graft hybrids," both showing that the subepidermal layer of a plant—the layer from which the germ cells are derived—may bear exclusively the characters of a part only of the soma, give hints of curious complications, and suggest that in plants at least the interrelations between soma and gamete may be far less simple than we have supposed. Nevertheless, speaking generally, we see nothing to indicate that qualitative characters descend, whether in plants or animals, according to systems which are incapable of factorial representation.

The body of evidence accumulated by this method of analysis is now very large, and is still growing fast by the labors of many workers. Progress is also beginning along many novel and curious lines. The details are too technical for inclusion here. Suffice it to say that not only have we proof that segregation affects a vast range of characteristics, but in the course of our analysis phenomena of most unexpected kinds have been encountered. Some of these things 20 years ago must have seemed inconceivable. For example, the two sets of sex organs, male and female, of the same plant may not be carrying the same characteristics; in some animals characteristics, quite independent of sex, may be distributed solely or predominantly to one sex; in certain species the male may be breeding true to its own type, while the female is permanently mongrel, throwing off eggs of a distinct variety in addition to those of its own type; characteristics, essentially independent, may be associated in special combinations which are largely retained in the next generation, so that among the grandchildren there is numerical preponderance of those combinations which existed in the grandparents—a discovery which introduces us to a new phenomenon of polarity in the organism.

We are accustomed to the fact that the fertilized egg has a polarity, a front and hind end, for example; but we have now to recognize that it, or the primitive germinal cells formed from it, may have another polarity shown in the groupings of the parental elements. I am entirely skeptical as to the occurrence of segregation solely in the maturation of the germ cells,[1] preferring at present to regard it as a special case of that patchwork condition we see in so many plants. These mosaics may break up, emitting bud sports at various cell divisions, and I suspect that the great regularity seen in the F_2 ratios of the cereals, for example, is a consequence of very late segregation, whereas the excessive irregularity found in other cases

[1] The fact that in certain plants the male and female organs respectively carry distinct factors may be quoted as almost decisively negativing the suggestion that segregation is confined to the reduction division.

may be taken to indicate that segregation can happen at earlier stages of differentiation.

The paradoxical descent of color blindness and other sex-limited conditions, formerly regarded as an inscrutable caprice of nature, has been represented with approximate correctness, and we already know something as to the way, or, perhaps, I should say ways, in which the determination of sex is accomplished in some of the forms of life, though, I hasten to add, we have no inkling as to any method by which that determination may be influenced or directed. It is obvious that such discoveries have bearings on most of the problems, whether theoretical or practical, in which animals and plants are concerned. Permanence or change of type, perfection of type, purity or mixture of race, "racial development," the succession of forms, from being vague phrases expressing matters of degree, are now seen to be capable of acquiring physiological meanings, already to some extent assigned with precision. For the naturalist—and it is to him that I am especially addressing myself to-day—these things are chiefly significant as relating to the history of organic beings—the theory of evolution, to use our modern name. They have, as I shall endeavor to show in my second address to be given in Sydney, an immediate reference to the conduct of human society.

I suppose that everyone is familiar in outline with the theory of the origin of species which Darwin promulgated. Through the last 50 years this theme of the natural selection of favored races has been developed and expounded in writings innumerable. Favored races certainly can replace others. The argument is sound, but we are doubtful of its value. For us that debate stands adjourned. We go to Darwin for his incomparable collection of facts. We would fain emulate his scholarship, his width, and his power of exposition, but to us he speaks no more with philosophical authority. We read his scheme of evolution as we would those of Lucretius or of Lamarck, delighting in their simplicity and their courage. The practical and experimental study of variation and heredity has not merely opened a new field; it has given a new point of view and new standards of criticism. Naturalists may still be found expounding teleological systems[1] which would have delighted Dr. Pangloss himself, but at

[1] I take the following from the abstract of a recent Croonian lecture "On the Origin of Mammals" delivered to the Royal Society: "In Upper Triassic times the larger Cynodonts preyed upon the large Anomodont, *Kannemeyeria*, and carried on their existence so long as these Anomodonts survived, but died out with them about the end of the Trias or in Rhætic times. The small Cynodonts, having neither small Anomodonts nor small Cotylosaurs to feed on, were forced to hunt the very active long-limbed Thecodonts. The greatly increased activity brought about that series of changes which formed the mammals—the flexible skin with hair, the four-chambered heart and warm blood, the loose jaw with teeth for mastication, an increased development of tactile sensation and a great increase of cerebrum. Not improbably the attacks of the newly-evolved Cynodont or mammalian type brought about a corresponding evolution in the Psuedosuchian Thecodonts which ultimately resulted in the formation of Dinosaurs and Birds." Broom, R., Proc. Roy. Soc. B., 87, p. 88.

the present time few are misled. The student of genetics knows that the time for the development of theory is not yet. He would rather stick to the seed pan and the incubator.

In face of what we now know of the distribution of variability in nature the scope claimed for 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 attempt by this principle to find value in all definiteness of parts and functions, and in the name of science to see fitness everywhere is mere eighteenth-century optimism. Yet it was in application to the parts, to the details of specific difference, to the spots on the peacock's tail, to the coloring of an orchid flower, and hosts of such examples, that the potency of natural selection was urged with the strongest emphasis. 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. Tolerance plays almost as considerable a part. By these admissions almost the last shred of that teleological fustian with which Victorian philosophy loved to clothe the theory of evolution is destroyed. Those who would proclaim that whatever is is right will be wise henceforth to base this faith frankly on the impregnable rock of superstition and to abstain from direct appeals to natural fact.

My predecessor said last year that in physics the age is one of rapid progress and profound skepticism. In at least as high a degree this is true of biology, and as a chief characteristic of modern evolutionary thought we must confess also to a deep but irksome humility in presence of great vital problems. Every theory of evolution must be such as to accord with the facts of physics and chemistry, a primary necessity to which our predecessors paid small heed. For them the unknown was a rich mine of possibilities on which they could freely draw. For us it is rather an impenetrable mountain out of which the truth can be chipped in rare and isolated fragments. Of the physics and chemistry of life we know next to nothing. Somehow the characters of living things are bound up in properties of colloids, and are largely determined by the chemical powers of enzymes, but the study of these classes of matter has only just begun. Living things are found by a simple experiment to have powers undreamt of, and who knows what may be behind?

Naturally we turn aside from generalities. It is no time to discuss the origin of the mollusca or of dicotyledons, while we are not even sure how it came to pass that *Primula obconica* has in 25 years produced its abundant new forms almost under our eyes. Knowledge of heredity has so reacted on our conceptions of variation that very competent men are even denying that variation in the old sense is a genuine occurrence at all. Variation is postulated as the basis of all

evolutionary change. Do we then as a matter of fact find in the world about us variations occurring of such a kind as to warrant faith in a contemporary progressive evolution? Till lately most of us would have said "yes" without misgiving. We should have pointed, as Darwin did, to the immense range of diversity seen in many wild species, so commonly that the difficulty is to define the types themselves. Still more conclusive seemed the profusion of forms in the various domesticated animals and plants, most of them incapable of existing even for a generation in the wild state, and therefore fixed unquestionably by human selection. These, at least, for certain, are new forms, often distinct enough to pass for species, which have arisen by variation. But when analysis is applied to this mass of variation the matter wears a different aspect. Closely examined, what is the "variability" of wild species? What is the natural fact which is denoted by the statement that a given species exhibits much variation? Generally one of two things; either that the individuals collected in one locality differ among themselves, or perhaps more often that samples from separate localities differ from each other. As direct evidence of variation it is clearly to the first of these phenomena that we must have recourse—the heterogeneity of a population breeding together in one area. This heterogeneity may be in any degree, ranging from slight differences that systematists would disregard, to a complex variability such as we find in some moths, where there is an abundance of varieties so distinct that many would be classified as specific forms, but for the fact that all are freely breeding together. Naturalists formerly supposed that any of these varieties might be bred from any of the others. Just as the reader of novels is prepared to find that any kind of parents might have any kind of children in the course of the story, so was the evolutionist ready to believe that any pair of moths might produce any of the varieties included in the species. Genetic analysis has disposed of all these mistakes. We have no longer the smallest doubt that in all these examples the varieties stand in a regular descending order, and that they are simply terms in a series of combinations of factors separately transmitted, of which each may be present or absent.

The appearance of contemporary variability proves to be an illusion. Variation from step to step in the series must occur either by the addition or by the loss of a factor. Now, of the origin of new forms by loss there seems to me to be fairly clear evidence, but of the contemporary acquisition of any new factor I see no satisfactory proof, though I admit there are rare examples which may be so interpreted. We are left with a picture of variation utterly different from that which we saw at first. Variation now stands out as a definite physiological event. We have done with the notion that Darwin came latterly to favor, that large differences can arise by accumu-

lation of small differences. Such small differences are often mere ephemeral effects of conditions of life, and as such are not transmissible; but even small differences, when truly genetic, are factorial like the larger ones, and there is not the slightest reason for supposing that they are capable of summation. As to the origin or source of these positive separable factors, we are without any indication or surmise. By their effects we know them to be definite, as definite, say, as the organisms which produce diseases; but how they arise and how they come to take part in the composition of the living creature so that when present they are treated in cell-division as constituents of the germs, we can not conjecture.

It was a commonplace of evolutionary theory that at least the domestic animals have been developed from a few wild types. Their origin was supposed to present no difficulty. The various races of fowl, for instance, all came from *Gallus bankiva*, the Indian jungle fowl. So we are taught; but try to reconstruct the steps in their evolution and you realize your hopeless ignorance. To be sure there are breeds, such as Black-red Game and Brown Leghorns, which have the colors of the jungle fowl, though they differ in shape and other respects. As we know so little as yet of the genetics of shape, let us assume that those transitions could be got over. Suppose, further, as is probable, that the absence of the maternal instinct in the Leghorn is due to loss of one factor which the jungle fowl possesses. So far we are on fairly safe ground. But how about White Leghorns? Their origin may seem easy to imagine, since white varieties have often arisen in well-authenticated cases. But the white of White Leghorns is not, as white in nature often is, due to the loss of the color elements, but to the action of something which inhibits their expression. Whence did that something come? The same question may be asked respecting the heavy breeds, such as Malays or Indian Game. Each of these is a separate introduction from the East. To suppose that these, with their peculiar combs and close feathering, could have been developed from preexisting European breeds is very difficult. On the other hand, there is no wild species now living any more like them. We may, of course, postulate that there was once such a species, now lost. That is quite conceivable, though the suggestion is purely speculative. I might thus go through the list of domesticated animals and plants of ancient origin and again and again we should be driven to this suggestion, that many of their distinctive characters must have been derived from some wild original now lost. Indeed, to this unsatisfying conclusion almost every careful writer on such subjects is now reduced. If we turn to modern evidence the case looks even worse. The new breeds of domestic animals made in recent times are the carefully selected products of recombination of preexisting breeds. Most of the new varieties of

cultivated plants are the outcome of deliberate crossing. There is generally no doubt in the matter. We have pretty full histories of these crosses in gladiolus, orchids, cineraria, begonia, calceolaria, pelargonium, etc. A very few certainly arise from a single origin. The sweet pea is the clearest case, and there are others which I should name with hesitation. The cyclamen is one of them, but we know that efforts to cross cyclamens were made early in the cultural history of the plant, and they may well have been successful. Several plants for which single origins are alleged, such as the Chinese primrose, the dahlia, and tobacco, came to us in an already domesticated state, and their origins remain altogether mysterious. Formerly single origins were generally presumed, but at the present time numbers of the chief products of domestication, dogs, horses, cattle, sheep, poultry, wheat, oats, rice, plums, cherries, have in turn been accepted as "polyphyletic" or, in other words, derived from several distinct forms. The reason that has led to these judgments is that the distinctions between the chief varieties can be traced as far back as the evidence reaches, and that these distinctions are so great, so far transcending anything that we actually know variation capable of effecting, that it seems pleasanter to postpone the difficulty, relegating the critical differentiation to some misty antiquity into which we shall not be asked to penetrate. For it need scarcely be said that this is mere procrastination. If the origin of a form under domestication is hard to imagine, it becomes no easier to conceive of such enormous deviations from type coming to pass in the wild state. Examine any two thoroughly distinct species which meet each other in their distribution, as for instance, *Lychnis diurna* and *vespertina* do. In areas of overlap are many intermediate forms. These used to be taken to be transitional steps, and the specific distinctness of *vespertina* and *diurna* was on that account questioned. Once it is known that these supposed intergrades are merely mongrels between the two species the transition from one to the other is practically beyond our powers of imagination to conceive. If both these can survive, why has their common parent perished? Why, when they cross, do they not reconstruct it instead of producing partially sterile hybrids? I take this example to show how entirely the facts were formerly misinterpreted.

When once the idea of a true-breeding—or, as we say, homozygous—type is grasped, the problem of variation becomes an insistent oppression. What can make such a type vary? We know, of course, one way by which novelty can be introduced—by crossing. Cross two well-marked varieties—for instance, of Chinese Primula—each breeding true, and in the second generation by mere recombination of the various factors which the two parental types severally

introduced, there will be a profusion of forms, utterly unlike each other, distinct also from the original parents. Many of these can be bred true, and if found wild would certainly be described as good species. Confronted by the difficulty I have put before you, and contemplating such amazing polymorphism in the second generation from a cross in *Antirrhinum*, Lotsy has lately with great courage suggested to us that all variation may be due to such crossing. I do not disguise my sympathy with this effort. After the blind complacency of conventional evolutionists it is refreshing to meet so frank an acknowledgment of the hardness of the problem. Lotsy's utterance will at least do something to expose the artificiality of systematic zoology and botany. Whatever might or might not be revealed by experimental breeding, it is certain that without such tests we are merely guessing when we profess to distinguish specific limits and to declare that this is a species and that a variety. The only definable unit in classification is the homozygous form which breeds true. When we presume to say that such and such differences are trivial and such others valid, we are commonly embarking on a course for which there is no physiological warrant. Who could have foreseen that the apple and the pear—so like each other that their botanical differences are evasive—could not be crossed together, though species of *Antirrhinum* so totally unlike each other as *majus* and *molle* can be hybridized, as Baur has shown, without a sign of impaired fertility? Jordan was perfectly right. The true-breeding forms which he distinguished in such multitudes are real entities, though the great systematists, dispensing with such laborious analysis, have pooled them into arbitrary Linnean species, for the convenience of collectors and for the simplification of catalogues. Such pragmatical considerations may mean much in the museum, but with them the student of the physiology of variation has nothing to do. These "little species," finely cut, true breeding, and innumerable mongrels between them, are what he finds when he examines any so-called variable type. On analysis the semblance of variability disappears, and the illusion is shown to be due to segregation and recombination of series of factors on predetermined lines. As soon as the "little species" are separated out they are found to be fixed. In face of such a result we may well ask with Lotsy, Is there such a thing as spontaneous variation anywhere? His answer is that there is not.

Abandoning the attempt to show that positive factors can be added to the original stock, we have further to confess that we can not often actually prove variation by loss of factor to be a real phenomenon. Lotsy doubts whether even this phenomenon occurs. The sole source of variation, in his view, is crossing. But here I think he is on unsafe ground. When a well-established variety like "Crimson King" Primula, bred by Messrs. Sutton in thousands of in-

dividuals, gives off, as it did a few years since, a salmon-colored variety, "Coral King," we might claim this as a genuine example of variation by loss. The new variety is a simple recessive. It differs from "Crimson King" only in one respect, the loss of a single color-factor, and, of course, bred true from its origin. To account for the appearance of such a new form by any process of crossing is exceedingly difficult. From the nature of the case there can have been no cross since "Crimson King" was established, and hence the salmon must have been concealed as a recessive from the first origin of that variety, even when it was represented by very few individuals, probably only by a single one. Surely, if any of these had been heterozygous for salmon this recessive could hardly have failed to appear during the process of self-fertilization by which the stock would be multiplied, even though that selfing may not have been strictly carried out. Examples like this seem to me practically conclusive.[1] They can be challenged, but not, I think, successfully. Then again in regard to those variations in number and division of parts which we call meristic, the reference of these to original cross-breeding is surely barred by the circumstances in which they often occur. There remain also the rare examples mentioned already in which a single wild origin may with much confidence be assumed. In spite of repeated trials, no one has yet succeeded in crossing the sweet pea with any other leguminous species. We know that early in its cultivated history it produced at least two marked varieties, which I can only conceive of as spontaneously arising, though, no doubt, the profusion of forms we now have was made by the crossing of those original varieties. I mention the sweet pea thus prominently for another reason, that it introduces us to another though subsidiary form of variation, which may be described as a fractionation of factors. Some of my Mendelian colleagues have spoken of genetic factors as permanent and indestructible. Relative permanence in a sense they have, for they commonly come out unchanged after segregation. But I am satisfied that they may occasionally undergo a quantitative disintegration, with the consequence that varieties are produced intermediate between the integral varieties from which they were derived. These disintegrated conditions I have spoken of as subtraction—or reduction—stages. For example, the Picotee Sweet Pea, with its purple edges, can surely be nothing but a condition produced by the factor which ordinarily makes the fully purple flower, quantitatively diminished. The pied animal, such as the Dutch rabbit, must similarly be regarded as the result of partial defect of the chromogen from which the pigment is formed, or conceivably of the factor which

[1] The numerous and most interesting "mutations" recorded by Prof. T. H. Morgan and his colleagues in the fly, *Drosophila*, may also be cited as unexceptionable cases.

effects its oxidation. On such lines I think we may with great confidence interpret all those intergrading forms which breed true and are not produced by factorial interference.

It is to be inferred that these fractional degradations are the consequence of irregularities in segregation. We constantly see irregularities in the ordinary meristic processes and in the distribution of somatic differentiation. We are familiar with half segments, with imperfect twinning, with leaves partially petaloid, with petals partially sepaloid. All these are evidences of departures from the normal regularity in the rhythms of repetition or in those waves of differentiation by which the qualities are sorted out among the parts of the body. Similarly, when in segregation the qualities are sorted out among the germ cells in certain critical cell divisions, we can not expect these differentiating divisions to be exempt from the imperfections and irregularities which are found in all the grosser divisions that we can observe. If I am right, we shall find evidence of these irregularities in the association of unconformable numbers with the appearance of the novelties which I have called fractional. In passing let us note how the history of the sweet pea belies those ideas of a continuous evolution with which we had formerly to contend. The big varieties came first. The little ones have arisen later, as I suggest, by fractionation. Presented with a collection of modern sweet peas, how prettily would the devotees of continuity have arranged them in a graduated series, showing how every intergrade could be found, passing from the full color of the wild Sicilian species in one direction to white, in the other to the deep purple of "Black Prince," though happily we know these two to be among the earliest to have appeared.

Having in view these and other considerations which might be developed, I feel no reasonable doubt that, though we may have to forego a claim to variations by addition of factors, yet variation both by loss of factors and by fractionation of factors is a genuine phenomenon of contemporary nature. If then we have to dispense, as seems likely, with any addition from without we must begin seriously to consider whether the course of evolution can at all reasonably be represented as an unpacking of an original complex which contained within itself the whole range of diversity which living things present. I do not suggest that we should come to a judgment as to what is or is not probable in these respects. As I have said already, this is no time for devising theories of evolution, and I propound none. But, as we have got to recognize that there has been an evolution, that somehow or other the forms of life have arisen from fewer forms, we may as well see whether we are limited to the old view that evolutionary progress is from the simple to the complex, and whether after all it is conceivable that the process was the other

way about. When the facts of genetic discovery become familiarly known to biologists and cease to be the preoccupation of a few, as they still are, many and long discussions must inevitably arise on the question, and I offer these remarks to prepare the ground. I ask you simply to open your minds to this possibility. It involves a certain effort. We have to reverse our habitual modes of thought. At first it may seem rank absurdity to suppose that the primordial form or forms of protoplasm could have contained complexity enough to produce the divers types of life. But is it easier to imagine that these powers could have been conveyed by extrinsic additions? Of what nature could these additions be? Additions of material can not surely be in question. We are told that salts of iron in the soil may turn a pink hydrangea blue. The iron can not be passed on to the next geenration. How can the iron multiply itself? The power to assimilate the iron is all that can be transmitted. A disease-producing organism like the pebrine of silkworms can in a very few cases be passed on through the germ cells. Such an organism can multiply and can produce its characteristic effects in the next generation. But it does not become part of the invaded host, and we can not conceive it taking part in the geometrically ordered processes of segregation. These illustrations may seem too gross; but what refinement will meet the requirements of the problem, that the thing introduced must be, as the living organism itself is, capable of multiplication and of subordinating itself in a definite system of segregation? That which is conferred in variation must rather itself be a change—not of material but of arrangement, or of motion. The invocation of additions extrinsic to the organism does not seriously help us to imagine how the power to change can be conferred, and if it proves that hope in that direction must be abandoned, I think we lose very little. By the rearrangement of a very moderate number of things we soon reach a number of possibilities practically infinite.

That primordial life may have been of small dimensions need not disturb us. Quantity is of no account in these considerations. Shakespeare once existed as a speck of protoplasm not so big as a small pin's head. To this nothing was added that would not equally well have served to build up a babboon or a rat. Let us consider how far we can get by the process of removal of what we call "epistatic" factors, in other words, those that control, mask, or suppress underlying powers and faculties. I have spoken of the vast range of colors exhibited by modern sweet peas. There is no question that these have been derived from the one wild bicolor form by a process of successive removals. When the vast range of form, size, and flavor to be found among the cultivated apples is considered, it seems difficult to suppose that all this variety is hidden

in the wild crab apple. I can not positively assert that this is so, but I think all familiar with Mendelian analysis would agree with me that it is probable and that the wild crab contains presumably inhibiting elements which the cultivated kinds have lost. The legend that the seedlings of cultivated apples become crabs is often repeated. After many inquiries among the raisers of apple seedlings, I have never found an authentic case; once only even an alleged case, and this on inquiry proved to be unfounded. I have confidence that the artistic gifts of mankind will prove to be due not to something added to the makeup of an ordinary man but to the absence of factors which in the normal person inhibit the development of these gifts. They are almost beyond doubt to be looked upon as releases of powers normally suppressed. The instrument is there, but it is "stopped down." The scents of flowers or fruits, the finely repeated divisions that give its quality to the wool of the Merino or, in an analogous case, the multiplicity of quills to the tail of the fantail pigeon are in all probability other examples of such releases. You may ask what guides us in the discrimination of the positive factors and how we can satisfy ourselves that the appearance of a quality is due to loss. It must be conceded that in these determinations we have as yet recourse only to the effects of dominance. When the tall pea is crossed with the dwarf, since the offspring is tall we say that the tall parent passed a factor into the crossbred which makes it tall. The pure tall parent had two doses of this factor, the dwarf had none; and since the crossbred is tall we say that one dose of the dominant tallness is enough to give the full height. The reasoning seems unanswerable. But the commoner result of crossing is the production of a form intermediate between the two pure parental types. In such examples we see clearly enough that the full parental characteristics can only appear when they are homozygous—formed from similar germ cells—and that one dose is insufficient to produce either effect fully. When this is so we can never be sure which side is positive and which negative. Since, then, when dominance is incomplete we find ourselves in this difficulty, we perceive that the amount of the effect is our only criterion in distinguishing the positive from the negative, and when we return, even to the example of the tall and dwarf peas, the matter is not so certain as it seemed. Prof. Cockerell lately found among thousands of yellow sunflowers one which was partly red. By breeding he raised from this a form wholly red. Evidently the yellow and the wholly red are the pure forms and the partially red is the heterozygote. We may then say that the yellow is YY with two doses of a positive factor which inhibits the development of pigment, the red is yy with no dose of the inhibitor, and the partially red are Yy with only one dose of it. But we might be tempted to think the red was a

positive characteristic and invert the expressions, representing the red as *RR*, the partly red as *Rr*, and the yellow as *rr*. According as we adopt the one or the other system of expression we shall interpret the evolutionary change as one of loss or as one of addition. May we not interpret the other apparent new dominants in the same way? The white dominant in the fowl or in the Chinese primula can inhibit color. But may it not be that the original colored fowl or primula had two doses of a factor which inhibited this inhibitor? The pepper moth, *Amphidasys betularia*, produced in England about 1840 a black variety, then a novelty, now common in certain areas, which behaves as a full dominant. The pure blacks are no blacker than the crossbred. Though at first sight it seems that the black must have been something added, we can without absurdity suggest that the normal is the term in which two doses of inhibitor are present, and that in the absence of one of them the black appears.

In spite of seeming perversity, therefore, we have to admit that there is no evolutionary change which in the present state of our knowledge we can positively declare to be not due to loss. When this has been conceded it is natural to ask whether the removal of inhibiting factors may not be invoked in alleviation of the necessity which has driven students of the domestic breeds to refer their diversities to multiple origins. Something, no doubt, is to be hoped for in that direction, but not until much better and more extensive knowledge of what variation by loss may effect in the living body can we have any real assurance that this difficulty has been obviated. We should be greatly helped by some indication as to whether the origin of life has been single or multiple. Modern opinion is, perhaps, inclining to the multiple theory, but we have no real evidence. Indeed, the problem still stands outside the range of scientific investigation, and when we hear the spontaneous formation of formaldehyde mentioned as a possible first step in the origin of life we think of Harry Lauder in the character of a Glasgow schoolboy pulling out his treasures from his pocket—"That's a wassher—for makkin' motor cars."

As the evidence stands at present all that can be safely added in amplification of the evolutionary creed may be summed up in the statement that variation occurs as a definite event, often producing a sensibly discontinuous result; that the succession of varieties comes to pass by the elevation and establishment of sporadic groups of individuals owing their origin to such isolated events; and that the change which we see as a nascent variation is often, perhaps always, one of loss. Modern research lends not the smallest encouragement or sanction to the view that gradual evolution occurs by the transformation of masses of individuals, though that fancy has fixed itself on popular imagination. The isolated events to which varia-

tion is due are evidently changes in the germinal tissues, probably in the manner in which they divide. It is likely that the occurrence of these variations is wholly irregular, and as to their causation we are absolutely without surmise or even plausible speculation. Distinct types once arisen, no doubt a profusion of the forms called species have been derived from them by simple crossing and subsequent recombination. New species may be now in course of creation by this means, but the limits of the process are obviously narrow. On the other hand, we see no changes in progress around us in the contemporary world which we can imagine likely to culminate in the evolution of forms distinct in the larger sense. By intercrossing dogs, jackals, and wolves new forms of these types can be made, some of which may be species, but I see no reason to think that from such material a fox could be bred in indefinite time or that dogs could be bred from foxes.

Whether science will hereafter discover that certain groups can by peculiarities in their genetic physiology be declared to have a prerogative quality justifying their recognition as species in the old sense, and that the differences of others are of such a subordinate degree that they may in contrast be termed varieties, further genetic research alone can show. I myself anticipate that such a discovery will be made, but I can not defend the opinion with positive conviction.

Somewhat reluctantly, and rather from a sense of duty, I have devoted most of this address to the evolutionary aspects of genetic research. We can not keep these things out of our heads, though sometimes we wish we could. The outcome, as you will have seen, is negative, destroying much that till lately passed for gospel. Destruction may be useful, but it is a low kind of work. We are just about where Boyle was in the seventeenth century. We can dispose of Alchemy, but we can not make more than a quasi-chemistry. We are awaiting our Priestly and our Mendeléeff. In truth it is not these wider aspects of genetics that are at present our chief concern. They will come in their time. The great advances of science are made like those of evolution, not by imperceptible mass improvement, but by the sporadic birth of penetrative genius. The journeymen follow after him, widening and clearing up, as we are doing along the track that Mendel found.

PART II.

At Melbourne I spoke of the new knowledge of the properties of living things which Mendelian analysis has brought us. I indicated how these discoveries are affecting our outlook on that old problem of natural history, the origin and nature of species, and the chief

conclusion I drew was the negative one, that, though we must hold to our faith in the evolution of species, there is little evidence as to how it has come about and no clear proof that the process is continuing in any considerable degree at the present time. The thought uppermost in our minds is that knowledge of the nature of life is altogether too slender to warrant speculation on these fundamental subjects. Did we presume to offer such speculations they would have no more value than those which alchemists might have made as to the nature of the elements. But though in regard to these theoretical aspects we must confess to such deep ignorance, enough has been learned of the general course of heredity within a single species to justify many practical conclusions which can not in the main be shaken. I propose now to develop some of these conclusions in regard to our own species—man.

In my former address I mentioned the condition of certain animals and plants which are what we call "polymorphic." Their populations consist of individuals of many types, though they breed freely together with perfect fertility. In cases of this kind which have been sufficiently investigated it has been found that these distinctions—sometimes very great and affecting most diverse features of organization—are due to the presence or absence of elements, or factors, as we call them, which are treated in heredity as separate entities. These factors and their combinations produce the characteristics which we perceive. No individual can acquire a particular characteristic unless the requisite factors entered into the composition of that individual at fertilization, being received either from the father or from the mother, or from both, and consequently no individual can pass on to his offspring positive characters which he does not himself possess. Rules of this kind have already been traced in operation in the human species, and though I admit that an assumption of some magnitude is involved when we extend the application of the same system to human characteristics in general, yet the assumption is one which I believe we are fully justified in making. With little hesitation we can now declare that the potentialities and aptitudes, physical as well as mental, sex, colors, powers of work or invention, liability to diseases, possible duration of life, and the other features by which the members of a mixed population differ from each other, are determined from the moment of fertilization, and by all that we know of heredity in the forms of life with which we can experiment we are compelled to believe that these qualities are in the main distributed on a factorial system. By changes in the outward conditions of life the expression of some of these powers and features may be excited or restrained. For the development of some an external opportunity is needed, and if that be withheld the character is never seen any more

than if the body be starved can the full height be attained, but such influences are not superficial and do not alter the genetic constitution.

The factors which the individual receives from his parents and no others are those which he can transmit to his offspring; and if a factor was received from one parent only, not more than half the offspring, on an average, will inherit it. What is it that has so long prevented mankind from discovering such simple facts? Primarily the circumstance that as man must have two parents it is not possible quite easily to detect the contributions of each. The individual body is a double structure, whereas the germ cells are single. Two germ cells unite to produce each individual body, and the ingredients they respectively contribute interact in ways that leave the ultimate product a medley in which it is difficult to identify the several ingredients. When, however, their effects are conspicuous the task is by no means impossible. In part also even physiologists have been blinded by the survival of ancient and obscurantist conceptions of the nature of man by which they were discouraged from the application of any rigorous analysis. Medical literature still abounds with traces of these archaisms, and, indeed, it is only quite recently that prominent horse breeders have come to see that the dam matters as much as the sire. For them, though vast pecuniary considerations were involved, the old "homunculus" theory was good enough. We were amazed at the notions of genetic physiology which Prof. Baldwin Spencer encountered in his wonderful researches among the natives of Central Australia; but in truth, if we reflect that these problems have engaged the attention of civilized man for ages, the fact that he, with all his powers of recording and deduction, failed to discover any part of the Mendelian system is almost as amazing. The popular notion that any parents can have any kind of children within the racial limits is contrary to all experience, yet we have gravely entertained such ideas. As I have said elsewhere, the truth might have been found out at any period in the world's history if only pedigrees had been drawn the right way up. If, instead of exhibiting the successive pairs of progenitors who have contributed to the making of an ultimate individual, some one had had the idea of setting out the posterity of a single ancestor who possessed a marked feature such as the Hapsburg lip, and showing the transmission of this feature along some of the descending branches and the permanent loss of the feature in collaterals, the essential truth that heredity can be expressed in terms of presence and absence must have at once become apparent. For the descendant is not, as he appears in the conventional pedigree, a sort of pool into which each tributary ancestral stream has poured something, but rather a conglomerate of ingredient characters taken from his progenitors in such a way that some ingredients are represented and others are omitted.

Let me not, however, give the impression that the unravelling of such descents is easy. Even with fairly full details, which in the case of man are very rarely to be had, many complications occur, often preventing us from obtaining more than a rough general indication of the system of descent. The nature of these complications we partly understand from our experience of animals and plants which are amenable to breeding under careful restrictions, and we know that they are mostly referable to various effects of interaction between factors by which the presence of some is masked.

Necessarily the clearest evidence of regularity in the inheritance of human characteristics has been obtained in regard to the descent of marked abnormalities of structure and congenital diseases. Of the descent of ordinary distinctions such as are met with in the normal healthy population we know little for certain. Hurst's evidence, that two parents both with light-colored eyes—in the strict sense, meaning that no pigment is present on the front of the iris—do not have dark-eyed children, still stand almost alone in this respect. With regard to the inheritance of other color-characteristics some advance has been made, but everything points to the inference that the genetics of color and many other features in man will prove exceptionally complex. There are, however, plenty of indications of system comparable with those which we trace in various animals and plants, and we are assured that to extend and clarify such evidence is only a matter of careful analysis. For the present, in asserting almost any general rules for human descent, we do right to make large reservations for possible exceptions. It is tantalizing to have to wait, but of the ultimate result there can be no doubt.

I spoke of complications. Two of these are worth illustrating here, for probably both of them play a great part in human genetics. It was discovered by Nilsson-Ehle, in the course of experiments with certain wheats, that several factors having the same power may coexist in the same individual. These cumulative factors do not necessarily produce a cumulative effect, for any one of them may suffice to give the full result. Just as the pure-bred tall pea with its two factors for tallness is no taller than the cross-bred with a single factor, so these wheats with three pairs of factors for red color are no redder than the ordinary reds of the same family. Similar observations have been made by East and others. In some cases, as in the Primulas studied by Gregory, the effect is cumulative. These results have been used with plausibility by Davenport and the American workers to elucidate the curious case of the mulatto. If the descent of color in the cross between the negro and the white man followed the simplest rule, the offsprihg of two first-cross mulattos would be, on an average, one black, two mulattos, one white, but this

is notoriously not so. Evidence of some segregation is fairly clear, and the deficiency of real whites may perhaps be accounted for on the hypothesis of cumulative factors, though by the nature of the case strict proof is not to be had. But at present I own to a preference for regarding such examples as instances of imperfect segregation. The series of germ-cells produced by the cross-bred consists of some with no black, some with full black, and others with intermediate quantities of black. No statistical tests of the condition of the gametes in such cases exist, and it is likely that by choosing suitable crosses all sorts of conditions may be found, ranging from the simplest case of total segregation, in which there are only two forms of gametes, up to those in which there are all intermediates in various proportions. This at least is what general experience of hybrid products leads me to anticipate. Segregation is somehow effected by the rhythms of cell-division, if such an expression may be permitted. In some cases the whole factor is so easily separated that it is swept out at once; in others it is so intermixed that gametes of all degrees of purity may result. That is admittedly a crude metaphor, but as yet we can not substitute a better. Be all this as it may, there are many signs that in human heredity phenomena of this kind are common, whether they indicate a multiplicity of cumulative factors or imperfections in segregation. Such phenomena, however, in no way detract from the essential truths that segregation occurs, and that the organism can not pass on a factor which it has not itself received.

In human heredity we have found some examples, and I believe that we shall find many more, in which the descent of factors is limited by sex. The classical instances are those of color blindness and hæmophilia. Both these conditions occur with much greater frequency in males than in females. Of color blindness at least we know that the sons of the color-blind man do not inherit it (unless the mother is a transmitter) and do not transmit it to their children of either sex. Some, probably all, of the daughters of the color-blind father inherit the character, and though not themselves color blind, they transmit it to some (probably on an average half) of their offspring of both sexes. For since these normal-sighted women have only received the color blindness from one side of their parentage, only half their offspring on an average can inherit it. The sons who inherit the color blindness will be color blind and the inheriting daughters become themselves again transmitters. Males with normal color vision, whatever their own parentage, do not have color-blind descendants, unless they marry transmitting women. There are points still doubtful in the interpretation, but the critical fact is clear, that the germ cells of the color-blind man are of two kinds—(i) those which do not carry on the affection and are destined to take part in the formation of sons, and (ii) those which do carry on the color

blindness and are destined to form daughters. There is evidence that the ova also are similarly predestined to form one or other of the sexes, but to discuss the whole question of sex determination is beyond my present scope. The descent of these sex-limited affections nevertheless calls for mention here, because it is an admirable illustration of factorial predestination. It moreover exemplifies that parental polarity of the zygote, to which I alluded in my first address—a phenomenon which we suspect to be at the bottom of various anomalies of heredity, and suggests that there may be truth in the popular notion that in some respects sons resemble their mothers and daughters their fathers.

As to the descent of hereditary diseases and malformations, however, we have abundant data for deciding that many are transmitted as dominants and a few as recessives. The most remarkable collection of these data is to be found in family histories of diseases of the eye. Neurology and dermatology have also contributed many very instructive pedigrees. In great measure the ophthalmological material was collected by Edward Nettleship, for whose death we so lately grieved. After retiring from practice as an oculist he devoted several years to this most laborious task. He was not content with hearsay evidence, but traveled incessantly, personally examining all accessible members of the families concerned, working in such a way that his pedigrees are models of orderly observation and recording. His zeal stimulated many younger men to take part in the work, and it will now go on, with the result that the systems of descent of all the common hereditary diseases of the eye will soon be known with approximate accuracy.

Give a little imagination to considering the chief deduction from this work. Technical details apart, and granting that we can not wholly interpret the numerical results, sometimes noticeably more and sometimes fewer descendants of these patients being affected than Mendelian formulæ would indicate, the expectation is that in the case of many diseases of the eye a large proportion of the children, grandchildren, and remoter descendants of the patients will be affected with the disease. Sometimes it is only defective sight that is transmitted; in other cases it is blindness, either from birth or coming on at some later age. The most striking example perhaps is that form of night blindness still prevalent in a district near Montpellier, which has affected at least 130 persons, all descending from a single affected individual[1] who came into the country in the seventeenth century. The transmission is in every case through an affected

[1] The first human descent proved to follow Mendelian rules was that of a serious malformation of the hand studied by Farabee in America. Drinkwater subsequently worked out pedigrees for the same malformation in England. After many attempts, he now tells me that he has succeeded in proving that the American family and one of his own had an abnormal ancestor in common, five generations ago.

parent, and no normal has been known to pass on the condition. Such an example well serves to illustrate the fixity of the rules of descent. Similar instances might be recited relating to a great variety of other conditions, some trivial, others grave.

At various times it has been declared that men are born equal and that the inequality is brought about by unequal opportunities. Acquaintance with the pedigrees of disease soon shows the fatuity of such fancies. The same conclusion, we may be sure, would result from the true representation of the descent of any human faculty. Never since Galton's publications can the matter have been in any doubt. At the time he began to study family histories even the broad significance of heredity was frequently denied, and resemblances to parents or ancestors were looked on as interesting curiosities. Inveighing against hereditary political institutions, Tom Paine remarks that the idea is as absurd as that of an "hereditary wise man," or an "hereditary mathematician," and to this day I suppose many people are not aware that he is saying anything more than commonly foolish. We, on the contrary, would feel it something of a puzzle if two parents, both mathematically gifted, had any children not mathematicians. Galton first demonstrated the overwhelming importance of these considerations, and had he not been misled, partly by the theory of pangenesis, but more by his mathematical instincts and training, which prompted him to apply statistical treatment rather than qualitative analysis, he might, not improbably, have discovered the essential facts of Mendelism.

It happens rarely that science has anything to offer to the common stock of ideas at once so comprehensive and so simple that the courses of our thoughts are changed. Contributions to the material progress of mankind are comparatively frequent. They result at once in application. Transit is quickened; communication is made easier; the food supply is increased and population multiplied. By direct application to the breeding of animals and plants such results must even flow from Mendel's work. But I imagine the greatest practical change likely to ensue from modern genetic discovery will be a quickening of interest in the true nature of man and in the biology of races. I have spoken cautiously as to the evidence for the operation of any simple Mendelian system in the descent of human faculty; yet the certainty that systems which differ from the simpler schemes only in degree of complexity are at work in the distribution of characters among the human population can not fail to influence our conceptions of life and of ethics, leading perhaps ultimately to modification of social usage. That change can not but be in the main one of simplification. The eighteenth century made great pretense of a return to nature, but it did not occur to those philosophers first to inquire what nature is; and perhaps not even the patristic writings

contain fantasies much further from physiological truth than those which the rationalists of the "Enclyclopædia" adopted as the basis of their social schemes. For men are so far from being born equal or similar that to the naturalist they stand as the very type of a polymorphic species. Even most of our local races consist of many distinct strains and individual types. From the population of any ordinary English town as many distinct human breeds could in a few generations be isolated as there are now breeds of dogs, and indeed such a population in its present state is much what the dogs of Europe would be in 10 years' time but for the interference of the fanciers. Even as at present constituted, owing to the isolating effects of instinct, fashion, occupation, and social class, many incipient strains already exist.

In one respect civilized man differs from all other species of animal or plant in that, having prodigious and ever-increasing power over nature, he invokes these powers for the preservation and maintenance of many of the inferior and all the defective members of his species. The inferior freely multiply, and the defective, if their defects be not so grave as to lead to their detention in prisons or asylums, multiply also without restraint. Heredity being strict in its action, the consequences are in civilized countries much what they would be in the kennels of the dog breeder who continued to preserve all his puppies, good and bad; the proportion of defectives increases. The increase is so considerable that outside every great city there is a smaller town inhabited by defectives and those who wait on them. Round London we have a ring of such towns with some 30,000 inhabitants, of whom about 28,000 are defective, largely, though, of course, by no means entirely, bred from previous generations of defectives. Now, it is not for us to consider practical measures. As men of science we observe natural events and deduce conclusions from them. I may perhaps be allowed to say that the remedies proposed in America, in so far as they aim at the eugenic regulation of marriage on a comprehensive scale, strike me as devised without regard to the needs either of individuals or of a modern State. Undoubtedly if they decide to breed their population of one uniform puritan gray, they can do it in a few generations; but I doubt if timid respectability will make a nation happy, and I am sure that qualities of a different sort are needed if it is to compete with more vigorous and more varied communities. Everyone must have a preliminary sympathy with the aims of eugenists both abroad and at home. Their efforts at the least are doing something to discover and spread truth as to the physiological structure of society. The spirit of such organizations, however, almost of necessity suffers from a bias toward the accepted and the ordinary, and if they had power it would go hard with many ingredients of society that could be ill-spared. I notice an ominous

passage in which even Galton, the founder of eugenics, feeling perhaps some twinge of his Quaker ancestry, remarks that "as the Bohemianism in the nature of our race is destined to perish, the sooner it goes, the happier for mankind." It is not the eugenists who will give us what Plato has called divine releases from the common ways. If some fancier with the catholicity of Shakespeare would take us in hand, well and good; but I would not trust even Shakespeares meeting as a committee. Let us remember that Beethoven's father was an habitual drunkard and that his mother died of consumption. From the genealogy of the patriarchs also we learn, "what may very well be the truth," that the fathers of such as dwell in tents, and of all such as handle the harp or organ, and the instructor of every artificer in brass and iron—the founders, that is to say, of the arts and the sciences—came in direct descent from Cain, and not in the posterity of the irreproachable Seth, who is to us, as he probably was also in the narrow circle of his own contemporaries, what naturalists call a nomen nudum.

Genetic research will make it possible for a nation to elect by what sort of beings it will be represented not very many generations hence, much as a farmer can decide whether his byres shall be full of shorthorns or Herefords. It will be very surprising, indeed, if some nation does not make trial of this new power. They may make awful mistakes, but I think they will try.

Whether we like it or not, extraordinary and far-reaching changes in public opinion are coming to pass. Man is just beginning to know himself for what he is—a rather long-lived animal, with great powers of enjoyment if he does not deliberately forego them. Hitherto superstition and mythical ideas of sin have predominantly controlled these powers. Mysticism will not die out; for those strange fancies knowledge is no cure; but their forms may change, and mysticism as a force for the suppression of joy is happily losing its hold on the modern world. As in the decay of earlier religions, Ushabti dolls were substituted for human victims, so telepathy, necromancy, and other harmless toys take the place of eschatology and the inculcation of a ferocious moral code. Among the civilized races in Europe we are witnessing an emancipation from traditional control in thought, in art, and in conduct which is likely to have prolonged and wonderful influences. Returning to freer or, if you will, simpler conceptions of life and death, the coming generations are determined to get more out of this world than their forefathers did. Is it, then, to be supposed that when science puts into their hand means for the alleviation of suffering immeasurable, and for making this world a happier place, that they will demur to using those powers? The intenser struggle between communities is only now beginning, and with the approaching exhaustion of that capital of energy

stored in the earth before man began.it must soon become still more fierce. In England some of our great-grandchildren will see the end of the easily accessible coal, and, failing some miraculous discovery of available energy, a wholesale reduction in population. There are races who have shown themselves able at a word to throw off all tradition and take into their service every power that science has yet offered them. Can we expect that they, when they see how to rid themselves of the ever-increasing weight of a defective population, will hesitate? The time can not be far distant when both individuals and communities will begin to think in terms of biological fact, and it behooves those who lead scientific thought carefully to consider whither action should lead. At present I ask you merely to observe the facts. The powers of science to preserve the defective are now enormous. Every year these powers increase. This course of action must reach a limit. To the deliberate intervention of civilization for the preservation of inferior strains there must sooner or later come an end, and before long nations will realize the responsibility they have assumed in multiplying these "cankers of a calm world and a long peace."

The definitely feeble-minded we may with propriety restrain, as we are beginning to do even in England, and we may safely prevent unions in which both parties are defective, for the evidence shows that as a rule such marriages, though often prolific, commonly produce no normal children at all. The union of such social vermin we should no more permit than we would allow parasites to breed on our own bodies. Further than that in restraint of marriage we ought not to go, at least not yet. Something, too, may be done by a reform of medical ethics. Medical students are taught that it is their duty to prolong life at whatever cost in suffering. This may have been right when diagnosis was uncertain and interference usually of small effect, but deliberately to interfere now for the preservation of an infant so gravely diseased that it can never be happy or come to any good is very like wanton cruelty. In private few men defend such interference. Most who have seen these cases lingering on agree that the system is deplorable, but ask where can any line be drawn. The biologist would reply that in all ages such decisions have been made by civilized communities with fair success both in regard to crime and in the closely analogous case of lunacy. The real reason why these things are done is because the world collectively cherishes occult views of the nature of life, because the facts are realized by few, and because between the legal mind—to which society has become accustomed to defer—and the seeing eye, there is such physiological antithesis that hardly can they be combined in the same body. So soon as scientific knowledge

becomes common property, views more reasonable and, I may add, more humane, are likely to prevail.

To all these great biological problems that modern society must sooner or later face there are many aspects besides the obvious ones. Infant mortality we are asked to lament without the slightest thought of what the world would be like if the majority of these infants were to survive. The decline in the birth rate in countries already overpopulated is often deplored, and we are told that a nation in which population is not rapidly increasing must be in a decline. The slightest acquaintance with biology, or even schoolboy natural history, shows that this inference may be entirely wrong, and that before such a question can be decided in one way or the other hosts of considerations must be taken into account. In normal stable conditions population is stationary. The laity never appreciates what is so clear to a biologist, that the last century and a quarter corresponding with the great rise in population has been an altogether exceptional period. To our species this period has been what its early years in Australia were to the rabbit. The exploitation of energy capital of the earth in coal, development of the new countries, and the consequent pouring of food into Europe, the application of antiseptics, these are the things that have enabled the human population to increase. I do not doubt that if population were more evenly spread over the earth it might increase very much more, but the essential fact is that under any stable conditions a limit must be reached. A pair of wrens will bring off a dozen young every year, but each year you will find the same number of pairs in your garden. In England the limit beyond which under present conditions of distribution increase of population is a source of suffering rather than of happiness has been reached already. Younger communities living in territories largely vacant are very probably right in desiring and encouraging more population. Increase may, for some temporary reason, be essential to their prosperity. But those who live, as I do, among thousands of creatures in a state of semistarvation will realize that too few is better than too many, and will acknowledge the wisdom of Ecclesiasticus who said, "Desire not a multitude of unprofitable children."

But at least it is often urged that the decline in the birth rate of the intelligent and successful sections of the population (I am speaking of the older communities) is to be regretted. Even this can not be granted without qualification. As the biologist knows, differentiation is indispensable to progress. If population were homogeneous civilization would stop. In every army the officers must be comparatively few. Consequently, if the upper strata of the community produce more children than will recruit their numbers some must fall into the lower strata and increase the pressure there. Statisticians

tell us that an average of four children under present conditions is sufficient to keep the number constant, and as the expectation of life is steadily improving we may perhaps contemplate some diminution of that number without alarm.

In the study of history biological treatment is only beginning to be applied. For us the causes of the success and failure of races are physiological events, and the progress of man has depended upon a chain of these events, like those which have resulted in the "improvement" of the domesticated animals and plants. It is obvious, for example, that had the cereals never been domesticated cities could scarcely have existed. But we may go further, and say that in temperate countries of the Old World (having neither rice nor maize) populations concentrated in large cities have been made possible by the appearance of a "thrashable" wheat. The ears of the wild wheats break easily to pieces, and the grain remains in the thick husk. Such wheat can be used for food, but not readily. Ages before written history began, in some unknown place, plants, or more likely a plant, of wheat lost the dominant factor to which this brittleness is due, and the recessive, thrashable wheat resulted. Some man noticed this wonderful novelty, and it has been disseminated over the earth. The original variation may well have occurred once only in a single germ-cell.

So must it have been with man. Translated into terms of factors, how has that progress in control of nature which we call civilization been achieved? By the sporadic appearance of variations mostly, perhaps all, consisting in a loss of elements, which inhibit the free working of the mind. The members of civilized communities, when they think about such things at all, imagine the process a gradual one, and that they themselves are active agents in it. Few, however, contribute anything but their labor; and except in so far as they have freedom to adopt and imitate, their physiological composition is that of an earlier order of beings. Annul the work of a few hundreds—I might almost say scores—of men, and on what plane of civilization should we be? We should not have advanced beyond the medieval stage without printing, chemistry, steam, electricity, or surgery worthy the name. These things are the contributions of a few excessively rare minds. Galton reckoned those to whom the term "illustrious" might be applied as one in a million, but in that number he is, of course, reckoning men famous in ways which add nothing to universal progress. To improve by subordinate invention, to discover details missed, even to apply knowledge never before applied, all these things need genius in some degree, and are far beyond the powers of the average man of our race; but the true pioneer, the man whose penetration creates a new world, as did that of Newton and of Pasteur, is inconceivably rare. But for a few thousands of such men

we should perhaps be in the Palaeolithic era, knowing neither metals, writing, arithmetic, weaving, nor pottery.

In the history of art the same is true, but with this remarkable difference, that not only are gifts of artistic creation very rare, but even the faculty of artistic enjoyment, not to speak of higher powers of appreciation, is not attained without variation from the common type. I am speaking, of course, of the non-Semitic races of modern Europe, among whom the power whether of making or enjoying works of art is confined to an insignificant number of individuals. Appreciation can in some degree be simulated, but in our population there is no widespread physiological appetite for such things. When detached from the centers where they are made by others, most of us pass our time in great contentment, making nothing that is beautiful, and quite unconscious of any deprivation. Musical taste is the most notable exception, for in certain races—for example, the Welsh and some of the Germans—it is almost universal. Otherwise, artistic faculty is still sporadic in its occurrence. The case of music well illustrates the application of genetic analysis to human faculty. No one disputes that musical ability is congenital. In its fuller manifestation it demands sense of rhythm, ear, and special nervous and muscular powers. Each of these is separable and doubtless genetically distinct. Each is the consequence of a special departure from the common type. Teaching and external influences are powerless to evoke these faculties, though their development may be assisted. The only conceivable way in which the people of England, for example, could become a musical nation would be by the gradual rise in the proportional numbers of a musical strain or strains until the present type became so rare as to be negligible. It by no means follows that in any other respect the resulting population would be distinguishable from the present one. Difficulties of this kind beset the efforts of anthropologists to trace racial origins. It must continually be remembered that most characters are independently transmitted and capable of such recombination. In the light of Mendelian knowledge the discussion whether a race is pure or mixed loses almost all significance. A race is pure if it breeds pure and not otherwise. Historically we may know that a race like our own was, as a matter of fact, of mixed origin. But a character may have been introduced by a single individual, though subsequently it becomes common to the race. This is merely a variant on the familiar paradox that in the course of time if registration is accurate we shall all have the same surname. In the case of music, for instance, the gift, originally perhaps from a Welsh source, might permeate the nation, and the question would then arise whether the nation, so changed, was the English nation or not.

Such a problem is raised in a striking form by the population of modern Greece, and especially of Athens. The racial characteristics of the Athenian of the fifth century B. C. are vividly described by Galton in "Hereditary Genius." The fact that in that period a population, numbering many thousands, should have existed, capable of following the great plays at a first hearing, revelling in subtleties of speech, and thrilling with passionate delight in beautiful things, is physiologically a most singular phenomenon. On the basis of the number of illustrious men produced by that age Galton estimated the average intelligence as at least two of his degrees above our own, differing from us as much as we do from the Negro. A few generations later the display was over. The origin of that constellation of human genius which then blazed out is as yet beyond all biological analysis, but I think we are not altogether without suspicion of the sequence of the biological events. If I visit a poultry breeder who has a fine stock of thoroughbred game fowls breeding true, and 10 years later—that is to say, 10 fowl-generations later—I go again and find scarcely a recognizable game fowl on the place, I know exactly what has happened. One or two birds of some other or of no breed must have strayed in and their progeny been left undestroyed. Now, in Athens, we have many indications that up to the beginning of the fifth century so long as the phratries and gentes were maintained in their integrity there was rather close endogamy, a condition giving the best chance of producing a homogeneous population. There was no lack of material from which intelligence and artistic power might be derived. Sporadically these qualities existed throughout the ancient Greek world from the dawn of history, and, for example, the vase painters, the makers of the Tanagra figurines, and the gem cutters were presumably pursuing family crafts, much as are the actor families[1] of England or the professorial families of Germany at the present day. How the intellectual strains should have acquired predominance we can not tell, but in an in-breeding community homogeneity at least is not surprising. At the end of the sixth century came the "reforms" of Cleisthenes (507 B. C.), which sanctioned foreign marriages and admitted to citizenship a number not only of resident aliens but also of manumitted slaves. As Aristotle says, Cleisthenes legislated with the deliberate purpose of breaking up the phratries and gentes, in order that the various sections of the population might be mixed up as much as posible, and the old tribal associations abolished. The "reform" was probably a recognition and extension of a process already begun; but is it too much to suppose that we have here the effective beginning of a series of genetic changes which in a few generations so greatly altered the character of the people? Under

[1] For tables of these families, see the Supplement to Who's Who in the Theater.

Pericles the old law was restored (451 B. C.), but losses in the great wars led to further laxity in practice, and though at the end of the fifth century the strict rule was reenacted that a citizen must be of citizen birth on both sides, the population by that time may well have become largely mongrelized.

Let me not be construed as arguing that mixture of races is an evil, far from it. A population like our own, indeed, owes much of its strength to the extreme diversity of its components, for they contribute a corresponding abundance of aptitudes. Everything turns on the nature of the ingredients brought in, and I am concerned solely with the observation that these genetic disturbances lead ultimately to great and usually unforeseen changes in the nature of the population.

Some experiments of this kind are going on at the present time, in the United States, for example, on a very large scale. Our grandchildren may live to see the characteristics of the American population entirely altered by the vast invasion of Italian and other South European elements. We may expect that the Eastern States, and especially New England, whose people still exhibit the fine Puritan qualities, with their appropriate limitations, absorbing little of the alien elements, will before long be in feelings and aptitudes very notably differentiated from the rest. In Japan also, with the abolition of the feudal system and the rise of commercialism, a change in population has begun which may be worthy of the attention of naturalists in that country. Till the revolution the Samurai almost always married within their own class, with the result, as I am informed, that the caste had fairly recognizable features. The changes of 1868 and the consequent impoverishment of the Samurai have brought about a beginning of disintegration which may not improbably have perceptible effects.

How many genetic vicissitudes has our own peerage undergone. Into the hard-fighting stock of medieval and Plantagenet times have successively been crossed the cunning shrewdness of Tudor statesmen and courtiers, the numerous contributions of Charles II and his concubines, reinforcing peculiar and persistent attributes which popular imagination especially regards as the characteristic of peers, ultimately the heroes of finance and industrialism. Definitely intellectual elements have been sporadically added—with rare exceptions, however—from the ranks of lawyers and politicians. To this aristocracy art, learning, and science have contributed sparse ingredients, but these mostly chosen for celibacy or childlessness. A remarkable body of men, nevertheless; with an average "horsepower," as Samuel Butler would have said, far exceeding that of any random sample of the middle class. If only man could be reproduced by budding what a simplification it would be. In vegetative repro-

duction heredity is usually complete. The Washington plum can be divided to produce as many identical individuals as are required. If, say, Washington, the statesman, or preferably King Solomon, could similarly have been propagated, all the nations of the earth could have been supplied with ideal rulers.

Historians commonly ascribe such changes as occurred in Athens, and will almost certainly come to pass in the United States, to conditions of life, and especially to political institutions. These agencies, however, do little unless they are such as to change the breed. External changes may indeed give an opportunity to special strains, which then acquire ascendency. The industrial developments which began at the end of the eighteenth century, for instance, gave a chance to strains till then submerged, and their success involved the decay of most of the old aristocratic families. But the demagogue who would argue from the rise of the one and the fall of the other that the original relative positions were not justifiable altogether mistakes the facts.

Conditions give opportunities but cause no variations. For example, in Athens, to which I just referred, the universality of cultivated discernment could never have come to pass but for the institution of slavery which provided the opportunity, but slavery was in no sense a cause of that development, for many other populations have lived on slaves and remained altogether inconspicuous.

The long-standing controversy as to the relative importance of nature and nurture, to use Galton's "convenient jingle of words," is drawing to an end, and of the overwhelmingly greater significance of nature there is no longer any possibility of doubt. It may be well briefly to recapitulate the arguments on which naturalists rely in coming to this decision both as regards races and individuals. First, as regards human individuals, there is the common experience that children of the same parents, reared under conditions sensibly identical, may develop quite differently, exhibiting in character and aptitudes a segregation just as great as in their colors or hair forms. Conversely all the more marked aptitudes have at various times appeared and not rarely reached perfection in circumstances the least favorable for their development. Next, appeal can be made to the universal experience of the breeder, whether of animals or plants, that strain is absolutely essential; that though bad conditions may easily enough spoil a good strain, yet that under the best conditions a bad strain will never give a fine result. It is faith, not evidence, which encourages educationists and economists to hope so greatly in the ameliorating effects of the conditions of life. Let us consider what they can do and what they can not. By reference to some sentences in a charming though pathetic book, "What Is, and What Might Be," by Mr. Edmond Holmes, which will be well known in

the educational section, I may make the point of view of us naturalists clear. I take Mr. Holmes's pronouncement partly because he is an enthusiastic believer in the efficacy of nurture as opposed to nature, and also because he illustrates his views by frequent appeals to biological analogies which help us to a common ground. Wheat badly cultivated will give a bad yield, though, as Mr. Holmes truly says, wheat of the same strain in similar soil well cultivated may give a good harvest. But, having witnessed the success of a great natural teacher in helping unpromising peasant children to develop their natural powers, he gives us another botanical parallel. Assuming that the wild bullace is the origin of domesticated plums, he tells us that by cultivation the bullace can no doubt be improved so far as to become a better bullace, but by no means can the bullace be made to bear plums. All this is sound biology; but translating these facts into the human analogy, he declares that the work of the successful teacher shows that with man the facts are otherwise, and that the *average* rustic child, whose normal ideal is "bullacehood," can become the rare exception, developing to a stage corresponding with that of the plum. But the naturalist knows exactly where the parallel is at fault. For the wheat and the bullace are both breeding approximately true, whereas the human crop, like jute and various cottons, is in a state of polymorphic mixture. The population of many English villages may be compared with the crop which would result from sowing a bushel of kernels gathered mostly from the hedges, with an occasional few from an orchard. If anyone asks how it happens that there are any plum kernels in the sample at all, he may find the answer perhaps in spontaneous variation, but more probably in the appearance of a long-hidden recessive. For the want of that genetic variation, consisting probably, as I have argued, in loss of inhibiting factors, by which the plum arose from the wild form, neither food, nor education, nor hygiene can in any way atone. Many wild plants are half starved through competition, and transferred to garden soil they grow much bigger; so good conditions might certainly enable the bullace population to develop beyond the stunted physical and mental stature they commonly attain, but plums they can never be. Modern statesmanship aims rightly at helping those who have got sown as wildings to come into their proper class; but let not any one suppose such a policy democratic in its ultimate effects, for no course of action can be more effective in strengthening the upper classes whilst weakening the lower.

In all practical schemes for social reform the congenital diversity, the essential polymorphism of all civilized communities, must be recognized as a fundamental fact, and reformers should rather direct their efforts to facilitating and rectifying class distinctions than to

any futile attempt to abolish them. The teaching of biology is perfectly clear. We are what we are by virtue of our differentiation. The value of civilization has in all ages been doubted. Since, however, the first variations were not strangled in their birth we are launched on that course of variability of which civilization is the consequence. We can not go back to homogeneity again, and differentiated we are likely to continue. For a period measures designed to create a spurious homogeneity may be applied. Such attempts will, I anticipate, be made when the present unstable social state reaches a climax of instability, which may not be long hence. Their effects can be but evanescent. The instability is due not to inequality, which is inherent and congenital, but rather to the fact that in periods of rapid change, like the present, convection currents are set up such that the elements of the strata get intermixed, and the apparent stratification corresponds only roughly with the genetic. In a few generations under uniform conditions these elements settle in their true levels once more.

In such equilibrium is content most surely to be expected. To the naturalist the broad lines of solution of the problems of social discontent are evident. They lie neither in vain dreams of a mystical and disintegrating equality nor in the promotion of that malignant individualism which in older civilizations has threatened mortification of the humbler organs, but rather in a physiological coordination of the constituent parts of the social organism. The rewards of commerce are grossly out of proportion to those attainable by intellect or industry. Even regarded as compensation for a dull life, they far exceed the value of the services rendered to the community. Such disparity is an incident of the abnormally rapid growth of population and is quite indefensible as a permanent social condition. Nevertheless capital, distinguished as a provision for offspring, is a eugenic institution; and unless human instinct undergoes some profound and improbable variation abolition of capital means the abolition of effort. But as in the body the power of independent growth of the parts is limited and subordinated to the whole; similarly in the community we may limit the powers of capital, preserving so much inequality of privilege as corresponds with physiological fact.

At every turn the student of political science is confronted with problems that demand biological knowledge for their solution. Most obviously is this true in regard to education, the criminal law, and all those numerous branches of policy and administration which are directly concerned with the physiological capacities of mankind. Assumptions as to what can be done and what can not be done to modify individuals and races have continually to be made, and the basis of fact on which such decisions are founded can be drawn only from biological study.

A knowledge of the facts of nature is not yet deemed an essential part of the mental equipment of politicians; but as the priest who began in other ages as medicine man has been obliged to abandon the medical parts of his practice, so will the future behold the schoolmaster, the magistrate, the lawyer, and ultimately the statesman, compelled to share with the naturalist those functions which are concerned with the physiology of race.

SOME ASPECTS OF PROGRESS IN MODERN ZOÖLOGY.[1]

By Edmund B. Wilson,

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It is our privilege to live in a time of almost unexampled progress in natural science, a time distinguished alike by discoveries of the first magnitude and by far-reaching changes in method and in point of view. The advances of recent years have revolutionized our conceptions of the structure of matter and have seriously raised the question of the transmutation of the chemical elements. They have continually extended the proofs of organic evolution but have at the same time opened wide the door to a reexamination of its conditions, its causes, and its essential nature. Such has been the swiftness of these advances that some effort is still required to realize what remarkable new horizons of discovery they have brought into view. A few years ago the possibility of investigating by direct experiment the internal structure of atoms, or the topographical grouping of hereditary units in the germ cells, would have seemed a wild dream. To-day these questions stand among the substantial realities of scientific inquiry. And lest we should lose our heads amid advances so sweeping, the principles that guide scientific research have been subjected as never before to critical examination. We have become more circumspect in our attitude toward natural "laws." We have attained to a clearer view of our working hypotheses—of their uses and their limitations. With the best of intentions we do not always succeed in keeping them clear of metaphysics, but at least we have learned to try. We perceive more and more clearly that science does not deal with ultimate problems or with final solutions. In order to live science must move. She attempts no more than to win successive points of vantage which may serve, one after another, as stepping stones to further progress. When these have played their part they are often left behind as the general advance proceeds.

In respect to the practical applications of science we have almost ceased to wonder at incredible prodigies of achievement, yet in some

[1] Address of the president of the American Association for the Advancement of Science, Philadelphia, Dec. 28, 1914. Printed by permission of author.

directions they retain a hold on our imagination that daily familiarity can not shake. Not in our time, at least, will the magnificent conquests of sanitary science and experimental medicine sink to the level of the commonplace. Science here renders her most direct and personal service to human welfare; and here in less direct ways she plays a part in the advance of our civilization that would have been inconceivable to our fathers. Popular writers delight to portray the naturalist as a kind of reanimated antediluvian, wandering aimlessly in a modern world where he plays the part of a harmless visionary; but what master of romance would have had the ingenuity to put into the head of his mythical naturalist a dream that the construction of the Panama Canal would turn upon our acquaintance with the natural history of the mosquito, or that the health and happiness of nations—nay, their advance in science, letters, and the arts—might depend measurably on the cultivation of our intimacy with the family lives of house flies, fleas, and creatures of still more dubious antecedants.

Fourteen years ago to-night it was my privilege to deliver an address before the American Society of Naturalists, entitled "Aims and Methods of Study in Natural History,"[1] in which I indicated certain important changes that were then rapidly gathering headway in zoology. To-night I once more ask attention to this subject as viewed in the fuller light of the remarkable period of progress through which biology has since been passing. I will not try to range over the whole vast field of zoology or to catalogue its specific advances. I will only permit myself a few rather desultory reflections suggested by a retrospect upon the progress of the past 25 years. If my view is not fully rounded, if it is colored by a long standing habit of looking at biological phenomena through the eyes of an embryologist, I will make no apology for what I am not able to avoid. Let me remind you also at how many points the boundaries between this and other branches of biology have become obliterated. The traditional separation between zoology and botany, for instance, has lost all significance for such subjects as genetics or cytology. Again, the artificial boundary often set up between zoology and animal physiology has wholly disappeared, owing to the extension of experimental methods to morphology and of comparative methods to physiology. I trust therefore that our brethren in botany and physiology—perhaps I should include also those in psychology—will not take it amiss if I include them with us under the good, old-fashioned name of naturalists.

The sum and substance of biological inquiry may be embodied in two questions: What is the living organism, and how has it come to

[1] Science, N. S., vol. 13, no. 314, Jan. 4, 1901.

be? We often find it convenient to lay the emphasis on one or the other of these questions, but fundamentally they are inseparable. The existing animal bears the indelible impress of its past; the extinct animal can be comprehended only in the light of the present. For instance, the paleontologist is most directly concerned with problems of the past, but at every step he is confronted by phenomena only to be comprehended through the study of organisms as they now are. Our main causal analysis of evolution must be carried out by experimental studies on existing forms. All this seems self-evident, yet the singular fact is that only in more recent years have students of evolution taken its truth fully to heart. And here lies the key to the modern movement in zoology of which I propose to speak.

I do not wish to dwell on matters of ancient history, but permit me a word concerning the conditions under which this movement first began to take definite shape as the nineteenth century drew toward its close. In the first three decades after the "Origin of Species" studies upon existing animals were largely dominated by efforts to reconstruct their history in the past. Many of us will recall with what ardor naturalists of the time threw themselves into this profoundly interesting task. Many of us afterwards turned to work of widely different type; but have our later interests, I wonder, been keener or more spontaneous than those awakened by the morphological-historical problems, some of them already half forgotten, which we then so eagerly tried to follow? I am disposed to doubt it. The enthusiasm of youth? No doubt; but something more, too. Efforts to solve those problems have in the past often failed; they no longer occupy a place of dominating importance; but they will continue so long as biology endures, because they are the offspring of an ineradicable historical instinct, and their achievement stands secure in the great body of solid fact which they have built into the framework of our science. Says Poincaré:

> The advance of science is not comparable to the changes of a city, where old edifices are pitilessly torn down to give place to new, but to the continuous evolution of zoologic types which develop ceaselessly and end by becoming unrecognizable to the common sight, but where an expert eye finds always traces of the prior work of the centuries past. One must not think, then, that the old-fashioned theories have been sterile and vain.

And, after all, science impresses us by something more than the cold light of her latest facts and formulas. The drama of progress, whether displayed in the evolution of living things or in man's age-long struggle to comprehend the world of which he is a product, stirs the imagination by a warmer appeal. Without it we should miss something that we fain would keep—something, one may suspect,

that has played an important part at the higher levels of scientific achievement.

I seem to have been caught unawares in the act of moralizing. If so, let it charitably be set down as an attempt to soften the hard fact that 30 years after the "Origin of Species" we found ourselves growing discontented with the existing methods and results of phylogenetic inquiry and with current explanations of evolution and adaptation. Almost as if by a preconcerted plan, naturalists began to turn aside from historical problems in order to learn more of organisms as they now are. They began to ask themselves whether they had not been overemphasizing the problems of evolution at the cost of those presented by life processes everywhere before our eyes to-day. They awoke to the insufficiency of their traditional methods of observation and comparison and they turned more and more to the method by which all the great conquests of physico-chemical science had been achieved, that which undertakes the analysis of phenomena by deliberate control of the conditions under which they take place—the method of experiment. Its steadily increasing importance is the most salient feature of the new zoology.

Experimental work in zoology is as old as zoology itself; nevertheless, the main movement in this direction belongs to the past two decades. I will make no attempt to trace its development; but let me try to suggest somewhat of its character and consequences by a few outlines of what took place in embryology.

The development of the egg has always cast a peculiar spell on the scientific imagination. As we follow it hour by hour in the living object we witness a spectacular exhibition that seems to bring us very close to the secrets of animal life. It awakens an irrepressible desire to look below the surface of the phenomena, to penetrate the mystery of development. The singular fact, nevertheless, is that during the phylogenetic period of embryological research this great problem, though always before our eyes, seemed almost to be forgotten in our preoccupation with purely historical questions—such as the origin of vertebrates or of annelids, the homologies of germ layers, gill slits or nephridia, and a hundred others of the same type. Now, these questions are and always will remain of great interest; but embryology, as at last we came to see, is but indirectly connected with historical problems of this type. The embryologist seeks first of all to attain to some understanding of development. It was therefore a notable event when, in the later eighties, a small group of embryologists headed by Wilhelm Roux turned away from the historical aspects of embryology and addressed themselves to experiments designed solely to throw light upon the mechanism of development. The full significance of this step first came home to

us in the early nineties with Driesch's memorable discovery that by a simple mechanical operation we can at will cause one egg to produce two, or even more than two, perfect embryos. I will not pause to inquire why this result should have seemed so revolutionary. It was as if the scales had fallen from our eyes. With almost a feeling of shock we took the measure of our ignorance and saw the whole problem of development reopened.

The immediate and most important result of this was to stimulate a great number of important objective investigations in embryology. But let me pause for a moment to point out that at nearly the same time a similar reawakening of interest in the experimental investigation of problems of the present became evident in many other directions—for example, in studies on growth and regeneration; on cytology and protozoology; on economic biology; on ecology, the behavior of animals and their reactions to stimuli; on heredity, variation and selection. The leaven was indeed at work in almost every field of zoology, and everywhere led to like results. It was a day of rapid obliteration of conventional boundary lines; of revolt from speculative systems toward the concrete and empirical methods of the laboratory; of general and far-reaching extension of experimental methods in our science.

But I will return to embryology. It may be doubted whether any period in the long history of this science has been more productive of varied and important discoveries than that which followed upon its adoption of experimental methods. In one direction the embryologist went forward to investigations that brought him into intimate relations with the physicist, the chemist, the pathologist, and even the surgeon. A flood of light was thrown on the phenomena of development by studies on differentiation, regeneration, transplantation, and grafting; on the development of isolated blastomeres and of egg fragments; on the symmetry and polarity of the egg; on the relations of development to mechanical, physical, and chemical conditions in the environment; on isolated living cells and tissues, cultivated like microorganisms, outside the body in vitro; on fertilization, artificial parthenogenesis, and the chemical physiology of development. In respect to the extension of our real knowledge these advances constitute an epoch-making gain to biological science. And yet these same researches afford a most interesting demonstration of how the remoter problems of science, like distant mountain peaks, seem to recede before us even while our actual knowledge is rapidly advancing. Thirty years after Roux's pioneer researches we find ourselves constrained to admit that in spite of all that we have learned of development the egg has not yet yielded up its inmost secrets. I have referred to the admirable discovery of Driesch concerning the artificial production of twins. That brilliant leader of

embryological research had in earlier years sought for an understanding of development along the lines of the mechanistic or physico-chemical analysis, assuming the egg to be essentially a physico-chemical machine. He now admitted his failure and, becoming at last convinced that the quest had from the first been hopeless, threw all his energies into an attempt to resuscitate the half extinct doctrines of vitalism and to found a new philosophy of the organism. Thus the embryologist, starting from a simple laboratory experiment, strayed further and further from his native land until he found himself at last quite outside the pale of science. He did not always return. Instead he sometimes made himself a new home—upon occasion even established himself in the honored occupancy of a university chair of philosophy.

The theme that is here suggested tempts me to a digression, because of the clear light in which it displays the attitude of modern biology toward the study of living things. It is impossible not to admire the keenness of analysis, and often the artistic refinement of skill (which so captivates us, for instance, in the work of M. Bergson) with which the neovitalistic writers have set forth their views. For my part I am ready to go further, admitting freely that the position of these writers may at bottom be well grounded. At any rate it is well for us now and then to be rudely shaken out of the ruts of our accustomed modes of thought by a challenge that forces upon us the question whether we really expect our scalpels and microscopes, our salt-solutions, formulas, and tables of statistics to tell the whole story of living things. It is, of course, impossible for us to assert that they will. And yet the more we ponder the question the stronger grows our conviction that the "entelechies" and such-like agencies conjured forth by modern vitalism are as sterile for science as the final causes of an earlier philosophy; so that Bacon might have said of the former as he did of the latter, that they are like the vestal virgins—dedicated to God, and barren. We must not deal too severely with the naturalist who now and then permits himself an hour of dalliance with them. An uneasy conscience will sooner or later drive him back into his own straight and narrow way with the insistent query: The specific vital agents, *sui generis*, that are postulated by the vitalist—are they sober realities? Can the existence of an "élan vital," of "entelechies," of "psychoids" be experimentally verified? Even if beyond the reach of verification may they still be of practical use in our investigations on living things or find their justification on larger grounds of scientific expediency? However philosophy may answer, science can find but one reply. The scientific method is the mechanistic method. The moment we swerve from it by a single step we set foot in a foreign land where a different idiom from ours is spoken. We have, it is true, no proof

whatever of its final validity. We do not adopt the mechanistic view of organic nature as a dogma but only as a practical program of work, neither more nor less. We know full well that our present mechanistic conceptions of animals and plants have not yet made any approach to a complete solution of the problems of life, whether past or present. This should encourage us to fresh efforts, for just in the present inadequacy of these conceptions lies the assurance of our future progress. But the way of unverifiable (and irrefutable) imaginative constructions is not our way. We must hold fast to the method by which all the great advances in our knowledge of nature have been achieved. We shall make lasting progress only by plodding along the old, hard-beaten trail blazed by our scientific fathers—the way of observation, comparison, experiment, analysis, synthesis, prediction, verification. If this seems a prosaic program we may learn otherwise from great discoverers in every field of science who have demonstrated how free is the play that it gives to the constructive imagination and even to the faculty of artistic creation.

Thus far I have desired to emphasize especially the reawakening of our interest in problems of the present, and the growing importance of experimental methods in our science. It is interesting to observe how these changes have affected our attitude toward the historical problem as displayed in the modern study of genetics. Even here we are struck by the same shifting of the center of gravity that has been remarked in other fields of inquiry. In the Darwinian era studies on variation and heredity seemed significant mainly as a means of approach to the problems of evolution. The post-Darwinians awoke once more to the profound interest that lies in the genetic composition and capacities of living things as they now are. They turned aside from general theories of evolution and their deductive application to special problems of descent in order to take up objective experiments on variation and heredity for their own sake. This was not due to any doubts concerning the reality of evolution or to any lack of interest in its problems. It was a policy of masterly inactivity deliberately adopted; for further discussion concerning the causes of evolution had clearly become futile until a more adequate and critical view of existing genetic phenomena had been gained. Investigators in genetics here followed precisely the same impulse that had actuated the embryologists; and they, too, reaped a rich harvest of new discoveries. Foremost among them stands the rediscovery of Mendel's long-forgotten law of heredity—a biological achievement of the first rank which in the year 1900 suddenly illuminated the obscurity in which students of heredity had been groping. Another towering landmark of progress is De Vries's great work on

the mutation theory, published a year later, which marked almost as great a transformation in our views of variation and displayed the whole evolution problem in a new light. In the era that followed, the study of heredity quickly became not only an experimental but almost an exact science, fairly comparable to chemistry in its systematic employment of qualitative and quantitative analysis, synthesis, prediction, and verification. More and more clearly it became evident that the phenomena of heredity are manifestations of definite mechanism in the living body. Microscopical studies on the germ-cells made known an important part of this mechanism and provided us with a simple mechanical explanation of Mendel's law. And suddenly in the midst of all this, by a kaleidoscopic turn, the fundamental problem of organic evolution crystallizes before our eyes into a new form that seems to turn all our previous conceptions topsy-turvy.

I will comment briefly on this latest view of evolution, partly because of its inherent interest, but also because it again exemplifies, as in the case of embryology, that temptation to wander off into metaphysics (*sit venia verbo*) which seems so often to be engendered by new and telling discoveries in science. The fundamental question which it raises shows an interesting analogy to that encountered in the study of embryology, and may conveniently be approached from this side.

To judge by its external aspects, individual development, like evolution, would seem to proceed from the simple to the complex; but is this true when we consider its inner or essential nature? The egg appears to the eye far simpler than the adult, yet genetic experiment seems continually to accumulate evidence that for each independent hereditary trait of the adult the egg contains a corresponding something (we know not what) that grows, divides, and is transmitted by cell division without loss of its specific character and independently of other somethings of like order. Thus arises what I will call the puzzle of the microcosm. Is the appearance of simplicity in the egg illusory? Is the hen's egg fundamentally as complex as the hen, and is development merely the transformation of one kind of complexity into another? Such is the ultimate question of ontogeny, which in one form or another has been debated by embryologists for more than two centuries. We still can not answer it. If we attempt to do so each replies according to the dictates of his individual temperament—that is to say, he resorts to some kind of symbolism—and he still remains free to choose that particular form which he finds most convenient, provided it does not stand in the way of practical efforts to advance our real knowledge through observation and experiment. Those who must have everything reduced to hard and fast formulas will no doubt find this rather disconcerting; but worse is to follow.

Genetic research now confronts us with essentially the same question as applied to the evolutionary germ. The puzzle of the microcosm has become that of the macrocosm. Were the primitive forms of life really simpler than their apparently more complex descendants? Has organic evolution been from the simple to the complex or only from one kind of complexity to another? May it even have been from the complex to the simple by successive losses of inhibiting factors which, as they disappear, set free qualities previously held in check? The last of these is the startling question that the president of the British association propounds in his recent brilliant address at Melbourne, asking us seriously to open our minds to the inquiry, "Whether evolution can at all reasonably be represented as an unpacking of an original complex which contained within itself the whole range of complexity which living things exhibit?" This conception, manifestly, is nearly akin to the theory of pangenesis and individual development, as elaborated especially by De Vries and by Weismann. It inevitably recalls also, if less directly, Bonnet's vision of "palingenesis," which dates from the eighteenth century.

We should be grateful to those who help us to open our minds; and Prof. Bateson, as is his wont, performs this difficult operation in so large and masterly a fashion as to command our lively admiration. It must be said of his picturesque and vigorous discussion that we are kept guessing how far we are expected to take it seriously, or at least literally. We have always a lurking suspicion that possibly his main purpose may after all be to remind us, by an object lesson, how far we still are from comprehending the nature and causes of evolution, and this suspicion is strengthened by the explicit statement in a subsequent address, delivered at Sydney, that our knowledge of the nature of life is "altogether too slender to warrant speculation on these fundamental questions." Let us, however, assume that we are seriously asked to go further and to enter the cul de sac that Prof. Bateson so invitingly places in our way. Once within it, evidently, we are stalemated in respect to the origin and early history of life; but as to that, one form of total ignorance is perhaps as good as another, and we can still work out how the game has been played, even though we can never find out how the pieces were set up. But has the day so soon arrived when we must resign ourselves to such an ending? Are we prepared to stake so much upon the correctness of a single hypothesis of allelomorphism and dominance? This hypothesis—that of "presence and absence"—has undoubtedly been a potent instrument of investigation; but there are some competent students of genetics who seem to find it equally simple to formulate and analyze the phenomena by the use of a quite different hypothesis, and one that involves no such paradoxical con-

sequences in respect to the nature of evolution. Are we not then invited to strain at a gnat and to swallow a camel?

But I pass over the technical basis of the conception in order to look more broadly at its theoretic superstructure. Is not this, once again, a kind of symbolism by which the endeavor is made to deal with a problem that is for the present out of our reach? Neither you nor I, I dare say, will hesitate to maintain that the primordial Amœba (if we may so dub the earliest of our ancestors) embodied in some sense or other all the potentialities, for better or for worse, that are realized before us at this moment in the American Association for the Advancement of Science. But if we ask ourselves exactly what we mean by this we discover our total inability to answer in more intelligible terms.

We can not, it is true, even if we would, conquer the temptation now and then to spread the wings of our imagination in the thin atmosphere of these upper regions; and this is no doubt an excellent tonic for the cerebrum provided we cherish no illusions as to what we are about. No embryologist, for example, can help puzzling over what I have called the problem of the microcosm; but he should be perfectly well aware that in striving to picture to his imagination the organization of the egg, of the embryological germ, that is actually in his hands for observation and experiment, he is perilously near to the habitat of the mystic and the transcendalist. The student of evolution is far over the frontier of that forbidden land in any present attack upon the corresponding problem of the macrocosm, for the primordial Amœba, the evolutionary germ, is inconceivably far out of our reach, hidden behind the veil of a past whose beginnings lie wholly beyond our ken. And why, after all, should we as yet attempt the exploration of a region which still remains so barren and remote? Surely not for the lack of accessible fields of genetic research that are fertile and varied enough to reward our best efforts, as no one has more forcibly urged or more brilliantly demonstrated by his own example than Prof. Bateson himself.

Perhaps it would be the part of discretion to go no further. But the remarkable questions that Prof. Bateson has raised concerning the nature of evolution leave almost untouched the equally momentous problem as to what has guided its actual course. In approaching my close I shall be bold enough to venture a step in this direction, even one that will bring us upon the hazardous ground of organic adaptations and the theory of natural selection. I need not say that this subject is beset by intricate and baffling difficulties which have made it a veritable bone of contention among naturalists in recent years. In our attempts to meet them we have gone to some curious extremes. On the one hand, some naturalists have in effect abandoned the problem, cutting the Gordian knot with the

conclusion that the power of adaptation is something given with organization itself and as such offers a riddle that is for the present insoluble. In another direction we find attempts to take the problem in flank—to restate it, to ignore it—sometimes it would almost seem to argue it out of existence.

It has been urged in a recent valuable work—by an author, I hasten to say, who fully accepts both the mechanistic philosophy and the principle of selection—that fitness is a reciprocal relation, involving the environment no less than the organism. This is both a true and a suggestive thought; but does it not leave the naturalist floundering amid the same old quicksands? The historical problem with which he has to deal must be grappled at closer quarters. He is everywhere confronted with specific devices in the organism that must have arisen long after the conditions of environment to which they are adjusted. Animals that live in water are provided with gills. Were this all, we could probably muddle along with the notion that gills are no more than lucky accidents. But we encounter a sticking point in the fact that gills are so often accompanied by a variety of ingenious devices, such as reservoirs, tubes, valves, pumps, strainers, scrubbing brushes, and the like, that are obviously tributary to the main function of breathing. Given water, asks the naturalist, how has all this come into existence and been perfected? The question is an inevitable product of our common sense. The metaphysician, I think, is not he who asks but he who would suppress it.

For all that, it would seem that some persons find the very word adaptation of too questionable a reputation for mention in polite scientific society. Allow me to illustrate by a leaf taken from my own notebook. I once ventured to publish a small experimental work on the movements of the fresh-water hydra with respect to light. What was my surprise to receive a reproof from a friendly critic because I had not been content with an objective description of the movements, but had also been so indiscreet as to emphasize their evident utility to the animal. I was no doubt too young then—I fear I am too old now—to comprehend in what respect I had sinned against the light. That was long ago. I will cite a more recent example from a public discussion on adaptation that took place before the American Society of Naturalists a year or two since. "The dominance of the concept of adaptation," said one naturalist, "which now distinguishes our science from the non-biological ones is related to the comparatively youthful stage of development so far attained by biology, and not to any observed character in the living objects with which we deal." Here we almost seem to catch an echo from the utterances of a certain sect of self-styled "scientists" who love to please themselves with the quaint

fancy that physical disease is but one of the "errors of mortal mind."

Now, it is undoubtedly true that many adaptations, to cite Prof. Bateson once more, are "not in practice a very close fit." Even the eye, as Helmholtz long ago taught us, has some defects as an optical instrument; nevertheless, it enables us to see well enough to discern some food for reflection concerning adaptations among living things. And it is my impression that efforts to explain adaptations are likely to continue for the reason that naturalists as a body, perhaps influenced by Huxley's definition of science, have an obstinate habit of clinging to their common sense.

At the present day there is no longer the smallest doubt of the great outstanding fact that few complex structural adaptations—it would probably be correct to say none such—have come into existence at a single stroke; they have moved forward step by step to the attainment of their full degree of perfection. What has dominated the direction and final outcome of such advancing lines? We can not yet answer this question with any degree of assurance; but, procrastinate as we may, it must in the end squarely be faced. We have seen one theory after another forced back within narrower lines or crumbling away before the adverse fire of criticism. I will not pause to recount the heavy losses that must be placed to the account of sexual selection, of neo-Lamarckism, of orthogenesis. Some naturalists no doubt would assign a prominent place in this list of casualties to natural selection, but probably there are none who would hold that it has been destroyed utterly. The crux lies in the degree of its efficacy. Stated as an irreducible minimum, the survival of the fit is an evident fact. Individuals that are unfitted to live or to reproduce leave few or no descendants—so much, at least, must be admitted by all. But does this colorless and trite conclusion end the matter or adequately place before us the significance of the facts? Just here lies the whole issue. Does destruction of the unfit accomplish no other result than to maintain the status quo, or has it conditioned the direction of progress? Accepting the second of these alternatives, Darwin went so far as to assign to it a leading rôle among the conditions to which the living world owes its existing configuration. Since his time the aspect of the problem has widely changed. We must rule out of the question the origin of neutral or useless traits. We must not confuse the evolution of adaptations with the origin of species. We must bear in mind the fact that Darwin often failed to distinguish between non-heritable fluctuations and hereditary mutations of small degree. We are now aware that many apparently new variations may be no more than recombination products of preexisting elements. We should no doubt make a larger

allowance for the rôle of single "lucky accidents" in evolution than did many of the earlier evolutionists. And yet, as far as the essence of the principle is concerned, I am bound to make confession of my doubts whether any existing discussion of this problem affords more food for reflection, even to-day, than that contained in the sixth and seventh chapters of the "Origin of Species" and elsewhere in the works of Darwin.

Undeniably there is a large measure of truth in the contention that natural selection still belongs rather to the philosophy than to the science of biology. In spite of many important experimental and critical studies on the subject Darwin's conception still remains to-day in the main what it was in his own time, a theory, a logical construction, based, it is true, on a multitude of facts, yet still awaiting adequate experimental test. Simple though the principle is, its actual effect in nature is determined by conditions that are too intricate and operate through periods too great to be duplicated in the experimental laboratory. Hence it is that even after more than 50 years of Darwinism the time has not yet come for a true estimate of Darwin's proposed solution of the great problem.

But there is still another word to be said. Too often in the past the facile formulas of natural selection have been made use of to carry us lightly over the surface of unsuspected depths that would richly have repaid serious exploration. In a healthy reaction from this purblind course we have made it the mode to minimize Darwin's theory, and no doubt a great service has been rendered to our study of this problem by the critical and sceptical spirit of modern experimental science. But there is a homely German saying that impresses upon us the need of caution as we empty out the bath lest we pour out the child too. This suggests that we should take heed lest we underestimate the one really simple and intelligible explanation of organic adaptations, inadequate though it now may seem, that has thus far been placed in our hands. And in some minds—if I include my own among them let it be set down to that indiscretion at which I have hinted—the impression grows that our preoccupation with the problem as it appears at short focus may in some measure have dimmed our vision of larger outlines that must be viewed at longer range; that we may have emphasized minor difficulties at the cost of a larger truth. To such minds it will seem that the principle of natural selection, while it may not provide a master key to all the riddles of evolution, still looms up as one of the great contributions of modern science to our understanding of nature.

I have taken but a passing glance at a vast and many sided subject. I have tried to suggest that the tide of speculation in our science has far receded; that experimental methods have taken their rightful place of importance; that we have attained to a truer per-

spective of past and present in our study of the problems of animal life. The destructive phase through which we have passed has thoroughly cleared the ground for the new constructive era on which we now have entered. All the signs of the times indicate that this era will long endure. And this is of good augury for a future of productive effort, guided by the methods of physico-chemical science, impatient of merely a priori constructions, of academic discussions, of hypotheses that can not be brought to the test of experimental verification. The work ahead will make exacting technical demands upon us. The pioneer days of zoology are past. The naturalist of the future must be thoroughly trained in the methods and results of chemistry and physics. He must prepare himself for a life of intensive research, of high specialization; but in the future, even more than in the past, he will wander in vain amid the dry sands of special detail if the larger problems and general aims of his science be not held steadfastly in view. For these are the outstanding beacon lights of progress; and while science viewed at close range seems always to grow more complex, a wider vision shows that her signal discoveries are often singularly simple. This, perhaps, may help us to keep alive the spirit of the pioneers who led the advances of a simpler age, and it is full of hope for the future.

LINGUISTIC AREAS IN EUROPE: THEIR BOUNDARIES AND POLITICAL SIGNIFICANCE.[1]

By Leon Dominian.

[With 5 maps in color.]

1. INTRODUCTION.

The purpose of this paper is to show that definite relations exist between linguistic areas in Europe and the geography of the continent and that application of facts derived from a study of this science to frontier delimitation is valid and practicable. The work was planned and executed under the direction of Councillor Madison Grant, who has drawn on his studies of European anthropology and history, as well as on a wide knowledge of the European continent, to supply the writer with numerous notes, besides carefully revising the final proof and making many valuable additions. It is regretted that limitations of space have necessitated restricting presentation of a number of fundamental relations to bare statements of fact. This deficiency is remedied in part by the list of sources given in the footnotes. The nationality of authorities cited should be determined prior to consultation, as divergences of views corresponding to conflicting national aims are not infrequent.[2]

Modern history has entered a stage in which determination of national boundaries is intimately connected with distribution of languages. International events in the past two centuries have been marked by constant endeavor to provide conformity of political and linguistic frontiers. The progress of western Europe in this respect is satisfactory. The eastern section of the continent contains problems which have defied diplomatic solution.

Linguistic areas in common with other data of geography have been largely determined by the character of the surface covered or

[1] Reprinted by courtesy of the American Geographical Society of New York. Bulletin of the American Geographical Society, vol. 47, June, 1915.

[2] Acknowledgment of important suggestions is due to Profs. Palmer, Le Compte, and Seymour of Yale University, as well as to Prof. Jordan of Columbia University.

delimited. Occurrences such as the expansion of Polish to the Carpathian barrier or the restriction of Flemish to the lowland of northwestern central Europe can not be attributed to mere haphazard. Determination of linguistic boundaries, therefore, implies due recognition of selective influences attributable to surface features. But the influence of region upon expansion or confinement of language is far from absolute. The part played by economic factors will be shown in the following lines to have been of prime importance.

Considered as political boundaries, linguistic lines of cleavage have a twofold importance. They are sanctioned by national aspirations and they conform with physical features. Every linguistic area considered in this paper bears evidence of relation between language and its natural environment.[1] A basis of delimitation is therefore provided by nature. Eastern extension of French to the Vosges, confinement of Bohemian to a plateau inclosed by mountains, uniformity of language in open plains and river basins, all are examples of data provided by geography for the use of statesmen engaged in the task of revising boundaries.

Europe may be aptly regarded as a vast field of settlement where the autochthonous stock has again and again been swamped by successive flows of eastern and southern immigrants. The wanderings of these invaders have been directed in part into channels provided by Eurasian structural features. Within historic times Celts have been driven westward by Teutons, who in turn were pressed in the same direction by Slavs. The consequence is that few Frenchmen or Germans of our day can lay claim to racial purity. As a matter of fact, northern France is perhaps more Teutonic than southern Germany, while eastern Germany is in some respects more Slavic than Russia. The political significance of race is, therefore, trifling.

Nationality, however, an artificial product derived from racial raw material, confers distinctiveness based on history. It is the cultivated plant blossoming on racial soil and fertilized by historical association. Language, the medium in which is expressed successful achievement or struggle and sorrow shared in common, therefore acquires cementing qualities. Its value as the cohesive power of nationality is superseded in rare instances by ideals similarly based on community of tradition or hope and in some cases of religion. Belgium and Switzerland afford good examples of such exceptional instances. Broadly, it may be submitted that the development of civilization in most countries has been marked by the progress of nationality, while nationality itself has been consolidated by identity of speech.

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[1] Linguistic maps accompanying this paper should, in every instance, be examined concurrently with good atlas sheets.

2. THE FRANCO-FLEMISH LINGUISTIC BOUNDARY.

The westernmost contact between Romance and Teutonic languages occurs in French Flanders and Belgium. Starting at a few miles south of Dunkirk,[1] the linguistic divide follows a direction which is generally parallel to the political boundary until, at a few miles east of Aire, it strikes northeast to Halluin, which remains within the area of French speech. From here on to Sicken-Sussen, near the German border, the line assumes an almost due east trend.

This division corresponds to the mountainous and depressed areas into which Belgium is divided. The upland has ever been the home of French. Walloon is but a modified form of the old langue d'oïl.[2] Flemish, on the other hand, is a Germanic language which spread over Belgian lowlands as naturally as the Niederdeutsch dialects to which it is related had invaded the plains of northern Europe. This east-west line also marks the separation of the tall, blond, long-skull Flemings from the short, dark, round-skull Alpine Walloons.

In northwestern France the language of the plain has steadily receded since the thirteenth century before the uplander's speech.[3] At that time Flemish was spoken as far south as the region between Boulogne and Aire. The area spreading east of the Strait of Dover between the present linguistic boundary and a line connecting these two cities is now bilingual, with French predominating. It might be noted here, however, that Boulogne has been a city of French language since Frankish days.

Within Belgian territory the linguistic line has sustained slight modification in the course of centuries. The country may be conveniently divided into a northern section, the inhabitants of which consider Flemish as their vernacular, but who also generally know French, and a southern section peopled by French-speaking inhabitants who adhere to the use of Walloon dialects in the intimacy of their home life. A small area in eastern Belgium is peopled by Germans.[4]

The figures of the last (Dec. 31, 1910) Belgian census[5] show that the Flemish provinces are bilingual, whereas the Walloon region is

[1] G. Kurth, La Frontière Linguistique en Belgique et dans le Nord de la France. Mém. couronnés, Acad. R. Sci. Let. et Beaux-Arts de Belg., 48, vol. 1, 1895, vol. 2, 1898, Bruxelles; Map, 1 : 400,000 published in Feb., 1900.

[2] Cf. map: Ausbreitung der Romanischen Sprachen in Europa, 1 : 8,000,000. Gröber's Grundriss der Romanischen Philologie, Trübner, Strassburg, 1904–1906. See also Gillieron et Edmont, Atlas Linguistique de la France, Champion, Paris.

[3] Kurth, loc. cit. Kurth's work is based partly on toponymic data; its value as an ethnographic document equals its importance as a contribution to the distribution of languages in western Europe. L. De Backer, La Langue flamande en France. Samyn, Gand, 1893.

[4] N. Warker, Die deutschen Orts- und Gewässernamen der Belgischen Provinz Luxemburg, Deut. Erde, vol. 8, 1909, pp. 99, 139. Maps important.

[5] Statistique de la Belgique, Recensement général de 1910, vol. 2, 1912, vol. 3, 1913, Bruxelles.

altogether French. Knowledge of French as an educational and business requirement accounts for its occurrence in Flanders. The Romance language, therefore, tends to supersede the Germanic idiom as a national vernacular. Utter absence of Flemish in the Belgian Congo constitutes perhaps the strongest evidence in favor of French as Belgium's national language.

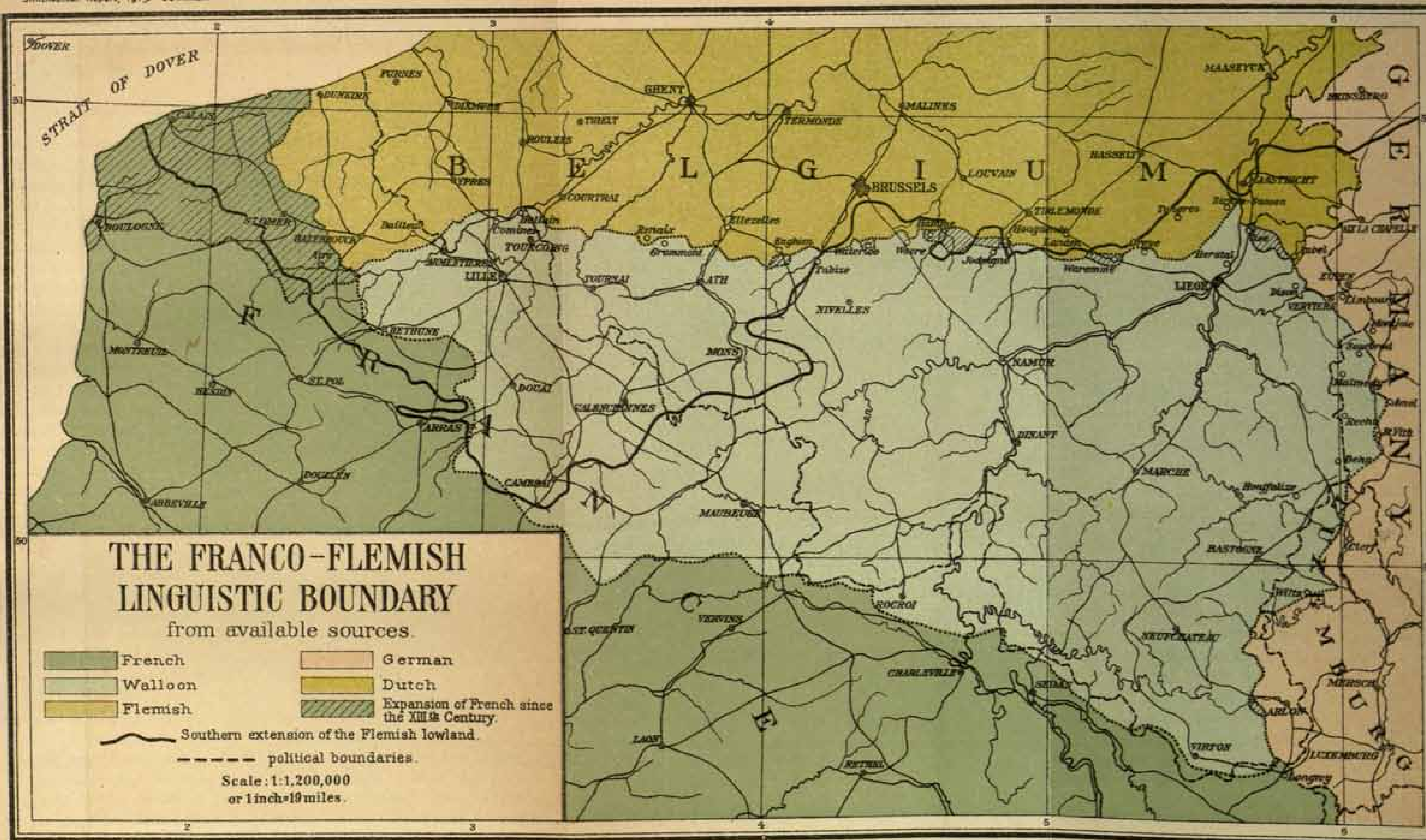
The linguistic dualism is traceable to the period of the Roman conquest. Intercourse at that time between the Belgæ dwelling south of the Via Agrippa and the Romans, who were pushing steadily northwards, was intimate. The Latin of the Roman invaders, modified by the Celtic and Germanic of the native populations, gave birth eventually to the Walloon of subsequent times.[1]

The Belgæ of the lowlands farther north, however, successfully resisted the efforts made by the Romans to conquer them. The marshes of their nether country and the forested area which was to be laid bare by the monks of the middle ages constituted a stronghold, in the shelter of which Germanic dialects took root.

At a later date the growth of the temporal power of the Roman Church witnessed the establishment of a number of bishoprics over districts segregated irrespective of linguistic differences. Perhaps one of the most notable facts of Belgian history is found in the fact that its linguistic and political boundaries have never coincided. Every century is marked by renewal of the age-long clashes between the Germanic and Romance races which have been thrown in contact along the western end of the line of severance between the plains of northern Europe and the mountainous southland of the continent.

In recent years a keen struggle for predominance between Flemings and Walloons is observable in Belgium. Language had been adopted as the rallying standard of both parties. Aggravation of this feud may yet lead to secession. The Flemish provinces might then cast their political lot with the Dutch. The languages spoken in Holland and Flanders are practically identical. Religious differences alone have stood in the way of political fusion in the past. The revolt of the Netherlands from Spanish authority had led to the independence of Protestant provinces only. Flemish princes, swayed by religious scruples, refused to side with the Protestant communities whose political connection had been established by the Union of Utrecht in 1579. At present the severance of religious from political issues and the menace of absorption by Germany may drive the Flemings to join their close kinsmen of the lowlands on the north. A state formed by this union could be named the Netherlands in all propriety. Its geographical foundation would

[1] The Belgæ of Cæsar are probably represented by the Teutonic populations of northern France, Flanders, and Batavia rather than by the Walloons.


THE FRANCO-FLEMISH
LINGUISTIC BOUNDARY
from available sources.
French
Walloon
Flemish
German
Dutch
Expansion of French since the XIII th Century.
Southern extension of the Flemish lowland.
political boundaries.
Scale: 1:1,200,000
or 1 inch=19 miles.
STRAIT OF DOVER
DOVER
B E L G I U M
F R A N C E
GERMANY
LUXEMBURG
GHENT
BRUSSELS
LOUVAIN
MALINES
TERMONDE
FURNES
DUNKIRK
DIXMUDE
ROULERS
YPRES
COURTRAI
CALAIS
BOULOGNE
ST. OMER
HAZEBROUCK
ARMENTIERES
LILLE
TOURCOING
TOURNAI
ATH
MONS
NIVELLES
NAMUR
LIEGE
TIRLEMONT
HASSELT
MAASEYCK
MAESTRICHT
BETHUNE
MONTREUIL
ST. POL
ARRAS
DOUAI
VALENCIENNES
CAMBRAI
DOULLENS
ABBEVILLE
MAUBEUGE
DINANT
MARCHE
BASTOGNE
ROCROI
VERVINS
ST. QUENTIN
CHARLEVILLE
SEDAN
NEUFCHATEAU
ARLON
VIRTON
LUXEMBURG
LAON
RETHEL
VERVIERS

be secure. Walloons would then naturally revert to French allegiance. The coincidence of political and linguistic boundaries in the westernmost section of central Europe would thus become an accomplished fact.

3. THE FRANCO-GERMAN LINGUISTIC BOUNDARY.

In its central section the long contact line between French and German languages conforms approximately with the political line dividing the two countries. Modifications which French frontiers underwent since the treaty of Utrecht may be regarded as final adjustments in a prolonged process of adapting political to linguistic boundaries. The Napoleonic period of political disturbances brought about an abnormal extension of the northern and eastern line. Between 1792 and 1814 almost all of the territory of Belgium and Holland was annexed and the eastern frontier extended to the Rhine. Foreign populations in Holland, Flanders, Rhenish Prussia, and the western sections of Hesse and Baden passed under the administrative control centered at Paris. But their subjection to Napoleon's artificial empire was of relatively short duration. The German-speaking people in 1813 united in a great effort to drive the French across the Rhine. They were merely repeating the feat of their ancestors, who at a distance of eighteen centuries had defeated the Latin-speaking invaders of their country led by the Roman Varus. Success in both movements was helped to a certain extent by community of feeling based on identity of language. In 9 A. D. the Romans were forced back to the Rhine from the line they occupied on the Weser. The treaty of Vienna restored French boundaries to the lines existing in 1790. French territory again reverted to the approximately normal boundaries which inclose members of the French-speaking family. The union of Frenchmen into a compact political body was shattered, however, by the treaty of Frankfurt in 1871, when France was obliged to cede important strips of French-speaking territories in Alsace-Lorraine to Germany.

The part to be played by Lorraine in the history of Franco-German relations was laid out by nature itself. The province has always been the seat of a wide pathway connecting highly attractive regions of settlement. It lies midway between the fertile plains of the Rhine and the hospitable Parisian basin. It is also placed squarely in the center of the natural route leading from Flanders to Burgundy. The region is physically part of France. It has therefore been inhabited mainly by French-speaking inhabitants. At the same time the lack of a natural barrier on the east facilitated Teutonic incursions. In particular, the Moselle Valley has favored easy access into Lorraine throughout history. In the Middle Ages

and until the 18th century the province was part of the Empire and largely German speaking. This language still persists in the eastern parts. The region was thus a border land disputed first by two adjoining races and subsequently by two neighboring countries.

This long period of successive conflicts necessarily witnessed modifications of linguistic boundaries. Glancing as far back as the end of the Middle Ages, a slight westerly advance of the area of German speech may be ascertained for the period between the 10th and 16th centuries.[1] From that time on, however, the regional gain of French has been in excess of previous German advances. Data obtained from place names often afford valuable clues to earlier distribution of languages in this region. Occurrences of the suffix "ange," which is the Frenchified form of the German "ingen," in names lying west of the present line show the extent of territory reclaimed by the French language.[2]

Alsace is the region defined by the valley of the Ill. The wall of the Vosges Mountains marks its western limits. Its easterly extension attains the banks of the Rhine. This elongated plain appears throughout history as a corridor through which races of men marched and countermarched. The Alpine race provided it with early inhabitants. Romans subjugated the land in the course of imperial colonization. The province subsequently passed under Germanic and Frankish sway. Its entry into linguistic history may be reckoned from the year 842, when the celebrated oaths of Strassburg were exchanged in Romance and Teutonic vernaculars by Charles the Bald and Louis the German. The alliance of these two sovereigns against Lothair at this time marked the beginnings of the German destiny of Alsace. After 925 the province became part of the Teutonic domain and remained German except during the period of French occupation which lasted from 1681 to 1871.

A highway of migration can not be the abode of a pure race. Its inhabitants necessarily represent the successive human flows by which it has been overrun.[3] The Alsatian of the present day is, accordingly, a product of racial mingling. But the blending has conferred distinctiveness, and Alsatians claiming a nationality of their own find valid argument in racial antecedents no less than in geographical habitation. The red soil of their fertile plains symbolizes the native land in their minds as it reveals itself to perception with the attribute of unity. Alsatians have responded to such an environment to the extent of representing a distinct group in

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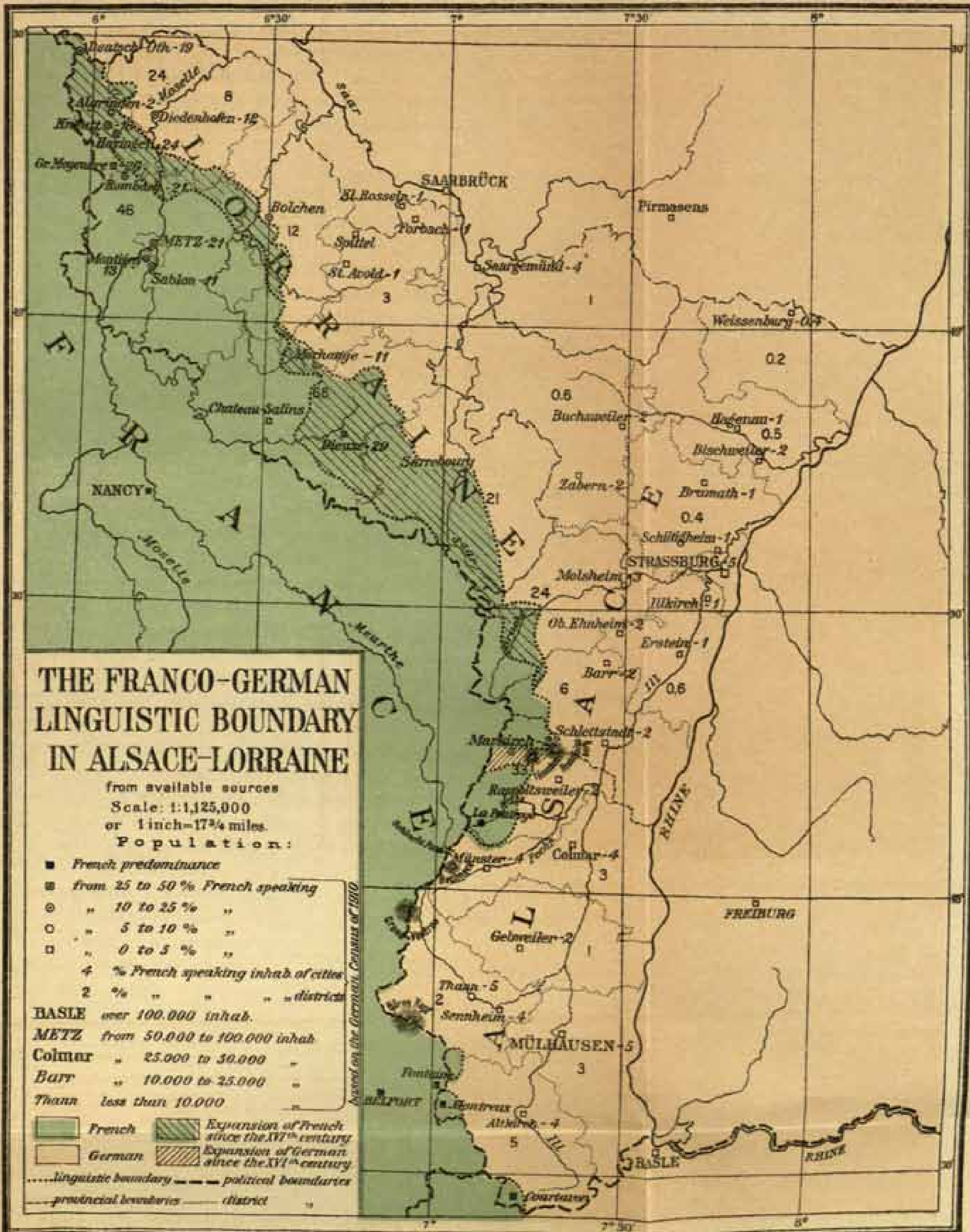
[1] H. Witte, Das Deutsche Sprachgebiet Lothringens und Seine Wandlungen, etc. Forsch. z. Deutsch-Landes- u. Volksk., 8, 1894, pp. 407–535.

[2] L. Gallois, Les Limites linguistiques du français, Ann. de Géogr., 9, 1900, p. 215.

[3] Anthropologic data for the southwestern section of Alsace are instructive. The generation of a transition type between the short and sturdy Alpine type and the "sesquepedal" Teuton is observable. Cf. Ripley, The Races of Europe, Appleton, New York, 1899, pp. 225–226.


THE FRANCO-GERMAN LINGUISTIC BOUNDARY IN ALSACE-LORRAINE
from available sources
Scale: 1:1,125,000
or 1 inch=17¾ miles.
Population:
French predominance
from 25 to 50 % French speaking
" 10 to 25 % "
" 5 to 10 % "
" 0 to 5 % "
4 % French speaking inhab. of cities
2 % " " " districts
BASLE over 100.000 inhab.
METZ from 50.000 to 100.000 inhab.
Colmar " 25.000 to 50.000 "
Barr " 10.000 to 25.000 "
Thann less than 10.000
French
German
Expansion of French since the XVIth century
Expansion of German since the XVIth century
linguistic boundary
political boundaries
provincial boundaries
district
Based on the German Census of 1910
LORRAINE
FRANCE
ALSACE
SAARBRÜCK
Pirmasens
Bolchen
Forbach-1
Spittel
St. Avold-1
Saargemünd-4
Diedenhofen-12
METZ-21
Sablon-11
NANCY
Chateau Salins
Dieuze-29
Saarburg
Weissenburg-0.4
Buchsweiler-2
Hagenau-1
Bischweiler-2
Zabern-2
Brumath-1
Schiltigheim-1
STRASSBURG-5
Molsheim-3
Illkirch-1
Ob. Ehnheim-2
Erstein-1
Barr-2
Schlettstadt-2
Markirch
Rappoltsweiler-2
La Poutroye
Münster-4
Colmar-4
FREIBURG
Gebweiler-2
Thann-5
Sennheim-4
MÜLHAUSEN-5
BELFORT
Montreux
Altkirch-4
BASLE
Courtavon
RHINE
Moselle
Saar
Meurthe
Ill

which the basal Alpine strain has been permeated by strong admixtures of Teutonic blood. The confusion of dark and fair physiognomies represents the two elements in the population.[1] In a broader sense the Alsatians are identical with the Swiss population to the south and the Lorrainers and Walloons to the north. The districts occupied by all these people once constituted the Middle Kingdom of Burgundy.

Alsace was a province of purely German speech until the end of the eighteenth century. French took solid foothold mainly after the revolution and during the nineteenth century. An enlightened policy of tolerance toward the Province's institutions cemented strong ties of friendship between the inhabitants and their French rulers. Alsatian leanings toward France were regarded with suspicion by the victors of 1871, who proceeded to pass prohibitionary laws regarding the use of French in schools, churches or law courts. These measures of Germanization were attended by a notable emigration to France. In 1871 there were 1,517,494 inhabitants in Alsace-Lorraine. The number dwindled to 1,499,020 in 1875 in spite of 52.12 per cent excess of births over deaths.

Nancy by its situation was destined to welcome Alsatians who had decided to remain faithful to France. The number of immigrants it received after the Franco-Prussian war was estimated at 15,000.[2] Pressing need of workingmen in the city's growing industrial plants intensified this movement. Alsatian dialects were the only languages heard in entire sections of the urban area. Peopled by about 50,000 inhabitants in 1866, Nancy's population jumped to 66,303 in 1876. Metz, on the other hand, with a population of 54,820 inhabitants in 1866, could not boast of more than 45,675 citizens in 1875. The census taken in 1910 raised this figure to 68,598 by including the unusually strong garrison maintained at this point.

The present line of linguistic demarcation in Alsace rarely coincides with the political boundary. Conformity is observable only in stretches of their southernmost extension. East and southeast of Belfort, however, two areas of French speech spread into German territory at Courtaron and Montreux.

In the elevated southern section of the Vosges the line runs from peak to peak with a general tendency to proceed east of the crest line and to reveal conspicuous deflections in certain high valleys of the eastern slope. Its irregularity with respect to topography may be regarded as an indication of the fluctuation of racial sites in early historical times.

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[1] French writers claim an average brunetteness of 70 per cent for Alsace and point thereby to the predominance of the Celtic strain.

[2] R. Blanchard, Deux Grandes Villes Françaises. La Géogr., 30, Nos. 2–6, 1914, pp. 120–121.

From Bären Kopf to about 10 miles beyond Schlucht Pass the mountainous divide and linguistic line coincide. Farther north, however, French prevails in many of the upper valleys of the Alsatian slope. This is true of the higher sections of the Weiss basin as well as the upper reaches of the Bruche. At a short distance south of the sources of the Liepvre, parts of the Valley of Markirch (Sainte-Marie aux Mines) are likewise French. Here, however, the influx of German miners who founded settlements as far back as the seventeenth century have converted the district into an area linguistically reclaimed by Germans. Altogether, it was estimated that in 1910 French was spoken by 204,262 inhabitants of Alsace-Lorraine out of a total population of 1,814,564.[1]

Two methods of indicating the presence of a French element in Alsace-Lorraine are given in the map of this region accompanying this article. Percentages according to administrative districts[2] have been contrasted with actual extension of French predominance.[3] The map shows concordance of French and German authorities regarding the German character of Alsace, as well as the French nature of a substantial portion of Lorraine. The Rhine Valley, a natural region, appears throughout as an area of German speech. Viewed in this light, French claims favoring extension of the country's western boundary to the left bank of the Rhine deserve consideration only if grounded on Alsatian preference for French nationality. They can not rest on a sound geographical foundation.

Of all so-styled natural boundaries, a river perhaps is the most unsatisfactory.[4] Conventional representation of its course on paper provides the map with black lines which on casual inspection impart semblance of a break in regional continuity. Reasoned examination, however, discloses the similarity of the land extending beyond both banks. Allowance being made for difference of elevation between the upper and lower courses of a river, the unit region is obviously constituted by the entire basin. All the data of observation reveal regional unity in the Valley of the Rhine.

The political case of Alsace-Lorraine, viewed from the linguistic standpoint, may be summed up as follows: Alsace is German. Areas of French in this Province consist of intrusion of minor importance. It is evident that the Vosges Mountains have prevented expansion of French toward the Valley of the Rhine. Lorraine, however, which was also German, was devoid of a natural barrier that might have arrested the spread of French. Consequently, it has been partly regained by that language.

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[1] The Statesman's Yearbook, 1914, p. 934.

[2] After the language map of Alsace-Lorraine in Andree's Handatlas, Pl. 67–68, 6th ed.

[3] After Gallois' map, Pl. 4, vol. 9, Ann. de Géogr., 1900.

[4] Lord Curzon, Frontiers, The Romanes Lectures, Clarendon Press, Oxford, 1907.

Beyond Alsace, French and German meet along a line which extends across western Swiss territory to the Italian frontier.[1] Its present course has been maintained since the fifteenth century.[2] Beginning at Lucelle, the line crosses the Jura Mountains west of Solothurn. Lake Neuchatel is surrounded on all sides except the northeast by French - speaking communities. The western and southern shores of Lake Morat are likewise French. Fribourg, a city in which the struggle for linguistic supremacy is strenuous, lies at the edge of French-speaking territory. The line becomes better defined in the upper Valley of the Rhone, where it coincides with the divide between the Val d'Anniviers and the Turtmann Thal. The construction of the Simplon Tunnel appears to have been the cause of an extension of French influence in this region and recession of German from the Morge Valley to the east of Sierre lies within the memory of living natives.

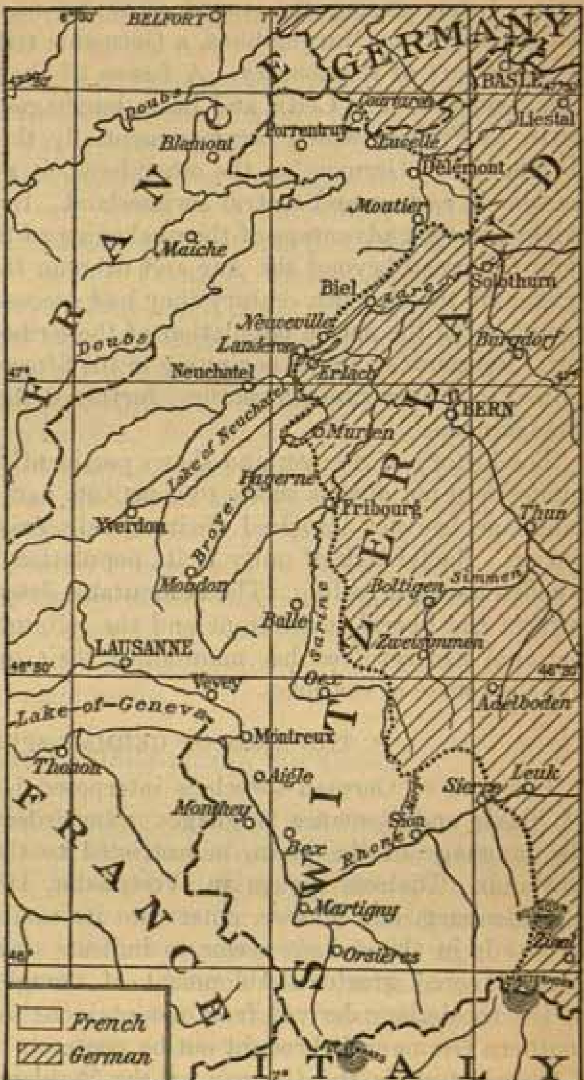

FIG. 1.—The boundary between French and German in Switzerland. Scale, 1:1,435,000.

[1] P. Langhans, Die Westschweiz mit deutscher Ortsbenennung 1 : 500,000. Deut. Erde, 5, 1906, Pl. 5.

[2] L. Gallois, Les limites linguistiques du français, Ann. de Géogr., vol. 9, 1900, p. 218.

The origin of linguistic differences in Switzerland may be traced to the early history of the country. At the time of Cæsar's conquests, Helvetia, then peopled by Celts, became subjected to Rome's imperial rule. Later, during the period of invasions, the Helvetians were conquered by the Burgundians, a Germanic tribe, who settled in the western part of the country. A fusion of the two peoples followed this conquest. The Celtic and Latin languages then prevailing gave birth to French, which became essentially the speech of the Jura highlanders. German, on the other hand, is a relic of Teutonic invasions in eastern and central Switzerland. In the sixth century the Alemanni took advantage of the weakening of the Burgundian kingdom to spread beyond the Aar and overrun the attractive lake district. By the eleventh century they had succeeded in imposing their language on the native population of the Fribourg and Valais country. Religious struggles beginning in the fifteenth century and maintained to the seventeenth century, furthered the westerly advance of the Germans.

The history of Switzerland shows pertinently that, at bottom, language does not always suffice to constitute nationality. Diversity of language has not impaired Switzerland's existence as a sovereign nation. Racial lack of unity in its population has likewise failed to weaken national feeling. The indomitable determination of Swiss to protect the liberal institutions and the religion around which their national life revolved has maintained their independence throughout the course of centuries.

4. THE AREA OF GERMAN SPEECH.

The area of German speech is interposed between the territories of Slavic and Romance languages. Niederdeutsch or Plattdeutsch, the language of the plain, is restricted to the extensive northern lowlands. Dialects spoken in Westphalia, Holstein, Mecklenburg, Brandenburg, and Prussia enter into its composition. The wealth of words in this tongue seems to indicate that ease of life on the plain favored greater development of thought. Relative sterility of the vocabulary derived from mountainous sections of central and southern Germany is brought out by contrast.

Oberdeutsch is the German of the highland. It comprises the Bavarian, Swabian, and Alemannic dialects of Bavaria, Wurtemberg, and Baden. Its adoption as the literary language of all German-speaking people became well established in the Middle Ages. Luther's translation of the Bible, written in a combination of Upper and Middle German, contributed no mean share in the diffusion of the language. Printed German also followed this form. Its use has been favored by Germany's most noted writers since the seventeenth century. It is fast becoming the language of the educated classes. Its

dissemination by the agency of schools and newspapers tends to convert it eventually into the only idiom that will survive within German boundaries.

The transition from the northern plain of Germany to high central regions is represented on the surface by a zone of intermediate uplands in Saxony, Lusatia, and Silesia. This area is also characterized linguistically by a transitional form of speech between Niederdeutsch and Oberdeutsch.[1] The greater similarity, however, of this intermediate language to Oberdeutsch is observable to the same extent that the rising land over which it is distributed presents greater analogy to the mountainous region toward which it tends. The transitional dialects include Frankish, Hennebergian, and Saxon. They occur in the middle Rhineland, Hesse, Thuringia, and Saxony.

Outside this central mass of Germans living in Germany and Austria, the language prevails in the Baltic Provinces of Russia, where Protestantism is strongly established. This region was known as the German Provinces up to 1876. In that year substitution of Russian to German inaugurated Russification of the area by the Government. Colonies of Germans are also found in southwestern Russia from the headwaters to the mouth of the Dniester. The valley of this river as well as that of the Dnieper was peopled by peasants who emigrated from Würtemberg, Saxony, and Switzerland during the reign of Catharine the Great. Many of the settlements still bear German names. The presence of Teutons in this part of Russia is devoid, however, of political significance.

5. THE DANISH-GERMAN BOUNDARY.

Lack of conformity between political and linguistic boundaries along the Danish-German frontier has caused ceaseless strife between the two nationalities. Denmark's hold on Schleswig-Holstein prior to 1866 had engendered bitter feeling among Germans who considered the subjection of their kinsmen settled on the right bank of the Elbe estuary as unnatural. After Prussia had annexed the contested region it was the Danes' turn to feel dissatisfied and to claim the districts occupied by their countrymen.

The present Danish-speaking population of Schleswig-Holstein is variously estimated at between 140,000 and 150,000. These subjects of the Kaiser occupy the territory south of the Danish boundary to a line formed by the western section of the Lecker Au, the southern border of the swampy region extending south of Renz and the northern extension of the Angeln Hills. Between this line and the area in

[1] Cf. Sheets 12a, Europa, Fluss-Gebirgskarte, and 12c, Europa, Sprachen and Völkerkarte, both 1 : 12,000,000, in Debes' Handatlas.

which German is spoken a zone of the old Frisian tongue of Holland survives along the western coast of the peninsula. Frisian is also spoken in the coastal islands.

The degree to which linguistic variations adapt themselves to physical configuration is admirably illustrated in this case by the southerly extension of Danish along the eastern section of the peninsula where persistence of the Baltic ridge appears in the hilly nature

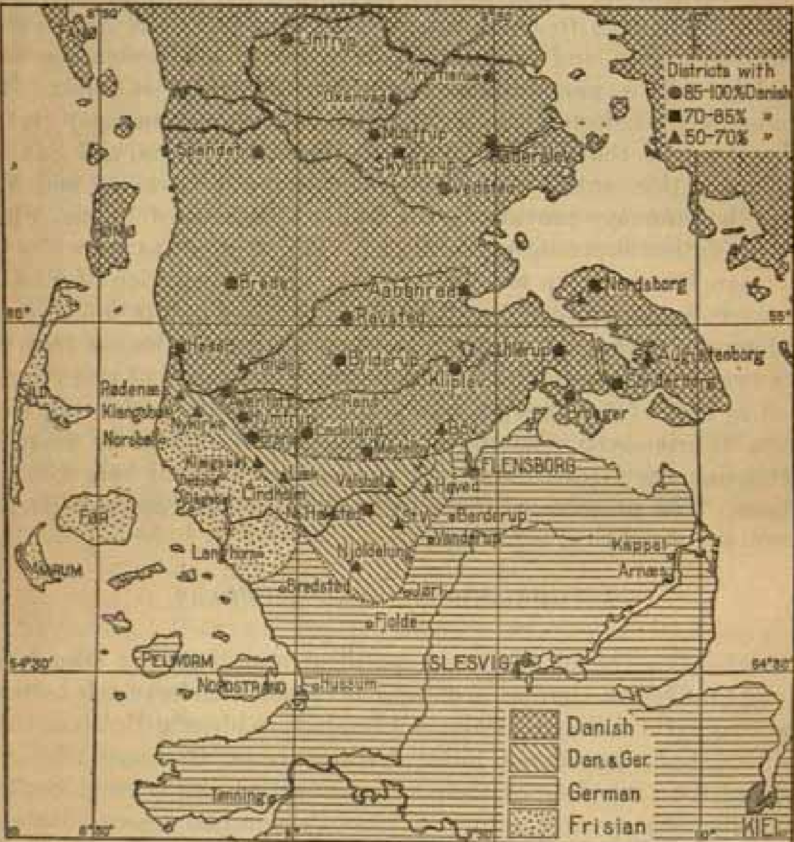

FIG. 2.—Sketch map of Schleswig-Holstein showing languages spoken. According to the Danish viewpoint. Scale, 1:1,200,000 (after Rosendal based on Clausens and Heyers).

of the land. The Niederdeutsch of the long Baltic plain also continued to spread unimpeded within the low-lying western portion of the narrow peninsula until its northerly expansion was arrested by uninhabited heath land. The presence of Frisian along the western coast is undoubtedly connected with the adaptability of Frisians to settle in land areas reclaimed from the sea.

The Province of Schleswig began to acquire historical prominence as an independent Duchy in the twelfth century. Barring few inter-

ruptions its union with the Danish Crown has been continuous to the time of the Prussian conquest. In 1848 both Schleswig and Holstein were disturbed by a wave of political agitation, which expressed itself in demands for the joint incorporation of both States in the German Confederation. The extent to which the mass of the Danish inhab-

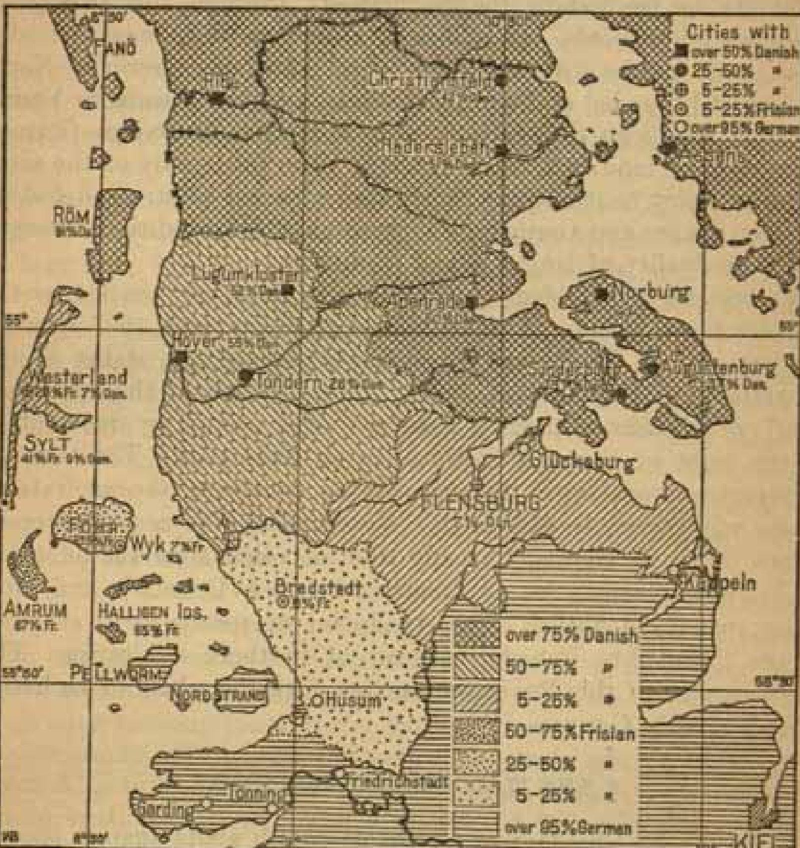

FIG. 2.—Sketch map of Schleswig-Holstein showing languages spoken. According to the German viewpoint. Scale, 1:1,200,000. (Based on maps on pp. 59 and 60, Andree's Handatlas, 6th ed.)

itants of the Duchies took part in this movement is open to historical controversy. Holstein was an ancient fief of the old Germano-Roman Empire. Its population has always been largely German. But the Duchy of Schleswig is peopled mainly by Danes. By the terms[1] of the Treaty of Prague, of August 23, 1866, both Austria and Prussia had

[1] [Translation]: Art. V. His Majesty the Emperor of Austria transfers to His Majesty the King of Prussia all the rights which he acquired by the Vienna Treaty of Peace of 30th October, 1864, over the Duchies of Holstein and Schleswig, with the condition that the populations of the Northern Districts of Schleswig shall be ceded to Denmark if, by a free vote, they express a wish to be united to Denmark. E. Herstlet, The Map of Europe by Treaty, vol. 3, p. 1722, Butterworths, London, 1875.

agreed to submit final decision on the question of nationality to popular vote. The provisions of the clause dealing with the referendum, however, were not carried out, and on January 12, 1867, Schleswig was definitely annexed by Prussia.[1]

Incorporation of the Danish Province was followed by systematic attempts to Germanize the population[2] through the agency of churches and schools. In addition, a number of colonization societies, such as the "Ansiedelungs Verein für das westliche Nordschleswig," founded at Rödding in 1891,[3] and the "Deutsche Verein für das nördliche Schleswig," were formed to introduce German ownership of land in Danish districts. The final years of the nineteenth century in particular constituted a period of strained feeling between Danes and Germans, owing to unsettled conditions brought about by duality of language and tradition.

At present the problem of Schleswig is considered settled by the German Government. A treaty signed on January 11, 1907, between the cabinets of Berlin and Copenhagen defined the status of the inhabitants of the annexed duchy. The problem of the "Heimatlose," or citizens without a country,[4] was solved by recognition of the right of choice of nationality on their part. The German Government considered this measure as satisfying the aspirations of its subjects of Danish birth. Nevertheless, the acquiescence of Danes living in Germany to any solution other than the adoption of linguistic boundaries as frontiers between Denmark and Germany remains doubtful. The standpoint of speech gives evidence of the thoroughly Danish character of northern Schleswig. The southern part of this Province, together with the whole of Holstein, is undoubtedly German.

6. THE ITALO-GERMAN BOUNDARY.

The southern boundary of Germanic speech abuts against Italian from Switzerland[5] to the Carinthian Hills. Along this contact zone a notable intrusion of the Romanic tongue within the Austrian political line is observable in the Tyrol. This foreign area lacks homogeneity, however, for it is Italian proper in western Tyrol and Ladin in its eastern extension.

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[1] A later treaty signed by Austria and Prussia at Vienna on Oct. 11, 1878, suppressed the referendum clause, which had never been viewed with favor by the German Government.

[2] M. R. Waultrin, Le rapprochement dano-allemand et la question du Schleswig. Ann. Sci. polit., May 15 and July 15, 1903.

[3] L. Gasselin, La Question du Schleswig-Holstein, Rousseau, Paris, 1909.

[4] L. Gasselin, loc. cit., p. 206.

[5] Blocher u. Garraux, Die deut. Ortsnamenformen in Westschweiz. Deut. Erde, 5, 1906, p. 170.

The southerly advance of German in the mountainous province has followed the valleys of the Etsch and Eisack, showing thereby that the channels through which mountain waters flowed toward the Adriatic also facilitated transit of goods and the language of the traders from the German highlands of central Europe to the Mediterranean. A steady current of freight has been maintained in a southerly course along this route since the origins of continental commerce in Europe. By the Middle Ages numerous colonies of German merchants had acquired solid footing along the much-traveled road over the Brenner Pass, which connected Augsberg and Venice.[1]

This protuberance of German occupies the valley of the Etsch south of its confluence with the Eisack. The divide between the two languages has its westernmost reach at Stelvio, near Trafoi.[2] The junction of Swiss and Austrian political boundaries at this point corresponds to the contact between the German of the Tyrol and the Romonsh idioms of Engadine. Thence the linguistic line of separation skirts the base of the Ortler massif and subsequently coincides with the watershed of the Etsch and Noce Rivers. Ladin settlements begin north of the Fleims Valley[3] and spread beyond the Gröden Basin to Pontebba and Malborghet, where the meeting of Europe's three most important linguistic stocks, the Romanic, Germanic, and Slavic, occurs.

The Italian section of the Tyrol constitutes the Trentino of present-day Italian irredentists. As early as 774 Charlemagne's division of the region between the Kingdoms of Bavaria and of Italy had implied recognition of linguistic variations. But the importance of maintaining German control over natural lines of access to southern seas determined his successors to award temporal rights in the south-eastern Alps to bishops upon whose adherence to Germanic interests reliance could be placed. The bishopric of Trentino thus passed under the Teutonic sphere of influence, which is preserved to-day by the political union of the territory of the old see to the Austrian Empire. Definite annexation of the Trentino to the Province of Tyrol took place in 1815.

In its eventful history during the present millennium the Tyrol has been the cockpit of Germano-Romance clashes. A lively trade competition between German and Italian traders has ever been maintained within its borders. During the era of religious upheavals the Germans rallied to the cause of reformation, while the Italian element remained faithful to the authority of the Vatican. Contact

[1] O. Noel, Histoire du Commerce du Monde, 2, pp. 148–168. Plon, Paris, 1891.
[2] B. Auerbach, Races et Nationalités en Autriche-Hongrie, Alcan, Paris, 1898, p. 86.
[3] Schneller, Deutsche u. Romanen in Südtirol u. Venetien. Petermanns Mitt., 1877, pp. 365–385.

with the Teutonic element appears to have failed, however, to eradicate or modify the Italian character of the region's institutions or its life.[1] In this respect the colossal statue of Dante in front of the main railway station in the city of Trent symbolizes faithfully the aspirations of the majority of the inhabitants of the Trentino.

7. THE ITALO-SLAVIC BOUNDARY.

The Adriatic provinces of the Austro-Hungarian Empire are peopled mainly by Italians and Slavs. German and Hungarian elements in the population consist of civil and military officials as well as of merchants. From an ethnological and linguistic standpoint the maritime district is Italian or Slav according to its elevation. The Romanic stock forms the piedmont populations, while the dwellers of the hilly coast chains are of Slavic issue and speech.

The western coast of the Istrian Peninsula is an area of Italian speech. The vernacular of Dante is, however, feebly represented in the Dalmatian Islands and on the Illyrian coast.[2] It is generally confined to urban centers. Zara, Spalato, Sebenico, Ragusa, and Cattaro[3] contain flourishing colonies of Italians, whose secular commercial enterprise has contributed to establish prevalence, if not predominance, of their mother tongue in the region. Outside of these cities the Italian element wherever present is restricted to littoral strips. The Slavs invariably occupy the inland plateau and the slopes extending seaward.

The Istrian region of predominant Italian speech consists of the western peninsular lowland extending south of Triest[4] to the tip of the promontory beyond Pola.[5] Istrians, to whom Italian is a vernacular, form over a third of the peninsula's population. The Slavs of the Karst and terraced sections constituting the balance belong to the Roman Catholic faith, but have no other common bond with their Italian countrymen.

Settlement by Slavs of the hills dominating the Adriatic appears to have taken place continuously between the ninth and seventeenth centuries. Feudal chiefs of medieval times first resorted to this method of developing the uncultivated slopes and highlands of the eastern coast. The Venetian republic and the Austrian govern-

[1] A. Galanti, I Tedeschi sul versante meridionale delle Alpi, Typ. Acad. Lincei, Rome, 1885, p. 185.

[2] It is estimated that, in all, about 18,000 Italians live in Dalmatia.

[3] Italian predominates in both Zara and Spalato, the latter city being second in commercial importance along the Dalmatian coast.

[4] The city of Triest is peopled mainly by Italians. Its suburbs, however, are inhabited by crowded Slavic settlements. The census of 1910 shows 142,113 Italians, 57,063 Slovenes, 9,689 Germans, and 1,442 Croats. For Istria returns of the same year give 147,417 Italians, 168,184 Serbo-Croatians, and 55,134 Slovenes.

[5] M. Wutte, Das Deutschtum im österreichischen Küstenland. Deut. Erde, 8, 1909, p. 202.

ment adopted similar measures of colonization. Slavic tribes hard pressed by their kinsmen or by Tatars from the east thus found refuge in the mountainous Dalmatian coastland under the ægis of western nations. A traveler taking ship to-day and sailing from harbor to harbor along the shores of the eastern Adriatic could readily notice numerical predominance of the descendants of Slavs, who, for that section of the world, constitute the mass of toilers in every walk of life and who sooner or later will probably erect a political fabric on the foundation of their linguistic preponderance.

8. THE AREA OF FINNISH SPEECH.

The eastern half of the European land mass contains a region of excessive linguistic intermingling[1] along the contact zone of the Germanic and Slavic races. The Finns occupying the northernmost section of this elongated belt are linguistically allied to the Turki. Physically they constitute the proto-Teutonic substratum of the northern Russians, with whom they have been merged. Their land was transferred from Sweden to Russia in 1808. Autonomy conceded by the Czar's Government until rescinded by the imperial decree of February 15, 1899, provided the inhabitants with a tolerable political status. The opening years of the present century marked the inception of a policy of Slavicization prosecuted with extreme vigor on the part of the provincial administrators.

The area of Finnish speech forms a compact mass extending south of the sixty-ninth parallel to the Baltic shores. Its complete access to the sea is barred by two coastal strips in the Gulfs of Bothnia and Finland, in both of which Swedish predominates in varying percentages.[2] The group of the Aland Islands, although included in the Czar's dominions, are also peopled by Swedes all the way to the southwestern point of Finland.[3]

This broken fringe of Swedish is conceded to be a relic of the early occupation of Finland by Swedes.[4] The Bothnian strip is remarkably pure in composition. The band extending on the northern shore of the Gulf of Finland, however, contains enclaves of the Finnish element. This is ascribed to an artificial process of "Fennification," resulting from the introduction of cheap labor in the industrial regions of southern Finland. Slower economic development of the Provinces of the western coast, on the other hand, tends to maintain undisturbed segregation of the population.

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[1] H. Nabert, Verbreitung der Deutschen in Europa, 1 : 925,000. Flemming, Glogau.

[2] Atlas de Finlande, carte 46, Soc. de Géogr. de Finlande, Helsingfors, 1911.

[3] K. B. Wiklund, Språken i Finland, 1880–1900, Ymer, 1905, 2, pp. 132–149.

[4] R. Saxen, Répartition des Langues. Fennia, 30, 2, 1910–1911, Soc. de Géogr. de Fin., Helsingfors, 1911.

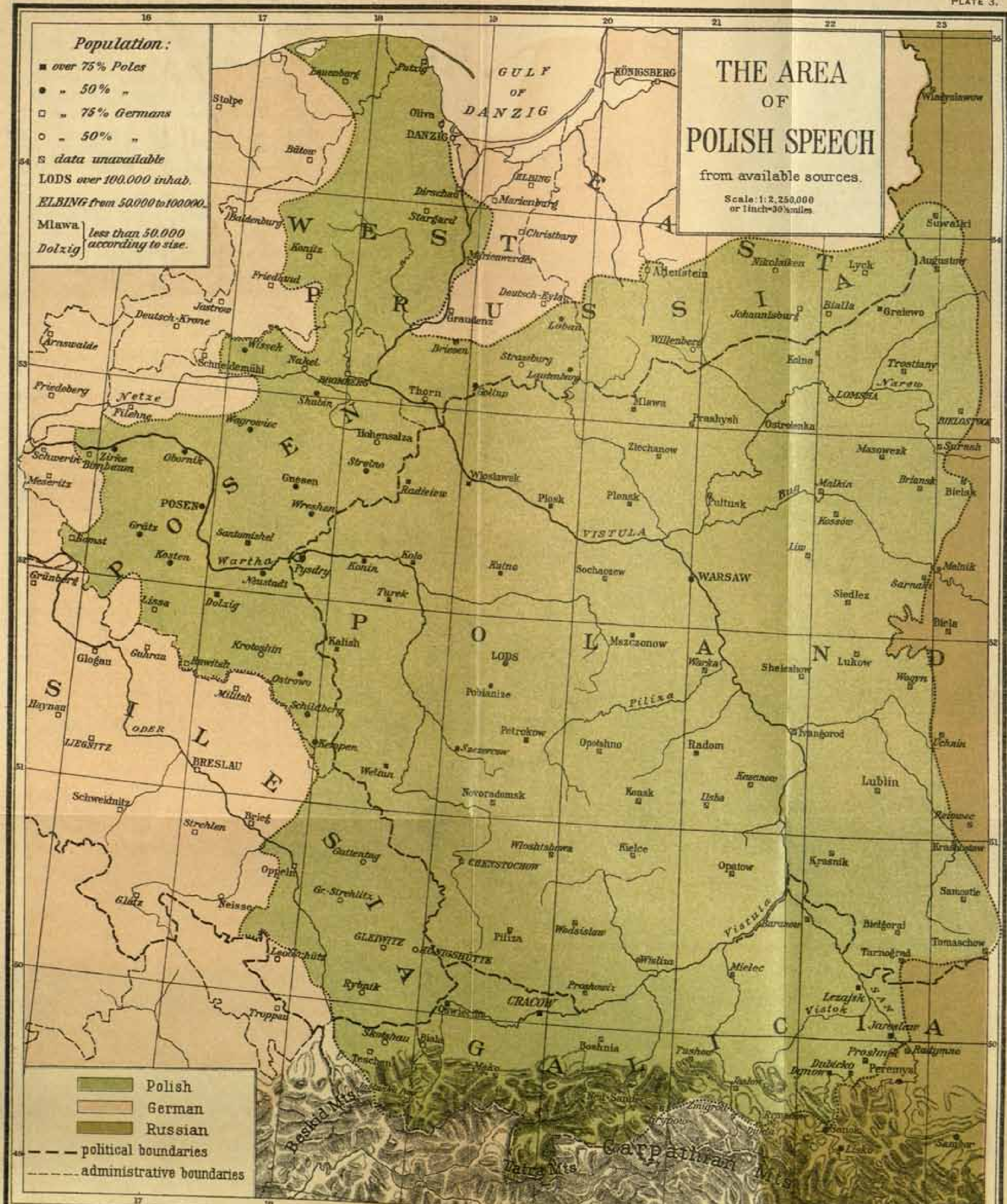
9. THE AREA OF POLISH SPEECH.

South of the Baltic the unbroken expanse now peopled by Germans merges insensibly into the western section of the great Russian plain. This extensive lowland is featureless and provides no natural barriers between the two empires it connects. The area of Polish speech alone intervenes as a buffer product of the basin of the middle Vistula. The region is a silt-covered lowland, which has emerged to light subsequently to the desiccation of a system of glacial lakes of recent geological age. It appears to have been inhabited by the same branch of the Slavic race since the beginning of the Christian era. It was the open country in which dearth of food and the consequent inducement to migration did not exist. The development of Poland rests primarily on this physical foundation. Added advantages of good land and water communication with the rest of the continent likewise contributed powerfully to the spread of Polish power, which at one time extended from the Baltic shores to the coast of the Black Sea.

The language is current at present within a quadrilateral, the angles of which are determined by the Jablunka pass in the Carpathians, Zirke on the Wartha, Suwalki in the eastern Masurian region and Sanok on the San. A northern extension is appended to this linguistic region in the form of a narrow band which detaches itself from the main mass above Bromberg and reaches the Baltic coast west of Danzig. In sum, from the Carpathians to the Baltic, the valley of the Vistula constitutes both the cradle and the blossoming field of Polish humanity and its institutions. In spite of the remoteness of the period of their occupation of the land, these children of the plains never attempted to scale mountainous slopes. The solid wall of the western Carpathians between Jablunka and Sanok, with its abrupt slopes facing the north, forms the southern boundary of the country.

This unit region in the midst of the diversity of the surface of the European continent has produced a unit language in the varied stock of European vernaculars. Uniformity of speech was thus the result of the unifying influence of a region characterized by a common physical aspect. Nevertheless, similarity of physical type among all individuals speaking Polish does not exist. Marked anthropological differences are found between the Poles of Russian Poland and of Galicia.[1] They correspond to the classification of northern Slavs into two main groups, the northernmost of which comprises the Poles of Russian Poland, together with White and

[1] J. Talko-Hryncevicz, Les Polonais du Royaume de Pologne d'après les données anthropologiques recueillies jusqu'à présent. Bul. Int. Ac. Sc. Cracovie, Classe des Sc. Math. et Nat. Bul. Sc. Nat., Juin, 1912, pp. 574–582.


THE AREA
OF
POLISH SPEECH
from available sources.
Scale: 1:2,250,000
or 1 inch=30½ miles.
Population:
over 75% Poles
„ 50% „
„ 75% Germans
„ 50% „
data unavailable
LODS over 100.000 inhab.
ELBING from 50.000 to 100.000
Mlawa
Dolzig
less than 50.000 according to size.
Polish
German
Russian
political boundaries
administrative boundaries
GULF OF DANZIG
WEST PRUSSIA
EAST PRUSSIA
POSEN
SILESIA
POLAND
GALICIA
DANZIG
KÖNIGSBERG
POSEN
BRESLAU
WARSAW
LODS
CRACOW
VISTULA
Wartha
Netze
ODER
Pilica
Narew
Bug
Beskid Mts.
Tatra Mts.
Carpathian Mts.

Great Russians. Traces of Finnish intermixture can still be detected among them, in spite of the process of Slavicization which they have undergone. The Poles of Galicia, on the other hand, like the Ruthenians and Little Russians, reveal crossing of autochthonous populations with Asiatic and Mongoloid invaders of Europe.[1]

The southeastern extremity of the language attains the sources of the Moravka, an affluent of the Ostrawica. In this district the line of demarcation between Ruthenians and Poles passes through Tarnograd and along the San Valley. Its southern extension skirts the foothills through Rymanow, Dukla, Zmigrad, Gorlica, and Gribow.[2] Thence to Jablunka it merges with the political boundary.

In its western section the physical boundary coincides for all practical purposes with the ethnographic line of division. The Polish-speaking Gorales mountaineers have never aspired to cross the divide of the Beskid Mountains. The result is that the gentler slopes of the southern side are peopled altogether by Slovaks, while habit and custom have prevented the Podhalians or Polish shepherds inhabiting the high valley of the Tatra from leading their flocks to the southern grazing slopes which form part of the Hungarian domain.[3]

Changes in the aspect of the land resulting from human activity provide an easily observable boundary between the territory inhabited by Poles and that occupied by Ruthenians. The first, proceeding from the Vistula lowland, are now scattered over a territory in which deforestation and large areas of tilled soil bespeak prolonged human occupancy of the land. The latter, coming from the Pontic steppes, reached the Carpathian slopes much later than their western neighbors. Consequently, only 20 per cent of the surface of the western Carpathians is now available as prairie and pasture land, whereas the percentage of grazing land in the eastern

[1] Southern Poland was overrun by Mongolians during their third invasion of Europe. The Asiatics were attacked near Szydlow on March 18, 1241, by an army of Polish noblemen recruited from Sandomir and Cracow. The defeat of the Christians enabled the invaders to plunder the latter city, besides opening the way for incursions farther north in the course of which they penetrated into Silesia by way of Ratibor and marched toward Breslau. Near Liegnitz an army of 30,000 Europeans was defeated again on Apr. 9 of the same year. These disasters were followed by a westerly spread of the Tatar scourge. Traces of its passage can still be detected among Poles.

[2] The Poles constitute the majority in the population of many cities in eastern or Russian Galicia. In Niederle's list Bobrka, Muszyna, Sanok, Lisko, Sambor, Peremysl, Rawaruska, Belz, Zolkiew, Grodek, Ceshanow, Stryj, Kalusz, Stanislawoff, Kalomya, Tarnopol, Husiatyn, Buczacz, Sokal, and Trembowla are credited with over 50 per cent Poles in their population. On the other hand, the predominance of German in the cities of Biala, Sczerzec, Dolina, Bolechow, Nadworna, Kossew, Kuty, Zablotow, and Brody is attributed by the same authority to the Jewish element present. L. Niederle, La Race Slave, Alcan, Paris, 1911. A digest in English of his conclusions will be found in Ann. Rep. Smiths. Inst., 1910, Washington, 1911, pp. 599–612.

[3] E. Reclus, Géogr. Univ., vol. 3, Europe Centrale. Hachette, Paris, 1878, p. 396.

section of the mountain chain is twice as high.[1] The area of plowed land in the western region covers between 40 and 50 per cent of the surface. In the east it barely varies between 5 and 10 per cent. Again, the Polish section is practically clear of the forests which cover in contrast from 50 to 60 per cent of the eastern Carpathians. Similar differences can be noted in the valleys up to an altitude of about 2,300 feet. Within them the proportion of plowed land constitutes 88 per cent of the surface in the Polish section. In the Ruthenian areas they do not exceed 15 per cent.

On the southwestern border the line attains the Oder in the vicinity of Bohumin. Here a number of localities in the Teschen country are claimed alike by Bohemians and Poles. The increasing use of Polish and German, however, tends to invalidate the claims of Bohemians.[2] A transition zone between Bohemian and Polish exists here and is characterized by a local dialect of mixed language.

The western linguistic boundary of Poland extends through the German Provinces of Silesia and Posen. Here a gradual replacement of the language by German since the sixteenth century is noticeable. At that time the Oder constituted the dividing line. As late as 1790 the population of Breslau was largely Polish. To-day over 75 per cent of the inhabitants of the city and of neighboring towns and villages are Germans. The district north and south constitutes in fact an area of linguistic reclamation. The westernmost extension of Polish occurs in Posen at the base of the provincial projection into Brandenburg. Around Bomst the percentage of Polish inhabitants is as high as 75 per cent. The line extends northward through Bentschen to Birnbaum, after which it assumes a northeasterly direction. In spite of this western extension, however, the area of Polish speech within German boundaries is broken in numerous places by German enclaves of varying size.[3]

In western Prussia the Poles form linguistic islands in the German mass and attain Baltic shores, where they occupy the entire western coast of the Gulf of Danzig. From Oliva and Danzig the line extends to Dirschau (Tezew) and crosses the Vistula about 6 miles below this city. It then strikes east to Altmark, whence it turns southward toward Marienwerder (Kwidzyn) and Graudenz (Grudziadz). Proceeding due east from here the boundary passes through Eylau, Osterode, the southern territory of the Masurian lakes and

[1] E. Romer, Esquisse Climatique de l'Ancienne Pologne. Bul. de la Soc. Vaud. des Sc. Nat., 5e Sér., vol. 46, June, 1910, p. 231.

[2] J. Zemmrich, Deutsche und Slaven in den österreichischen Sudetenländern, Deut. Erde, 2, 1903, pp. 1–4.

[3] P. Langhans, Nationalitäten-Karte der Provinz Schlesien, 1 : 500,000. Sonderkarte No. 1 in Deut. Erde, 1906; id., Nationalitäten-Karte der Provinz Ostpreussen, 1 : 500,000. Sonderkarte No. 1 in Deut. Erde, 1907.

on into Russian territory until Suwalki is reached. The eastern frontier begins at this point and is prolonged southward, according to Slav authorities, through Augustow, Bielostock, Surash, Bielsk, Sarnaki, and Krasnostaw.[1]

The struggle for predominance between Poles and Germans along Poland's western boundary is fully nine centuries old. In the sixth century Slavonic tribes had become widely distributed between the Oder and Elbe in the course of westerly expansions which correspond to south and west migrations of Teutonic peoples.[2] The beginning of the present millennium witnessed the inception of a slow and powerful Germanic drive directed toward the east. Repeated German aggressions brought about the earliest union of all Polish tribes into one nation at the beginning of the eleventh century. It proved, however, of little avail before the fighting prowess of the knights of the Teutonic Order who, by the first half of the thirteenth century, had succeeded in adding all Wend territory to Teutonic dominions. This early and northern phase of the "Drang nach Osten" brought the Germans to the coast of the Gulf of Finland. Their advance was rendered possible in part by the presence of Tatar hordes menacing southern Poland. Teutonic progress was also facilitated by the condition of defenselessness which characterizes an open plain. Between the Oder and the Vistula the slightly undulating lowland is continuous and devoid of barriers to communication which the interposition of uplifted or uninhabitable stretches of territory might have provided.

Polish history has been affected both favorably and adversely by this lack of natural bulwarks. The one-time extension of Polish sovereignty to the coasts of the Baltic and Black Seas or to within 50 miles of Berlin and the central plateau of Russia was a result of easy travel in a plain. This advantage was more than offset by the evident facility with which alien races were able to swarm back into the vast, featureless expanse forming Polish territory. The very dismemberment of the country is in part the result of the inability of the Poles to resort to the protection of a natural fortress, where a stand against oppressing foes might have been made.

Poland's easterly expansion, with its prolonged and finally disastrous conflict with Russia, began after the battle of Grunwald in 1410. Although the Poles then inflicted a decisive defeat on the German knights, the western Provinces they had lost could not be regained. In this eastern field the basin of the Dnieper merged without abrupt transition into that of the Vistula, just as the basin

[1] Niederle, loc. cit., p. 73, but cf. H. Praesent, Russisch Polen, etc. Petermanns Mitt., vol. 60. Dec., 1914, p. 257.

[2] A. C. Haddon, The Wanderings of Peoples, University Press, Cambridge, 1912, p. 48.

of the Oder on the west had formed the western continuation of the Baltic plain. Four centuries of struggle with Russia ensued, until the Muscovite Empire absorbed the greatest portion of Poland.

The German element is slowly spreading eastward throughout the eastern provinces of Prussia which once formed part of the Kingdom of Poland. The emigration of Poles to central and western Germany partly accounts for the German gain. From the larger cities of eastern Germany, and more especially from Posen, Bromberg, Gnesen, and Danzig, steady flows of emigrants continually wend their way toward the industrial centers of the west, where they find higher wages and generally improved economic conditions. The German Government favors this expatriation of its Slav subjects. None of the vexations to which the Poles are subjected by Government officials in their native plains are tolerated in the Rhine Provinces of the Empire. The result is that notable colonies of Poles have sprung up in the vicinity of industrial centers like Düsseldorf or Arnsberg, in the Münster district and the Rhine Provinces. From a racial standpoint these Poles are practically indistinguishable from the Nordic type of Teuton. Their presence in Rhenish Prussia and Westphalia is no menace to German unity. They are so easily assimilated that the second generation, speaking German alone, forgets its antecedents and becomes submerged in the mass of the native population. Slav settlements are particularly numerous and dense along the Rhine-Herne Canal between Duisburg and Dortmund.[1] The heavy preponderance of Poles in certain administrative divisions of eastern Germany has, nevertheless, been unimpaired by the Polish emigration. Their percentage in the "circles" (Kreise) of Odolanow, Koscian, Ostrzeszow, Posen, Pszczynsk, Olesia, and Skwierzyn still exceeds 80 per cent of the total population. In the province of Posen the German-speaking inhabitants still are in the minority.

The Poles scattered in the eastern section of Germany constitute the largest foreign-speaking element in the Empire's population. Their number is estimated at 3,450,000 by Niederle. German census returns for 1900 give 3,086,489. It must be noted here that the percentage of Jews in German Poland is high, particularly in the urban areas, and that the practice of census takers is to classify them with the German or Polish population according to their vernacular. In Russia the last available census (1897) figures reveal the existence of 1,267,194 Jews[2] disseminated in the Polish provinces. This represents 13.48 per cent of the population of Russian Poland. Here,

[1] K. Closterhalfen, Die Polen in Niederrheinisch-westfällisch Industriebezirk 1905. 1 : 200,000. Pl. 16 in Deut. Erde, vol. 10, 1911.

[2] N. Troïnitsky, Premier Recensement général de la population de l'Empire de la Russie 1897. Vols. 1 and 2, Petrograd, 1905.

as elsewhere, they are rarely engaged in agricultural pursuits, but show tendency to invade prosperous towns and cities.[1]

In addition to drastic educational measures compelling study of their language, the Germans have resorted to wholesale buying of Polish estates in the sections of the kingdom of Poland which fell to the lot of Prussia when the country was partitioned. A colonization law (Ansiedelungsgesetz), decreed on April 26, 1886, placed large funds at the disposal of the German government for the purchase of land owned by Poles and the establishment of colonies of German settlers.[2] The measure was artificial and proved valueless against economic conditions prevailing in the regions affected. A decrease in the percentage of the Polish population of the estates acquired by purchase was rarely brought about. The new settlers could rarely compete with the natives. The most tangible result consisted of a mere substitution of German for Polish ownership. The mass of laborers and dependents on most of the large estates remained Poles, as they had been prior to the transaction. The breach between Poles and Germans was widened in part by the change of masters. Nevertheless, although returns corresponding to the sum of effort and money expended were not obtained, the measure has contributed to the advance of Teutonism in northeastern Europe.[3]

From the east, pressure corresponding to Teutonic battering, although exerted with less intensity, is applied by Russian endeavor to create national homogeneity. Of all the different members of the widespread Slavic race the Poles and Russians are the most closely related by speech. But the affinity ends here. The formidable barrier of religious differences hampers fusion of the two nationalities. Caught between the Slavic hammer of Russian orthodoxy and the anvil of Teutonic reformation, the Poles have remained staunch Catholics. Creed in this case has played a considerable part in the preservation of national spirit.

The problem of delimiting Polish national boundaries is complicated on the east and west by the absence of prominent surface

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[1] The Jews cluster especially in the eastern governments of Warsaw, Lomza, and Siedlce where their percentage varies between 15.6 and 16.4. This ratio is lower in the southern and western administrative divisions. In Kalisz it reaches only 7.2 per cent and is reduced to 6.3 per cent in Petrokow. In the cities the Jews constitute on an average slightly over a third of the population, although here again they are more numerous in the east. Cf. D. Aitoff, Peuples et Langues de la Russie. Ann. de Géogr., 15, Mai, 1909, pp. 9–25.

[2] A law passed in 1908 authorizes the state to acquire land in the administrative circles in which German interests require development of colonization. B. Auerbach, La Germanisation de la Pologne Prussienne: La loi d'expropriation, Rev. Polit. & Parlem., 57, July, 1908, pp. 109–125.

[3] P. Langhans, Nationalitätenkarte der Provinz Schlesien 1:500,000. Deut. Er., 1906, Sonderkarte 1; P. Langhans, Nationalitätenkarte der Provinz Ostpreussen 1:500,000, Deut. Er., 1907, Sonderkarte 1; Die Provinzen Posen und Westpreussen unter besonderer Berücksichtigung der Ansiedlungsgüter und Ansiedlung, Staatsdomänen und Staatsforsten nach dem Stande von 1 Januar, 1911, Deut. Erde, 10, Taf. 1, 1911.

features. The lines of linguistic parting can not be emphasized and are apt to be unstable. This circumstance detracts from their political value.

10. THE AREAS OF BOHEMIAN AND SLOVAKIAN SPEECH.

The Bohemians, who with the Moravians constitute Slavdom's European vanguard, occupy the mountain-girt plateau of Bohemia in the very heart of Europe. Here the steady advance of Teutons has prevented expansion of these Slavs along the valleys providing them with lines of easy communication with the rest of the continent. Bohemians and Moravians thus found themselves bottled up inside the mountainous rim of their land by the Germans of Germany and of Austria.

The German ring surrounding Bohemia is composed of sections representing various types of the Teutonic family. The southwestern element represents the Bavarian settlers from which it is descended. Farmers and woodsmen were introduced into the Böhmerwald as an inevitable phase of the exploitation of the mountainous area by religious communities of the 13th century. The end of the Thirty Years' War was marked by a new influx of Germans needed to repopulate the sorely devastated Bohemian districts. The Bavarian element, however, never reached the foot of the eastern slopes. Modern Bohemian resistance to its spread toward the plateau persists unflinchingly.

The Erzgebirge uplift is a German ethnographic conquest. For centuries its mineral wealth has attracted artisans from Franconia, Thuringia and Saxony. The mountain slopes resound to-day to the sound of the dialects of these ancient countries. The Saxon element prevails particularly among the inhabitants of the Elbe valley.

Farther east, descendants of natives of Lusatia and Silesia still use the vernacular of their ancestors in the upland formed by the Iser and Riesen ranges. The valleys of these mountains yield a steady stream of German-speaking inhabitants who wend their way toward the industrial towns of the southern plain. The German workingman's competition with his Bohemian fellow-laborer is keen, however, in this district and has not been marked by notable advance of the Teutonic idiom.

Linguistically the Bohemians and Moravians form a unit hemmed in by Germans on all sides except the east, where they abut against their Slovak kinsmen. Community of national aspirations is generally ascribed to these three Slavic groups, in which the Bohemian is the leading element. The union has been fostered by the lack of a literary language among Moravians with the consequent adoption

of Bohemian forms of style in writing. The numerical inferiority of the Slovaks[1] found strength in this alliance.

The Bohemian linguistic area presents homogeneity of composition which is seldom encountered in other parts of Austria-Hungary. Intermingling of Slav and Teuton elements has been slight in this advanced strip of Slavdom. Overlap of German occurs in banded stretches generally parallel to the political divide. It is particularly noticeable in the eastern angle formed by the junction of the Böhmerwald and Erzgebirge, where it almost attains the town of Pilsen.[2] Beyond in a northerly direction the volcanic area characterized by thermal springs lies within the German line. Reichenberg, the strenuous center of Teutonism, maintains easterly and westerly prongs of German in the Iser-Riesen uplifts and the Elbe valley, respectively. The German of Silesia spreads into Moravia along the Zwittau-Olmütz-Neu Titschen line.

A short stretch of the southern linguistic area coincides with the political frontier in the neighborhood of Taus, but the balance of the southern Böhmerwald overlooking Bohemian levels is German in speech from its crests to the zone in which widening of the valleys becomes established. The disappearance of this mountainous chain in southern Moravia coincides with a southerly extension of Bohemian in the valley of the March. Contact with Slovak dialects begins in the Beskid area.

Celts, Teutons, and Slavs have occupied in turn the Bohemian lozenge. The appellation of Czechs first appears in the 6th century. National consolidation begins with the country's conversion to Christianity three hundred years later and is maintained with varying fortunes until 1620. Bohemian political freedom suffered annihilation in that year on the battlefield of the White Mountain. After this defeat the land and its inhabitants lapsed into a state of historical lethargy. Half a century ago Bohemian was almost extinct. Fortunately, the high cultural attainment of some modern Bohemians succeeded in rousing their countrymen to a sense of national feeling. In particular, the fire of Bohemian patriotism has been kept alive by literary activity.

Successful attempts on the part of Hungarians to assimilate the Slovaks have caused these mountaineers to turn to their Bohemian kinsmen for assistance in the preservation of race and tradition. Merging of national aspirations has been facilitated by close linguisitc affinity. A Bohemian-Slovak body consisting of 8,410,998 individuals[3] thus came into being within the Dual Monarchy in

[1] Official Austrian figures estimate the number of Slovaks at slightly over 2,000,000. Slavic authorities generally give higher figures.

[2] J. Zemmich, Deutsche und Slawen in den österreichischen Südetenlandern, Deut. Erde, 2, 1903, pp. 1–4.

[3] Census returns for 1910. New Inter. Encyc., Dodd, Mead & Co., New York, 1914.

order to maintain resistance against German and Hungarian encroachments.

The Slovaks are mountain dwellers who have but slightly fraternized with Bohemians and Moravians, notwithstanding close racial and linguistic affinity. The course of centuries failed to change their customs or the mode of life led in the western Carpathians. The Hungarian plain unfolded itself below their rocky habitation without tempting them to forsake the seclusion of their native valleys. Their language holds its own as far east as the Laborec Valley. Junction with Polish is effected in the Tatra.

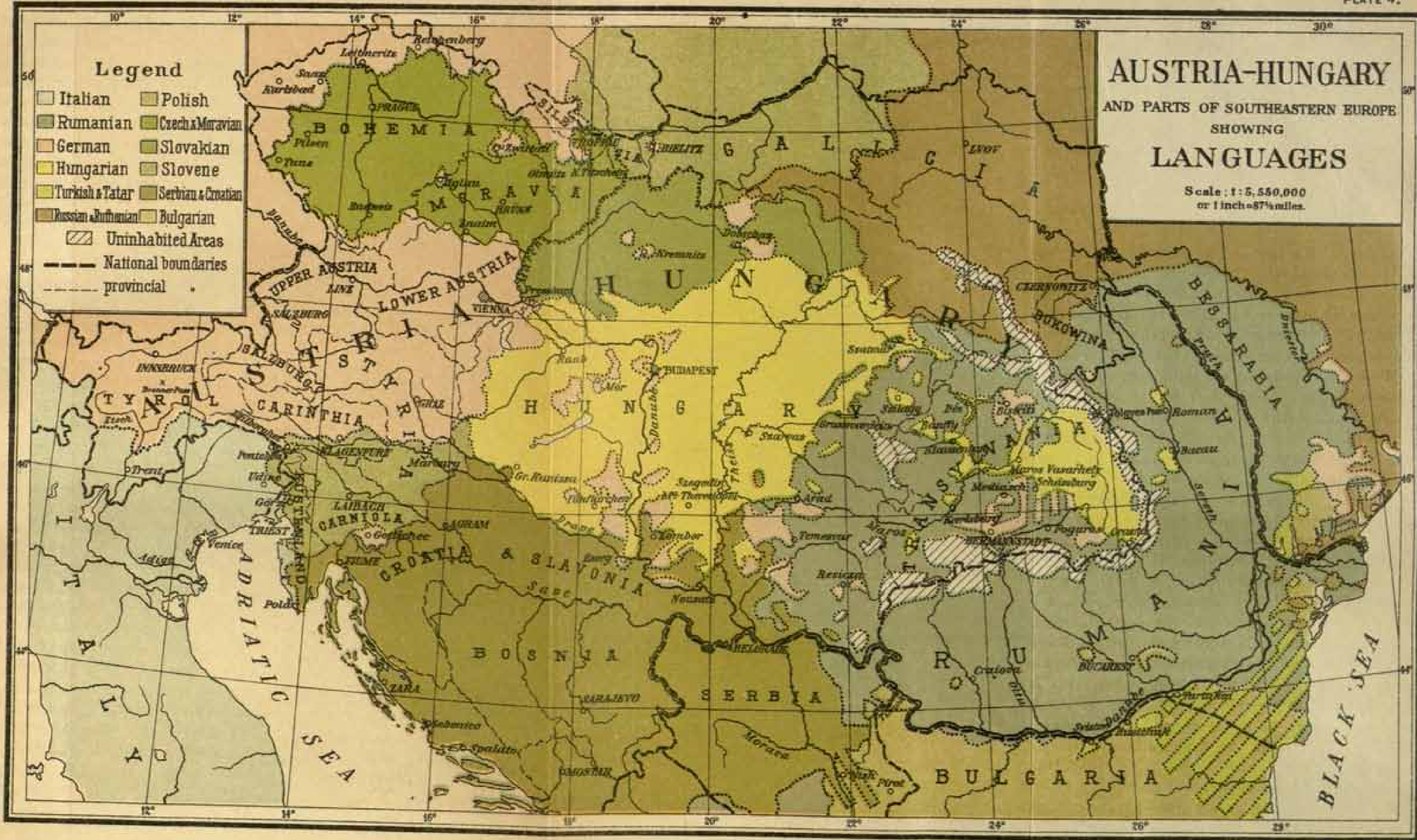
11. THE AREA OF HUNGARIAN SPEECH.

The presence in Europe of Hungarians, a race bearing strong linguistic and physical affinity to Turki tribesmen, is perhaps best explained by the prolific harvests yielded by the broad valleys of the Danube and Theiss. Huns, Avars, Hunagars, and Magyars, one and all Asiatics, wandering into Europe successively, were enticed into abandonment of nomadism by the fertility of the boundless Alföld. Western influences took solid root among these descendants of eastern ancestors after their conversion to Catholicism and the adoption of the Latin alphabet. So strongly did they become permeated by the spirit of occidental civilization that the menace of absorption by the Turks, their own kinsmen, was rendered abortive whenever the Sultan's hordes made successful advances toward Vienna. At the same time fusion with the Germans was prevented by the oriental origin of the race. The foundation of a separate European nation was thus laid in the Hungarian plains.

The linguistic boundary between Hungarian and German is found in the eastern extremity of the Austrian Alps.[1] The southern side of the Danube Valley between Pressburg and Raab is German. Magyar spreads, however, to the north to meet the Slovak area. The line then crosses the upper valleys of the Raab and attains the Drave, which forms the linguistic boundary between Croatian and Hungarian. East of the Theiss contact with the Rumanian of Transylvania begins in the vicinity of Arad on the Maros River and extends northward in an irregular line, hugging the western outlines of the Transylvania Alps, and attaining the sources of the Theiss. In the northeastern valley of this river Hungarian and Ruthenian language areas become contiguous.

The area of Magyar speech thus defined lacks homogeneity in its western section lying west of the Danube, where important enclaves of Germans are solidly entrenched. The central portion of the

[1] P. Hunfalvy, Die Ungarn oder Magyaren, pp. 104–120. Prochaska, Vienna, 1881.


AUSTRIA-HUNGARY
AND PARTS OF SOUTHEASTERN EUROPE
SHOWING
LANGUAGES
Scale: 1:5,550,000
or 1 inch=87½ miles.
Legend
Italian
Polish
Rumanian
Czech & Moravian
German
Slovakian
Hungarian
Slovene
Turkish & Tatar
Servian & Croatian
Russian & Ruthenian
Bulgarian
Uninhabited Areas
National boundaries
provincial
BOHEMIA
MORAVIA
GALICIA
HUNGARY
AUSTRIA
UPPER AUSTRIA
LOWER AUSTRIA
SALZBURG
STYRIA
TYROL
CARINTHIA
CARNIOLA
CROATIA & SLAVONIA
BOSNIA
SERBIA
BULGARIA
RUMANIA
BESSARABIA
BUKOWINA
TRANSYLVANIA
ITALY
ADRIATIC SEA
BLACK SEA
PRAGUE
VIENNA
BUDAPEST
LVOV
TRIEST
BUCAREST
BELGRADE
SARAJEVO
Danube
Save
Drave
Theiss

monotonous expanse unfolding itself between the Danube and the Theiss, on the other hand, is characterized by uniformity of the Hungarian population it supports. Enclaves exist again all along the eastern border of this area.

A minor group of Hungarians have settled on the eastern edge of the Transylvania Mountains. They live surrounded by Rumanians on all sides except on the west, where a lone outpost of Saxons brings Teutonic customs and speech to the east. The name of Szekler, meaning frontier guardsmen, applied to this body of Magyars, is indicative of their origin. Their presence on the heights overlooking the Rumanian plain bespeaks the solicitude of Hungarian sovereigns to control a site on which the natural bulwark dominating their plains had been raised. These Magyars represent at present the landed gentry of Transylvania.

This Hungarian colony was in full development at the end of the thirteenth century. Its soldiers distinguished themselves during the period of war with the Turks. Prestige acquired on the battle-field strengthened the separate and semi-independent existence of the community. The region occupied by these Hungarians is situated along the easternmost border of the Austro-Hungarian Empire. The towns of Schässburg and Maros Vasarhely lie on its western border. But the area of Rumanian speech situated between the land of the Szekler and the main Hungarian district is studded with numerous colonies of Magyars, thereby rendering delimitation of a linguistic boundary in the region almost impossible.

The Saxon colony adjoining the Szekler area on the west is also a relic of medieval strategic necessities. In spite of the name by which this German settlement is designated, its original members appear to have been recruited from different sections of western European regions occupied by Teutons.[1] Colonization had already been started when King Gesa II of Hungary gave it a fresh impulse in the middle of the twelfth century by inducing peasants of the middle Rhine and Moselle Valleys to forsake servitude in their native villages in return for land ownership in Transylvania.[2]

To promote the efficiency of the soldier colonists as frontier guardsmen an unusual degree of political latitude was accorded them. In time their deputies sat in the Hungarian diet on terms of equality with representatives of the nobility. The exigencies of prolonged warfare with the Tatar populations attempting to force entrance into the Hungarian plains determined selection of strategical sites

[1] F. Teutsch, Die Art der Ansiedelung der Siebenbürger Sachsen, Fors. z. deut. Land u. Volksk., vol. 9, pp. 1–22, 1896. Cf. also O. Wittstock, Volkstümliches der Siebenbürger Sachsen in the same volume.

[2] Luxemburg and the regions comprised between Treves, Düsseldorf, and Aix-la-Chapelle furnished many German colonists.

as nuclei of original settlements. These facts are responsible for the survival of the Teutonic groups in the midst of Rumanians and Hungarians. To-day the so-called Saxon area does not constitute a single group, but consists of separate agglomerations clustered in the vicinity of the passes and defiles which their ancestors were called upon to defend. The upper valley of the Oltu and its mountain affluents in the rectangle enclosed between the towns of Hermannstadt, Fogaras, Mediasch, and Schässburg contain at present the bulk of this Austrian colony of German ancestry.

12. THE AREA OF RUMANIAN SPEECH.

The Germans and Hungarians who founded settlements on the Transylvanian plateau were unable to impose their language on the inhabitants of the mountainous region. Rumanian, representing the easternmost expansion of Latin speech, is in use to-day on the greatest portion of this highland,[1] as well as in the fertile valleys and plains surrounding it between the Dniester and the Danube. A portion of Hungary and the Russian Province of Bessarabia is therefore included in this linguistic unit outside of the Kingdom of Rumania.[2] Beyond the limits of this continuous area the only important colony of Rumanians is found around Metsovo in Greece, where, in the recesses of the Pindus Mountains and surrounded by the Greeks, Albanians, and Bulgarians of the plains, almost half a million Rumanians[3] have managed to maintain the predominant Latin character of their language.[4]

The survival of Latin in an eastern land and in a form which presents closer analogies with the language of the Roman period than with any of its western derivatives had its origin in the Roman conquest of Dacia in the first decade of the second century. Occupation of the land by important bodies of legionaries and a host of civil administrators, their intermarriage with the natives, the advantages conferred by Roman citizenship, all combined to force Latin into current use. When in 275 Aurelian recalled Roman troops from the eastern Provinces of the Empire, the vernacular of Rome had taken such solid root in Dacia that its extirpation had become an impossibility.

[1] N. Mazere, Harta etnografica a Transilvanei 1 : 340,000, Inst. Geogr. al Armatei, Iasi, 1909.

[2] G. Weigand, Linguistischer Atlas des Dacorumänischen Sprachgebietes, Barth, Leipzig, 1909.

[3] Their number is given at 750,000 by G. Murgoeĕ and P. Papahagi in "Turcia cu privire speciala asupra Macedoniei," Bucarest, 1911. Greek computations, in contrast, rarely exceed the 100,000 figure.

[4] The total number of Rumanians in the Balkan peninsula is estimated at about 10,300,000 individuals, distributed as follows: Rumania, 5,489,296, or 92.5 per cent of the population; Russia, 1,121,669, of which 920,919 are in Bessarabia; Austria-Hungary, 3,224,147, of which 2,949,032 are in Transylvania; Greece, 373,520; Serbia, 90,000.

This abandonment of the region by the Romans is invoked for political reasons by the Magyar rulers of Transylvania in order to deny the autochthonous character of Rumanian natives of this Hungarian Province. Rumanian historians, however, have been able to demonstrate the untenability of this assumption.[1] Clues offered by geography also tend to validate Rumanian claims.

From the valley of the Dniester to the basin of the Theiss the steppes of southern Russia spread in unvarying uniformity, save where the tableland of the Transylvanian Alps breaks their continuity. The entire region was the Dacia colonized by the Romans.[2] Unity of life in this home of Rumanian nationality has been unaffected by the sharp physical diversity afforded by the enclosure of mountain and plain within the same linguistic boundary. The thoroughness with which Rumanians have adapted themselves to the pecularities of their land is evinced by the combination of the twin occupations of herder and husbandman followed by Moldavians and Wallachians. Cattle and flocks are led every summer to the rich grazing lands of the elevated Transylvanian valleys. In winter man and beast seek the pastures of the Danubian steppes and prairies. Rumanians thus maintain mountain and plain residences, which they occupy alternately in the year.[3] These seasonal migrations account for the intimacy between highlanders and lowlanders, besides affording adequate explanation of the peopling of the region by a single nationality.[4]

There was a time, however, when Rumanian nationality became entirely confined to the mountain zone. The invasions which followed the retirement of the Romans had driven Rumanians to the shelter of the Transylvanian ranges. Perched on this natural fortress, they beheld the irruption of Slavs and Tatars in the broad valleys which they had once held in undisputed sway. Only after the flow of southeastern migrations had abated did they venture to reoccupy the plains and resume their agricultural pursuits and seasonal wanderings.

The outstanding facts in these historical vicissitudes is that the mountain saved the Latin character of Rumanian speech. Had the Romanized Dacians been unable to find refuge in the Transylvanian Alps there is no doubt that they would have succumbed to Slavic or Tatar absorption. As it is, the life of Rumanians is

[1] A. D. Xenopol, Histoire des Roumains, Leroux, Paris, 1896.

[2] W. R. Shepherd, Historical Atlas. Holt, New York, 1911, pp. 34, 35, 39.

[3] Typical examples of seasonal migration are found in Switzerland, where conditions prevailing in the higher and lower valleys of the Alps have induced the inhabitants to shift their residence with the seasons.

[4] A similar nomadism is observable among the Rumanians of the Pindus Mountains; v. The Nomads of the Balkans: An account of life and customs among the Vlachs of Northern Pindus. By A. J. B. Wace and M. S. Thompson, Methuen, London, 1914.

strongly impregnated with eastern influences. Oddly enough, its Christianity was derived from Byzantium instead of from Rome, and were it not for a veritable renaissance of Latinism about 1860 its affinity with the Slavic world would have been far stronger in the present century.

13. THE AREA OF SLOVENE SPEECH.

Of the two groups of southern Slavs subjected to Austro-Hungarian rule the Slovenes are numerically inferior.[1] Settled on the calcareous plateaus of Carniola, they cluster around Laibach and attain the area of German speech, on the north, along the Drave between Marburg and Klagenfurt.[2] Eastward they march with Hungarians and the Serbo-Croat group of southern Slavs. Their southern linguistic boundary also coincides with the latter's. Around Gottschee, however, a zone of German intervenes between Slovene and Croatian dialects. Practically the entire eastern coast of the Gulf of Triest lies in the area of Slovene speech. The group thereby acquires the advantage of direct access to the sea, a fact of no mean importance among the causes that contribute to its survival to the present day in spite of being surrounded by Germans, Hungarians, Croats, and Italians.

The Slovenes may be considered as laggards of the Slavic migrations that followed Avar invasions. They would probably have occupied the fertile plains of the Hungarian "Mesopotamia" had they not been driven to their elevated home by the pressure of Magyar and Turkish advances. Confinement in the upland prevented fusion with the successive occupants of the eastern plains which unfolded themselves below their mountain habitations. Racial distinctiveness characterized by language no less than by highly developed attachment to tradition resulted from this state of seclusion.

14. THE AREA OF SERBIAN SPEECH.

South of the Hungarian and Slovene linguistic zones the Austro-Hungarian domain comprises a portion of the area of Serbian speech. The language predominates from the Adriatic coast to the Drave and Morava Rivers, as well as up to the section of the Danube comprised between its points of confluence with these two rivers.[3] Serbian, in fact, extends slightly east of the Morava Valley toward the Balkan slopes lying north of the Timok River, where

[1] 1,252,940, Census of 1910.

[2] P. Samassa, Deutsche und Windische in Südösterreich. Deut. Erde, 2, 1903, pp. 39–41, which cf. with Niederle's delimitation in La Race Slave, pp. 139–140.

[3] Scattered Serbian settlements are also found between the Danube and Theiss Valleys as far north as Maria-Thereslopel, and farther south at Zambor and Neusatz. Serbian is the language of the entire district of the confluence of the Theiss and Danube.

Rumanian prevails as the language of the upland.[1] To the south contact with Albanian is obtained.

The area of Serbian speech thus delimited includes the independent kingdoms of Montenegro and Serbia. Within the territory of the Dual Monarchy it is spoken in the provinces of Croatia, Slavonia, Bosnia, Herzegovina, and Dalmatia. The language is, therefore, essentially that of the region of uplift which connects the Alps and the Balkans or which intervenes between the Hungarian plain and the Adriatic.

Union between the inhabitants of this linguistic area is somewhat hampered by the division of Serbians into three religious groups. The westernmost Serbs, who are also known as Croats, adhere to the Roman Catholic faith in common with all their kinsmen, the western Slavs. Followers of this group are rarely met east of the 19th meridian. A Mohammedan body consisting of descendants of Serbs who had embraced Islam after the Turkish conquest radiates around Sarajevo as a center. The bulk of Serbians belong, however, to the Greek orthodox church. Cultural analogies between the Mohammedan and orthodox groups are numerous. Both use the Russian alphabet, whereas the Croats have adopted Latin letters in their written language.

The Serbian group made its appearance in the Balkan Peninsula at the time of the general westerly advance of Slavs in the fifth and sixth centuries. A northwestern contingent, wandering along the river valleys leading to the eastern Alpine foreland, settled in the regions now known as Croatia and Slavonia. Here the sea and inland watercourses provided natural communication with western Europe. Evolution of this northwestern body of Serbians into the Croatians of our day was facilitated by the infiltration of western ideas. But the great body of Serbians occupying the mountainous area immediately to the south had their foreign intercourse necessarily confined to eastern avenues of communication. They therefore became permeated with an eastern civilization in which Byzantine strains can be easily detected. In spite of these cultural divergences, the linguistic differentiation of the Croat from Serbian element has been slight.

To-day the political aspirations of this compact mass of Serbians are centered around the independent kingdom of Serbia, which is regarded as the nucleus around which a greater Serbia comprising all the Serbian-speaking inhabitants of the Balkan Peninsula will grow. This Serbo-Croatian element is estimated to comprise at least 10,300,000 individuals.[2]

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[1] Serbian authorities usually extend the zone of their vernacular to points farther east. Cf., J. Cvijić, Die Ethnographische Abgrenzung der Völker auf der Balkanhalbinsel. Petermanns Mitt., 59, I, March, 1913, pp. 113–118.

[2] J. Erdeljanović. Broj Srba i Khrvata, Davidović, Belgrad, 1911.

By its situation, the Serbian linguistic area and the rugged land over which it spreads afford a political and physical link whereby connection between problems pertaining respectively to western Europe and the Balkan peninsula is established. The process of nation-forging undertaken by Serbian-speaking inhabitants of southeastern Europe induces a southerly gravitation of Croatians and Bosnians. In opposition to this tendency, artificial forces are exerted at Vienna in order to prevent detachment of the Serbian element in the Dual Monarchy.

15. THE CASE OF MACEDONIAN.

Within the Balkan Peninsula linguistic groupings now conform to a large extent with the political divisions which ended the wars of 1912–13. Greater distance in time will undoubtedly afford an increasingly satisfactory perspective of the results which followed this attempt to totally eliminate the Turk from mastery over this portion of the European continent. Racial sifting followed close on territorial readjustments. Turks from all parts of the former Turkish Provinces transferred their lands to Christian residents and emigrated to Asia Minor. Special arrangements for this exodus were provided by the Turkish government. Greeks settled in the newly acquired Bulgarian and Serbian domain similarly sought new homes within the boundaries of the Hellenic kingdom. A heavy flow of Bulgarian emigrants is at present directed to Bulgaria from Bulgarian-speaking territory allotted to Serbia.[1]

Pressing need of further boundary revision on the basis of language is still felt in the Balkan peninsula. Resumption of hostilities in this part of Europe was due principally to the moot case of the nationality of the Slavs of Macedonia. Serbs and Bulgars claim them alike as their own. In reality the Macedonians constitute a transition people between the two. The land they occupy is surrounded by a mountainous bulwark which assumes crescentic shape as it spreads along the Balkan ranges, and the mountains of Albania and the Pindus. For centuries this Macedonian plain has constituted the cockpit of a struggle waged for linguistic supremacy on the part of Bulgarians and Serbs. The land had formed part of the domain of each of the two countries in the heyday of their national life. To this fact the present duality of claim must be ascribed in part.

The language of the Macedonians is likewise transitional between Serbian and Bulgarian. Its affinity with the latter, however, is

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[1] Such migrations generally follow boundary revisions. The crossing of Alsatians into French territory from the year 1870 on has been mentioned in its place above. A large number of Danes likewise abandoned their home in Schleswig-Holstein in 1865 and wandered into Denmark.

greater. It is, in fact, sufficiently pronounced to have generally led to its inclusion with Bulgarian. Travelers in the land of the Macedonian Slavs know that a knowledge of Bulgarian will obviate difficulties due to ignorance of the country's vernaculars. Serbian, however, is not as readily intelligible to the natives.

These relations have not illogically weighted the consensus of authority on the Bulgarian side. The result is that compilers of linguistic or ethnographic maps have generally abstained from differentiating the Macedonian from the Bulgarian area.[1] The impossibility for Bulgarians to regard the terms of the treaty of Bucarest as final are, therefore, obvious. Extension of the Rumanian boundary to the Turtukai-Black Sea line was also an encroachment on soil where Bulgarian was the predominant language.[2]

In its westernmost area the delimitation of a Bulgarian linguistic boundary is greatly hampered by the relatively large Serbian-speaking element on the north and a corresponding mass of Greeks on the south. Reliable statistics are still unavailable. The region in which determination of Bulgarian or Serbian linguistic predominance assumes its most complicated phase is found in the quadrangle constituted by Pirot-Nish-Vranja-Prisrend. Here the language of the Slavic natives departs equally from the Bulgarian and Serbian, between which it varies. This region, however, lies north of Macedonia proper. At the same time, there appears to be little room to doubt that the area of Bulgarian speech extends to the zone of the eastern Albanian dialects and that it attains the Gulf of Salonica. But the seafaring population of the Ægean coast is largely Greek except in the sections within Bulgarian boundaries which are now destitute of Greek fishermen.

The advance of Teutonic and Bulgarian forces in Serbia and Albania during the winter of 1915–16 has resulted in a westerly spread of the territory occupied by Bulgarians. Decision on the permanence of this occupation will rest with the peace congress to convene at the end of the present European war.

16. THE AREA OF ALBANIAN SPEECH.

Outside of Macedonia, a Balkan zone, in which political and linguistic boundaries fail to coincide, existed until recently in southern Albania. The frontier of this principality with Greece had been extended into a region in which Greek was undoubtedly spoken by

[1] D. M. Brancoff, La Macédoine et sa population Chrétienne, Plon, Paris, 1905. The Serbian viewpoint is resumed by J. Cvijić in "Ethnographie de la Macédoine," Ann. de Géogr., 15, 1906, pp. 115–132, and 249–266.

[2] It is estimated that 1,198,000 Bulgarians are still under foreign rule in the Balkans as a result of the treaty of Bucarest. Of these 286,000 live in Rumania, 315,000 in Greece, and 597,000 in Serbia. Cf. R. A. Tsanoff, Jour. of Race Develop., January, 1915, p. 251.

the majority of the inhabitants.[1] The Hellenic government, taking advantage of disturbances in Albania and the European war of 1914, despatched troops in the territory claimed by its citizens. As a result of this invasion the Albanian area of Greek speech is at this writing under Greek military occupation.[2]

The inhabitants of Albania are utterly devoid of national feeling. The formation of this independent state was a political move undertaken by Austrian statesmen to prevent expansion of Serbia to the Adriatic. Within the boundaries determined by the ambassadorial conference held in London in 1913, strife and dissensions prevail to-day as intensely as during the Turkish régime. Natives of the northern sections of the country speak Serbian dialects and are inclined to favor union with Serbia or Montenegro rather than independence. Malissori tribesmen fought side by side with Montenegrin troops in the fall of 1912, while the Albanians of Ipek gave assistance to Turkish regulars. The inhabitants of the valley of the upper Morava sent supplies to Serbian troops against which the chieftains of central Albania led their men. The purest type of Albanian found in the vicinity of Elbassan, Koritza, and Avlona[3] is practically submerged in a sea of Greeks. Under these circumstances partition of the country between Greece and Serbia might not be incompatible with native aspirations. Departure from linguistic differentiation in this case would probably be attended by political stability which could not be provided in any other manner.

17. CONCLUSIONS.

Certain inferences engage attention in this study of linguistic areas. Inspection of the map of Europe prepared for this article suggests strikingly that zones of linguistic contact were inevitably destined by their very location to become meeting places for men speaking different languages. They correspond to the areas of circulation defined by Ratzel.[4] The confusion of languages on their site is in almost every instance the result of human intercourse determined by economic advantages. In Belgium after the Norman conquest the burghers of Flanders were able to draw on English markets for the wool which they converted into the cloth that gave their country fame in the fairs of Picardy and Champagne.[5] We have here a typical example of Ratzel's "Stapelländern" or "transit regions." In a cross direc-

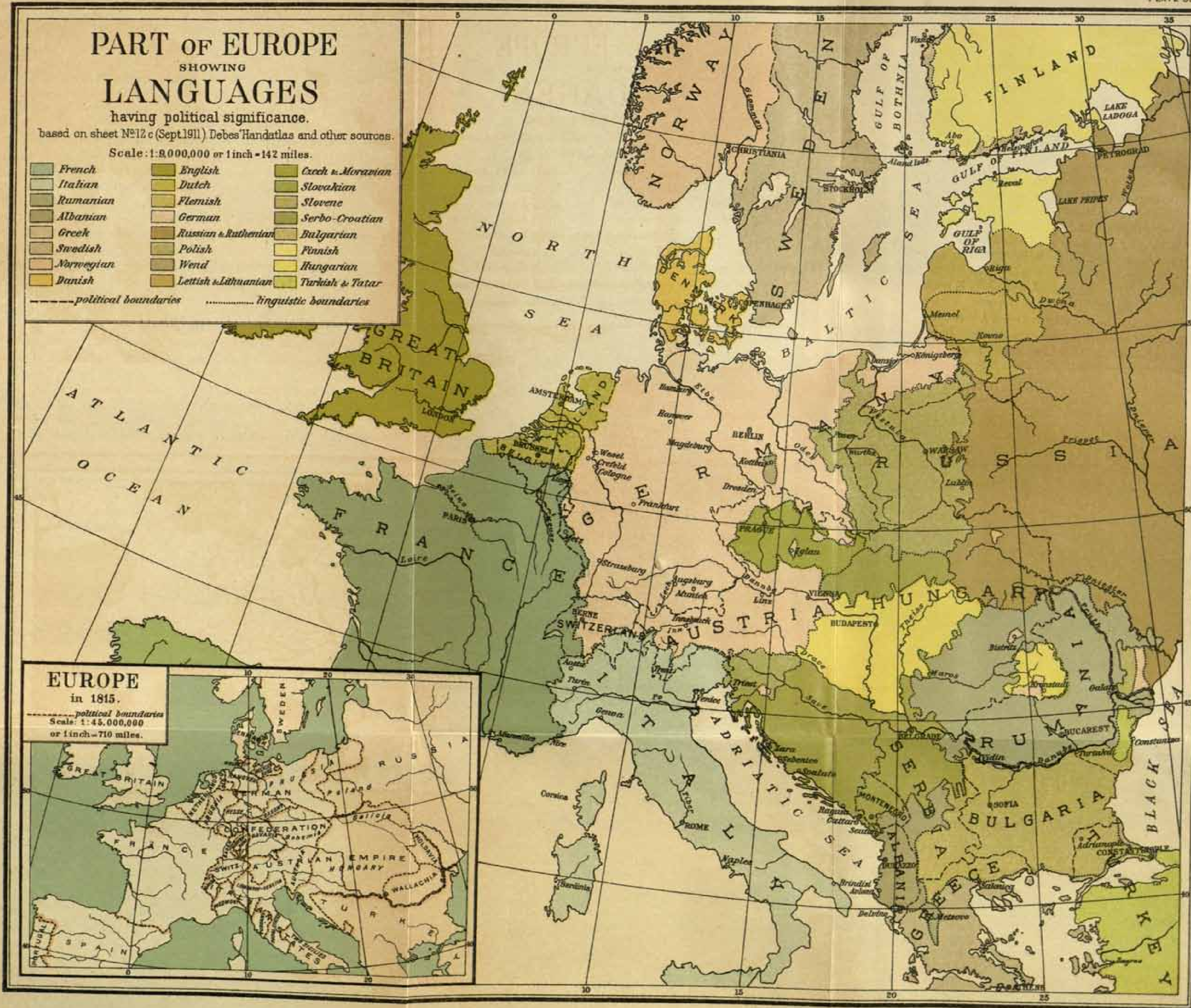
[1] R. Hüber, Carte Statistique des Cultes Chrétiens. 1 : 600,000. Baader & Gross, Cairo, 1910.

[2] L. Büchner, Die neue griechisch-albanische Grenze in Nordepirus. Petermanns Mitt. 61, 1915, February, p. 68.

[3] G. Gravier, L'Albanie et ses limites. Rev. de Paris, Jan. 1, 1913, pp. 200–224.

[4] F. Ratzel, Politische Geographie, 2d ed. Oldenbourg, Munich, 1903. Cf. chap. 16, "Der Verkehr als Raumbewältiger." pp. 447–534.

[5] R. Blanchard, La Flandre, Colin, Paris, 1906.


PART OF EUROPE
SHOWING
LANGUAGES
having political significance.
based on sheet No 12 c (Sept. 1911) Debes' Handatlas and other sources.
Scale: 1:8,000,000 or 1 inch = 142 miles.
French
Italian
Rumanian
Albanian
Greek
Swedish
Norwegian
Danish
English
Dutch
Flemish
German
Russian & Ruthenian
Polish
Wend
Lettish & Lithuanian
Czech & Moravian
Slovakian
Slovene
Serbo-Croatian
Bulgarian
Finnish
Hungarian
Turkish & Tatar
political boundaries
linguistic boundaries
NORTH SEA
ATLANTIC OCEAN
BALTIC SEA
ADRIATIC SEA
BLACK SEA
GULF OF BOTHNIA
GULF OF FINLAND
GULF OF RIGA
LAKE LADOGA
LAKE PEIPUS
GREAT BRITAIN
NORWAY
SWEDEN
DENMARK
FINLAND
RUSSIA
GERMANY
HOLLAND
BELGIUM
FRANCE
SWITZERLAND
AUSTRIA
HUNGARY
RUMANIA
SERBIA
MONTENEGRO
ALBANIA
BULGARIA
GREECE
ITALY
TURKEY
CHRISTIANIA
STOCKHOLM
COPENHAGEN
PETROGRAD
LONDON
AMSTERDAM
BRUSSELS
PARIS
BERLIN
WARSAW
PRAGUE
VIENNA
BUDAPEST
BELGRADE
BUCAREST
SOFIA
CONSTANTINOPLE
ROME
BERNE
ATHENS
Corsica
Sardinia
EUROPE
in 1815.
political boundaries
Scale: 1:45,000,000
or 1 inch = 710 miles.

tion the traffic of the Rhine ran at the end of the twelfth century from Cologne to Bruges along the divide between French and Flemish. Lorraine, inviting access from east and west, is known to historians as a Gallo-Germanic market place of considerable importance.[1] In our own time the river trade between Holland and Germany along the Rhine has caused expansion of Dutch into German territory as far as Wesel and Crefeld. The intruding language yields, however, to German everywhere.[2] Prevalence of French in parts of Switzerland is generally ascribed to travel through certain Alpine passes.[3] The penetration of German in the Trentino has already been explained. In Austria the entire valley of the Danube has provided continental trade with one of its most important avenues. I have called attention in a former article to the Balkan peninsula as an intercontinental highway.[4] In a word, language always followed in the wake of trade, and Babel-like confusion prevailed along channels wherein men and their marketable commodities flowed.

The history of Europe during the nineteenth century shows clearly that modern reconstruction of nationalities is based on language. Practically all the wars of this period are the outcome of three great constructive movements which led to the unification of Germany and of Italy, as well as to the disentanglement of Balkan nationalities. These were outward and visible signs of the progress of democratic ideals. The congress of Vienna failed to provide Europe with political stability, because popular claims were ignored during the deliberations. At present, inhabitants of linguistic areas under alien rule are clamoring for the right to govern themselves. The carrying out of plebiscites under international supervision can be relied upon to satisfy their aspirations and serve as a guide to frontier rearrangements.

All told, the growing coincidence of linguistic and political boundaries must be regarded as a normal development. It is a form of order evolved out of the chaos characterizing the origin of human institutions. The delimitation of international frontiers is as necessary as the determination of administrative boundaries or city lines. Human organization requires it and there is no reason why it should not be undertaken with a fair sense of the wishes and the feelings of all affected.

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[1] J. Vidal de la Blache, Étude sur la Vallée Lorraine de la Meuse, Colin, Paris, 1908, pp. 165–180.

[2] Cf. inset on pp. 63–64, Andree's Handatlas, 6th ed., 1915.

[3] J. Brunhes, La Géogr. Humaine, Alcan, Paris, 1912, pp. 598–599.

[4] The Balkan Peninsula, Bull. Amer. Geogr. Soc., vol. 45, no. 8, 1913.

EXCAVATIONS AT TELL EL-AMARNA, EGYPT, IN 1913–1914.[1]

By Ludwig Borchardt.

[With 13 plates.]

Following the discoveries of last year, which were mainly at the houses of the chief sculptor Thutmes and his workmen (pl. 1, P 47, 1–3), it was natural this year to investigate the adjoining estates, so far as they had not been previously excavated. The excavation was therefore started westward from the Thutmes' house and following the northern edge of the Wadi extended to the main street which connects the modern villages Hagg Qandil and Et-Till (see pl. 1). This street, corresponding to the main thoroughfare of the old city, was reached at house N 47, 1. There were also laid bare the groups of houses Q 48, 1–3 and O 48, 14–15 among the hills rising from the Wadi. Behind the first row of estates, west of "the street of the high priest" and north of the Wadi, the premises lying westward were disposed of as also a block of smaller estates, Q 46, 18–23, to the north of "the Christmas house" (Weihnachtshaus"), Q 46, 1. On the east side of this part of "the street of the high priest," between it and the eastern city line, several estates were cleared up, and the work was considerably advanced northward. The area of the city so far excavated was thus about the form of a T, the upper or horizontal bar running from south-southwest to north-northeast—from M 51 to Q 45—and the perpendicular bar extending from west-northwest to east-southeast—from N 47–48 to Q 48–49. The lower bar at the present state of the work appears split into two strips of houses separated by the Wadi, though it is certain that in ancient times the entire ground was fully built up.

Strange as it may appear, the ancient Egyptians in building up an area did not take the precaution to leave the lower levels free of structures. They apparently disregarded rains in distant parts of the desert which caused torrents to rush into the Nile Valley carry-

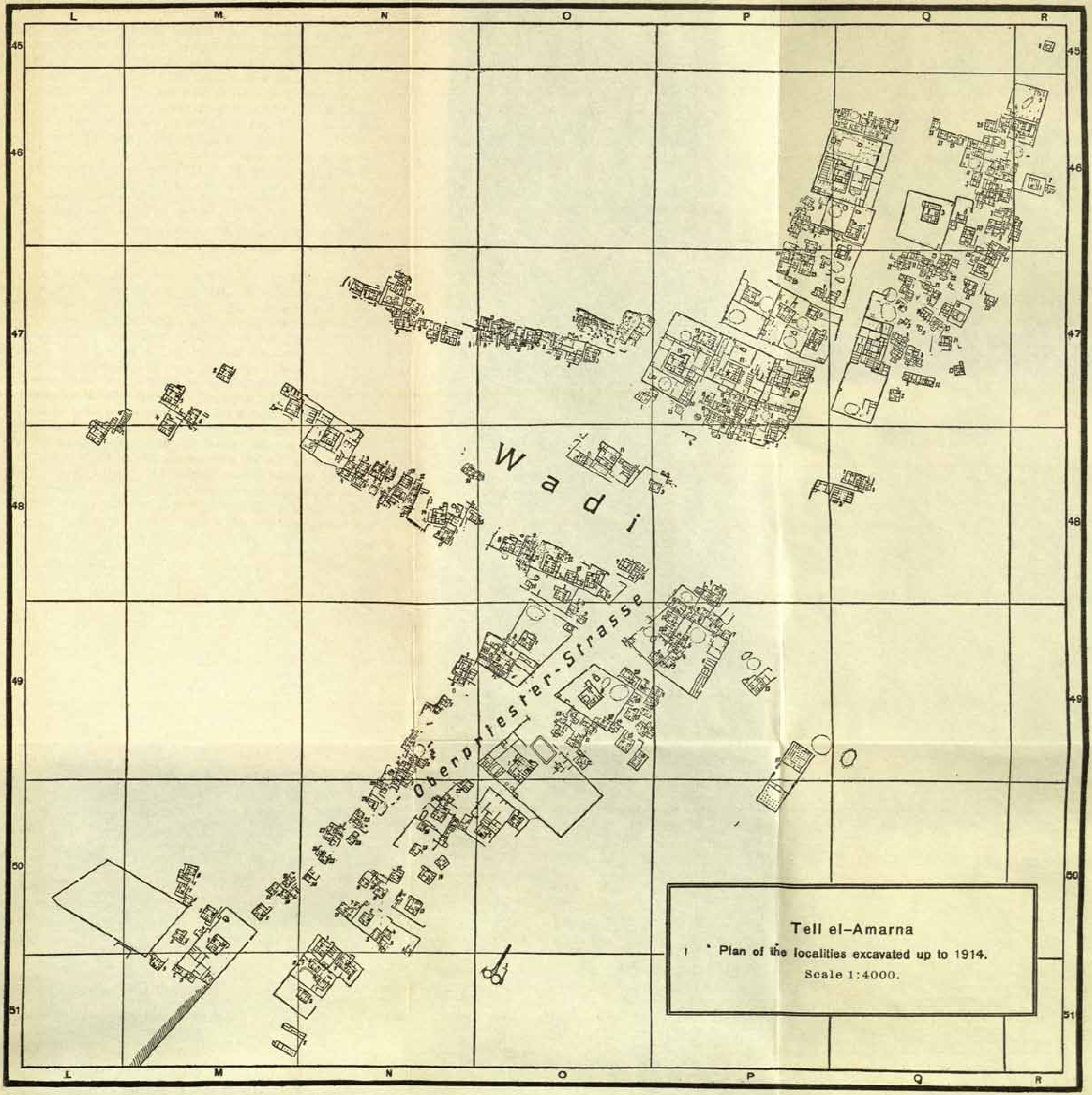
[1] Abstract translated from Mitteilungen der Deutschen Orient-Gesellschaft zu Berlin, No. 55, December, 1914, pp. 1–45.

ing everything before them, although the experience of millenniums should have taught them better. The difference of level which thus far could be established between the floor of house Q 48, 3 and that of N 47, 6 amounts to 4.50 meters which is quite a marked difference considering that these houses are only about 480 meters apart. The same mistake was made in the palace of Amenophis III, south of Medinet Habu, and elsewhere. The ancient Egyptian architects were, however, not alone in committing this error, for their modern colleagues and even Europeans building in Egypt do no better. As a result of this thoughtlessness and carelessness of transient engineers, parts of the railway dams, even in the recent decades, have often been swept away by floods, and in 1895 an entire corner of the place of Heluan in Cairo was carried off.

The appearance of the excavations in the Wadi differs from that in the rest of the city area. Elsewhere the house ruins appear as flat, desert hills where the still remaining upper rows of masonry are brought to light with the first stroke of the pick. In the Wadi a layer of sand or pebble, 0.5 to 1 meter deep, must first be removed before the upper parts of the walls, 1.5 meter or more in height, appear. The débris between the walls is here also more compact, due to alluviation and not merely to the rubbish from the upper buildings.

As the Wadis, which now form a break in the city area, must once have been fully built up, the extensive interruption of the ruin field in the neighborhood of the modern cemetery of Et-Till must be considered as only incidental, and those parts of the ruins formerly termed northern settlements must once have been directly connected with the present main part of the city.

We thus obtain a city area of about 7 kilometers from north to south with a greatest width of only 1.5 kilometers. This elongated form of the city, probably in part conditioned by its location along the river, is accounted for chiefly through its origin, which is even now clearly perceptible. The city was built on a long street which ran parallel to the course of the river or, since the river limited its development on the west side, more toward the east on the main street. This main street, which probably already existed as a country road when the city was founded, originally connected the palace and temple quarters near modern Et-Till with the similarly important quarter at the modern village Hagg Qandil. This main thoroughfare still exists as a connecting road between these villages, and appears on the plan (pl. 1) between the premises M 47, 2–6 and M 47, 1. The first plan of the city was probably limited to the building up of both sides of the main street and later other broad streets were laid out, running parallel to the main thoroughfare, but bending toward it from the


L
M
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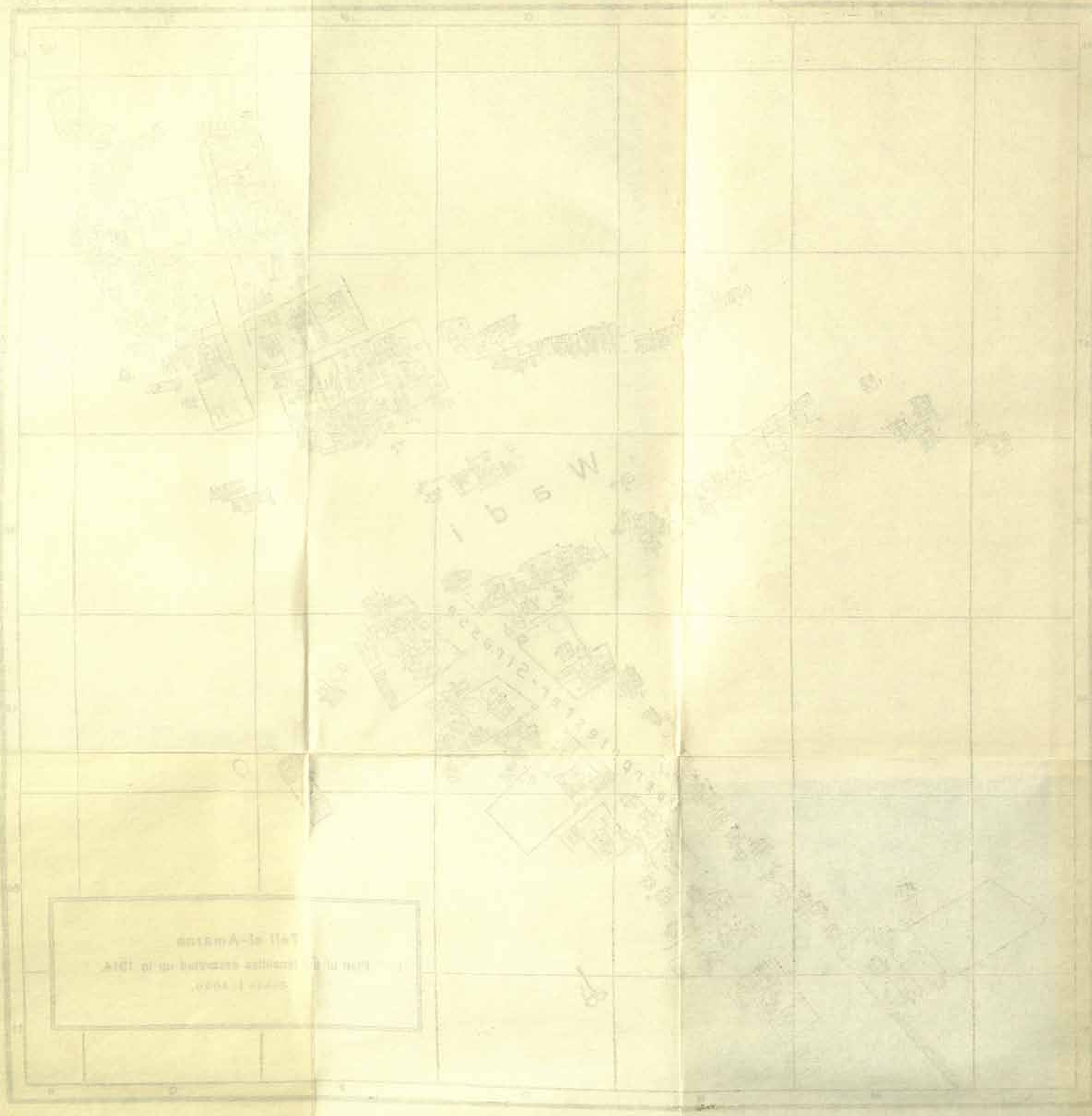
Wadi
Oberpriester-Strasse
Tell el-Amarna
Plan of the localities excavated up to 1914.
Scale 1:4000.



Tell el-Amarna
Scale 1:1000.

north and south, and probably leading from certain important centers to the main street. The first of these broad parallel streets which thus far can be traced, may be seen on the plan in front of house L 50, 1, between the houses N 48, 15 and O 48, 8, in front of the house O 48, 13, and between O 47, 2–4 and P 47, 19. The next, apparently the most extreme parallel street, is the one termed Oberpriester-Strasse (street of the high priest) and has been fully described in Mitteilungen der Deutschen Orient Gesellschaft, No. 52, page 7.

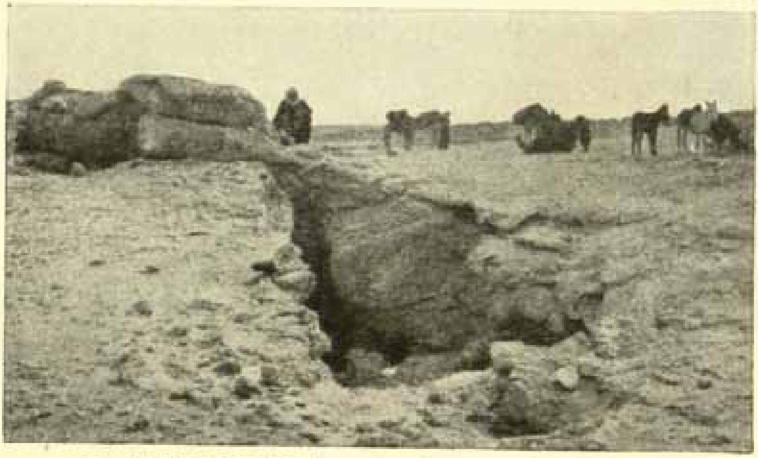
The necessary connections between these main arteries of the city were narrow cross streets varying from 1.50 meter (!) to 10 meters in width. They are clearly visible, as shown on the plan between the premises extending from Q 46 to P 48, but good examples of them are also recognizable south of the Wadi at the end of the "high priests' street." These cross streets do not always run in a straight line, but some are of a rectangular outline, as the one between Q 46, 2 and Q 47, 9.

So much concerning the streets within the city the system of which is gradually becoming more distinct. But likewise as regards the long-known street outside of the city area, to which the mapping of the region has added a large number, some views may now be given which may correct former statements on this subject. In the first place, a sharp distinction must be drawn between earlier streets of the time of Amenophis IV and later ones. One of the older streets was no doubt the one which led far into the desert to the alabaster quarry of the Old Kingdom, having a length of 17.5 kilometers, and in some places presenting for its time creditable "art structures," such as ramps and fortified side slopes. Two other roads on the eastern plateau lead still farther into the desert and to the stone quarry located 24 kilometers from the Nile in an air line. This is an alabaster quarry. Its original circular entrance shaft led through a sandstone elevation rising from the surface of the desert (pl. 2, fig. 1, top, on left side), but at present the entrance is somewhat more accessible because of a break in the covering, as shown in the central portion of the figure. In the interior there opens, first, an irregular space, from which passages lead down to other rooms, and from these to still lower levels. In some of the rooms late Roman potsherds were found, bearing witness to the age of the working of the quarry, which is also attested by the rude relief in the wall of the uppermost room on the left side, near the present entrance (pl. 2, fig. 2). This relief represents a priest sacrificing a gazelle before a row of five gods—Re, Atum, Thot, (?), and Har-si-ese. As the age of the quarry furnishes the date of the two roads which lead up to it, they must be disregarded in the reconstruction of the road-net at the time of Amenophis IV. There remain, therefore, for this

period only the so-called "round roads" which above, upon the mountain, connect the tombs and the frontier stelæ, and their connecting roads which lead through the plain from north to south, as also the roads from the tombs to the various points of the city. The "round," or encircling, roads possibly served for the military guard of the city territory. As regards the object of the other roads, the most plausible assumption for the present is that they connected the working places, unfinished tombs, and frontier stelæ with one another and with the factories in the city.

In this year's campaign only a few large estates, but very many small premises were cleared, especially such as already had been investigated and rummaged by our English and native predecessors during the excavation of the city, so that little was learned as to the general arrangement of buildings on large areas. But one assumption which was formerly questioned was definitely proved. What was formerly, though with some doubt, designated as a front garden on the street, is now proved to exist at house O 48, 14 (pl. 3, fig. 1) in the form of tree holes regularly arranged with a rectangular border of bricks. The general arrangement seems to be that the house garden proper was inclosed within high walls and thus hidden from public view, but in front of the high wall there was another garden surrounded by low fences, so that passers-by could enjoy the trees and bushes. This consideration for the public, however, is not a characteristic of the oriental, who timidly conceals his possessions behind high walls. But the customs of the ancient Egyptians, especially those practiced in the home and the family, must not be measured by the customs of modern Mohammedan Orientals.

One remarkable habit which was this year firmly established, though it was in former years often observed, but not clearly recognized, shows how conservative Egypt is. On the estate of a wealthy man (house P 47, 17) the main entrance on the street and the entrances to the dwelling were walled up. The walling-up was executed when the wooden doors were still in their frames. Later the white ants, which at Tell el-Amarna devour anything made of wood or similar substances, destroyed the wooden doors behind the masonry. The owners who departed from this estate, probably on their return to Thebes, secured their property, which they perhaps expected to use again, by walling it up against housebreakers. This custom had already been practiced in the Old Kingdom, as in the mortuary temple of King Saḥu-reʻ, near Abusir, and is still employed in Egypt. Thus several years ago the German consul general, after all the packing cases of his predecessor had been lost, had the storeroom which held his own properties walled up on the advice of natives who were familiar with the conditions of the country, and with the desired result, for the boxes were all there when he departed, though some-



1. ENTRANCE TO THE ALABASTER QUARRY OF LATER TIMES.

2. BAS-RELIEF IN THE ALABASTER QUARRY OF LATER TIMES.

1. FRONT GARDEN ON THE STREET IN FRONT OF HOUSE O 48, 14.

2. ALTAR OF BRICKS IN HOUSE P 47, 22.

what musty. There are instances, however, in Thebes where the officially walled-up tombs served merely as a cover for the pillagers of reliefs to perform their work of destruction. Every method for security leads to devising a corresponding method for breaking in.

The largest and best preserved house excavated this year, and which, because of its excellent condition, permitted the reproduction in a colored drawing of one of the main rooms, the deep hall, was that of General Raʿ-mose and his housekeeper 'Jnet (House P 47, 9), where the incomplete tombs, already known for some time, lie in the row of the so-called southern tombs in the eastern mountain of Tell el-Amarna. The house is of special interest because its owner is known, and the more so since it supplies some information about his personal history. Under the father of the king he had been active in the high administrative position of "superintendent of the house of King Amenophis III." His name at that time was Ptaḥ-mose, but under the young king he became "General of the king of both lands," and after he had moved with his master to Tell el-Amarna he changed the name to Raʿ-mose (pl. 4). With the constantly growing emphasis of the sun-cult, names in which other than solar deities played a part became unfashionable in good society.

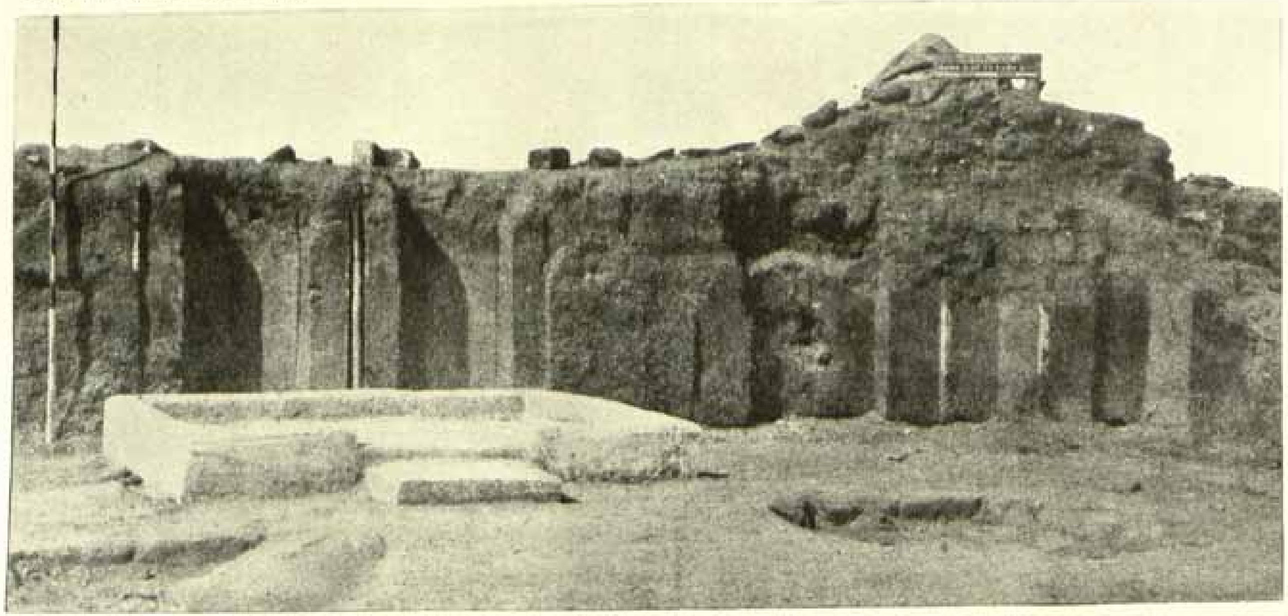
This custom of altering names, which has its foundation in the persecution of those gods who were not affiliated with the sun-cult, and therefore must have originated at the time of the highest development of the Aten cult, is important in the chronology of this remarkable religious movement. The house of this "General" is quite close to the confines of the city, which was not founded before the fourth year of Amenophis IV, and was therefore probably built a considerable time after the court had moved to Tell el-Amarna. The name was changed when the house was nearly finished, perhaps even considerably later. Hence the opposition to the names of the nonsolar divinities, as we see it in the above alteration of the name Ptaḥ-mose, regarded as characterizing the period of Amenophis IV, may be considered the last acute stage of the "reformation" of that king, which took place in the last decades of his reign. The introduction of the Aten cult was therefore not an abrupt, sudden phenomenon, but a gradual development, beginning probably far earlier than the time of Amenophis IV. In fact, there is in the British Museum a statue belonging to the time of the father of the king, bearing a regiment's name, "the god Aten sheds his rays upon King Amenophis III." Thus the so-called new god of Amenophis IV must already have been highly respected under Amenophis III, else a regiment would hardly have been named for him. Thus, after all, Amenophis IV, both as the ruler of a gigantic empire and as the founder of a religion, was only an heir, and, as the results in both spheres has shown, not a fortunate heir.

But to return to the house of General Ra'-mose. The first thing noticed was that all the doors, not only that of the main entrance but even those of the inner rooms, were framed in ashlar. This was later often observed in other, even plainer, houses, though they had no inscriptions as on the doorframes of Ra'-mose's house. These stone frames of interior doors are of some importance in connection with the colored reproduction of an inner room to be described below.

The Ra'-mose house also furnished new data concerning the "quadrangular" room hitherto regarded as the master's room, but now as that of the lady of the house. Its presumed function as the master's room was derived from the fact that it overlooked the courtyard and the storerooms. This would presuppose that it had a window from which one might look out. But Egyptian windows in the lower rooms, with the exception of the "audience windows" in the palace, are arranged for lighting the inner rooms, being placed high up, almost at the ceiling. So that this reason for considering it the "room of the master" fails. On the other hand, there are two reasons favoring its designation as the "room of the lady" in the case of the house of Ra'-mose. In the first place this is the only known instance where the name of the mistress of the house appears on the frame of a false door, in exactly the same manner that her husband's name is preserved architecturally pendant from a real door. But as all the doorframes of the house have not been preserved, it can not be asserted that the name of the wife occurred only on this one frame and that therefore the "quadrangular" room must be considered as that of the wife. But there is another and stronger reason. An annex to the "quadrangular" room, accessible through a short corridor, is evidently a wardrobe room. On two sides of this wardrobe or dressing room are wooden benches, about 70 centimeters high, resting on brick bases, and wide enough so that on and under them the clothing and ornaments of the lady could have been placed. This may seem a bold assumption, but not if it is recalled that in the female apartments of the palaces of Amenophis III, south of Medinet Habu, each bedroom of his numerous chief wives had a wardrobe chamber fitted up with like wooden benches, though of correspondingly greater dimensions. The wardrobe chamber near the "quadrangular" room therefore decidedly favors the assumption that it was the "room of the wife." However, it will be the safest plan to defer a positive statement as to such use of the "quadrangular" room until women's apparel and children's playthings have been found in such a room.

The painting on the walls of the "deep hall," the dining room of General Ra'-mose, is well preserved and offered a very interesting study which was gladly taken up, though with the consciousness that it can not at present be definitely interpreted, so that what has been accomplished must necessarily be considered as only a first attempt

DOORPOST IN THE HOUSE OF GENERAL RA'-MOSE.



WEST SIDE OF THE "DEEP HALL" IN HOUSE P 47, 19 OF GENERAL RA'-MOSE.

to reconstruct in a drawing the interior decoration of an Egyptian living room.

The "deep hall" or the dining room of the General Ra'-mose house was 7 by 7 meters in size, with entrances from the northwest through two vaulted doors in the center, and on the eastern side of these a single door counterbalanced by a false single door on the western side (pl. 5, right half). In this way there was produced that symmetry which is an absolute requisite in Egyptian architecture. Double doors with an additional single door between two rooms was at that time customary. The two side walls exhibit the same architectural arrangement: in the center are double niches with single doors or niches on either side of these as might be needed. The back wall, however, has only the two side doors, without the central vaulted doors or niches; in their stead there is on the floor the usual low elevation thought to be the place for the seats of the master of the house and his wife. Corresponding to this at the center of the west wall, there is the usual platform made of limestone, with raised sides (pl. 5, left half), perhaps the seating place during meals, since it is provided with receptacles for waste water, the washing of the hands before meals playing an important part in ancient Egypt. In this dining room there are also traces of four pairs of columns which stood in two rows (pl. 5, the two holes in the brick plaster of the front), and the limestone base of one of these columns may still be seen. The arrangement of the windows can be determined from the position of the staircase, which renders an opening for a window in the middle of the wall impossible, for there was space only for the door lintel, the fragments of which were found on the floor. It may seem strange that the doors were so low, but in Egyptian houses they were made just a man's height.

So much about the ground plan of the room and its architectural construction.

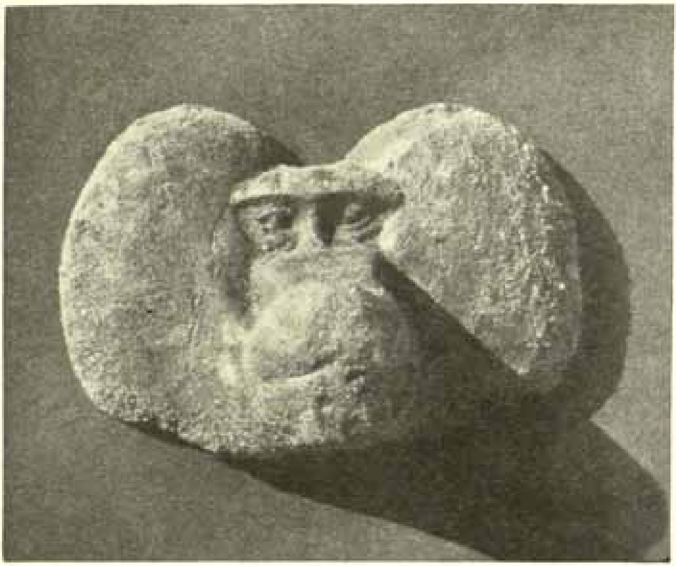
The painting on the walls, made directly on the Nile-mud plaster, is everywhere nearly as high as the remains of the walls themselves, reaching in some parts 1.30 meters above the floor. On the floor of the room were found fragments of the painting fallen from the upper parts of the walls, including parts of richly painted door headpieces, chamfers, tore, etc. Such were the data from which to reproduce a colored drawing of the room. The result is quite satisfactory, but as here represented in black and white (pl. 13) the light and shade effects of the colors could not fully be preserved, though the general impression is accurately rendered. The color tone of the wall is greenish-brown, like Nile mud. The doors have black-bordered white frames and white chamfers. The idea underlying this color combination must have originally been to represent limestone doors set in brick masonry. But in the present case this idea

was forgotten in the choice of colors, showing that we have here not something original but a mixing of various older motifs. The door frames are not of stone color, but that of red-brown wood, superposed by bright yellow hieroglyphic lines. They should represent an inlaid decoration in two wood colors. But glaring as the yellow tone of the hieroglyphics is in itself, it has an excellent effect in mass upon the dark-red brown. The folding doors are yellow, while the wider doors, which naturally would consist of several vertical boards in red brown, are yellow and red brown, each board separate. The papyrus stalk between the two halves of the double niche is likewise painted in natural colors, green with yellow basal leaves. Naturalism prevails also in the color scheme of the door headpiece of the tombs of Tell el-Amarna and the temple of Abydos, which is painted in the yellow and red-brown wood colors. The painting of the chamfer of the door headpiece is remarkable. Perhaps originally a frieze of uraei (sacred asps) was intended or erroneously laid on, while in the painting coarsely executed rosettes in different colors were employed. The yellow tone of the window grating is due to the fact that these structures date back to the period of original wood construction. Of the painted garlands which ran as a frieze around the walls, and which in the New Empire were always rendered in the correct forms and colors of the flowers, enough fragments were found to permit an accurate reconstruction.

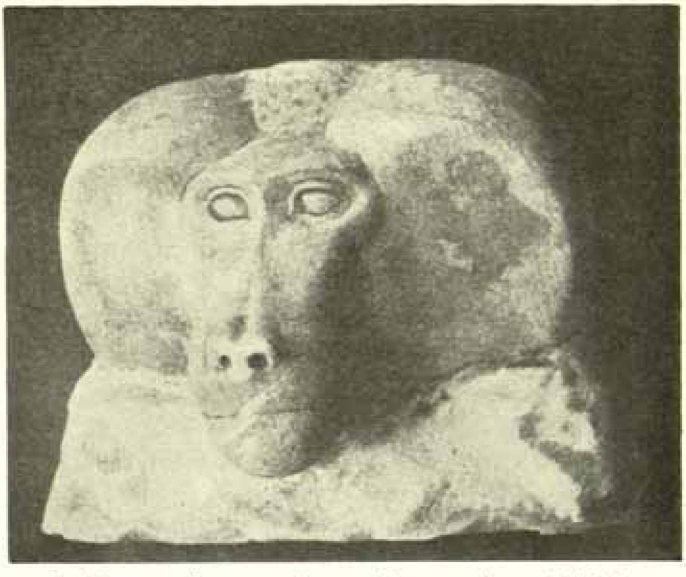
But now we come to the rather doubtful elements of the construction, the columns and architraves. Besides the white bases only the red-brown color of the shafts of the columns, traces of which can be discerned upon the bases, is assured. The form of the columns as palms was selected after old representations of the dining room in the palace of Amenophis IV, and consequently a green color was assumed for them. The abaci and architraves, as carried out in the reconstruction, may have been yellow, remains having been found of wooden architraves in another excavation.

These are the data for the attempted reconstruction which, in many cases, have shown that this dining room was quite a comfortable place and that the color scheme, even to our taste, was not coarse or glaring but produced rather a pleasing and harmonious effect. Life in such rooms must have been quite pleasant, although they were not very well lighted as evidenced by the frequent finds of lamps and lamp stands.

In exploring the environments of the atelier of the sculptor Thutmes some pieces which had been carried away from his workshop fell into our hands, notwithstanding that a considerable number of the finds of this year were from house ruins which had been already exploited by natives and, perhaps, also by our scientific predecessors at Tell el-Amarna. This year's experience has thus



1. MODELED HEAD OF A BABOON, FOUND IN HOUSE Q 48, 1.
Resin composition. Natural size.



2. MODELED HEAD OF A BABOON, FOUND IN HOUSE O 47, 5.
Limestone. Natural size.

AMENOPHIS IV WITH HIS WIFE.

Relief model of resin. Front side. About one-half natural size. Found in house P 47, 25.

shown that in making museum collections it is worth while to examine methodically places already rummaged, aside from the purely scientific results which such work always yields.

In house Q 48, 1, about 100 meters from the atelier of Thutmes, toward the southeast, there was found an exceedingly well executed model of the head of a baboon (pl. 6, fig. 1). In the same house there also came to light beautiful ivory carvings, which later on will be discussed. It need not be assumed that the baboon's head came from the workshop of Thutmes, for some artisan probably lived there in house Q 48, 1 who could make such a good model of the baboon, especially since, together with the baboon's head, there was found a small saucer containing remains of the material from which the model was made. The most remarkable feature of the baboon mask is its material, a brown and now hardened stuff at first designated as "resembling wax." This, then, was the material for modeling, and not clay, and from this first model a copy was made in stone. By chance we also found the head of a baboon made in limestone (pl. 6, fig. 2). It came from the house O 47, 5, about 100 meters from the atelier of Thutmes, toward the west. Judging by the location of this find, it may have come not from the atelier of Thutmes but from some other not yet discovered center of sculptural works. It need not be assumed that the limestone baboon was worked after that in "wax," though many details suggest it. The task of molding the head of a baboon, the sacred animal of Thot, the god of wisdom, must often have presented itself to the sculptors of Tell el-Amarna, since the center of the cult of this god, to whom the sun cult of Amenophis IV was not at all opposed, was at Eshmunejn, close to Tell el-Amarna.

Although the authorship of these two models must be left undetermined, yet that of the next and most important model (pls. 7 and 8) may safely be assigned to Thutmes. This one was found in house P 47, 25, about 125 meters north of Thutmes's atelier, in a region which is still within the circle of this atelier. Looking first at the back or reverse of this find (pl. 8), it shows nothing more than the accurate impression of a board which was roughly planed with an adze. The board itself, like all woodwork at Tell el-Amarna, had been devoured by white ants, but the impression reproduces all the details, even the grain marks. The material of which the model is made must therefore once have been so soft and flexible that it could with great sharpness adapt itself to the smallest differences in the surface of the original. At present it has the same glass-hard consistency and the identical brown color of the "wax-like" model of the baboon head (pl. 6, fig. 1). Prof. Schmidt, of Cairo, who made a preliminary examination of a small particle of the stuff, recognized it as a kind of gum resin, probably Oliban (frankincense) or bdellium, with an earthy (Nile-mud) admixture.

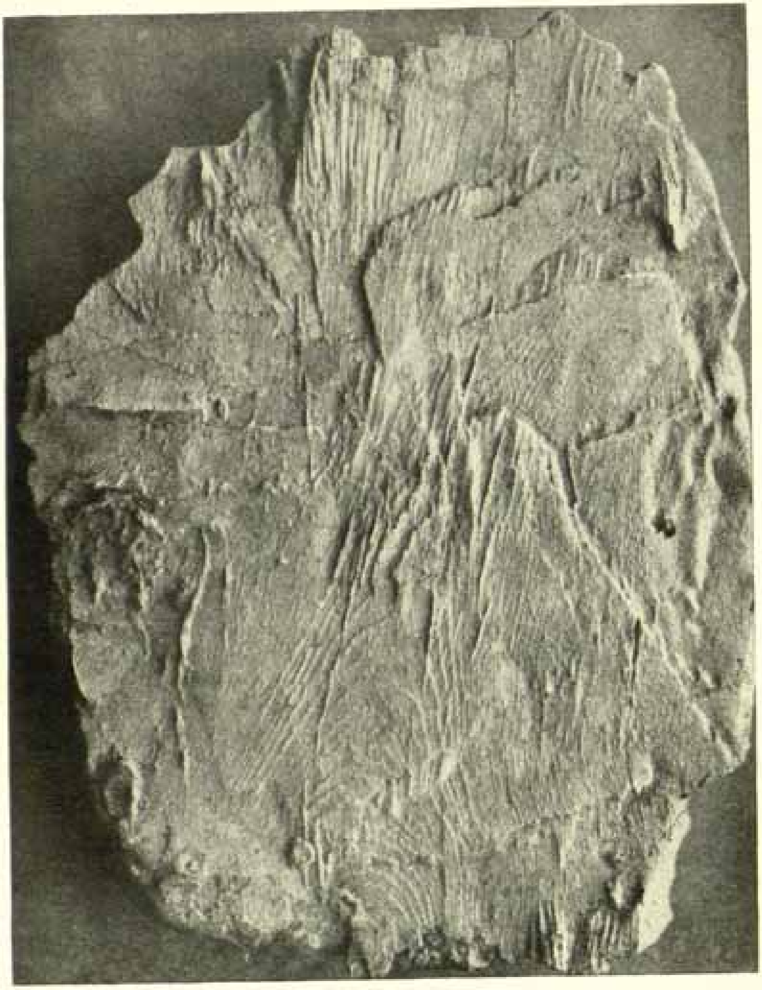
This stuff must, therefore, have been poured upon the board while liquid and presumably warm, and then the sculptor modeled into its surface, perhaps with a heated metal instrument, the charming reliefs represented in plate 7. The sculpture represents the king and the queen. He has embraced her with his left arm and loosely lays his hand upon her shoulder; she turns with her face to him and, with her right hand busying itself at his bosom, she nestles on his broad neck ornament. Costume, type, and treatment of the bodies leave no doubt as to the date of this art work. Even if the location where it was found were unknown, every connoisseur would unhesitatingly attribute it to the time of Amenophis IV, and, on account of the unartificial, dashing execution, with the same certainty would pronounce it the first sketch of a relief. This will suffice for the present. There are obviously connected with this find many other questions which are to be discussed later, such as the real composition of the "resin mass," the origin of the several ingredients, their workableness when combined, the instruments with which they were worked, their suitability for casts in gypsum, etc.

It was intimated above that in the square of houses O 47 we seem to have come across a new center of sculptural finds, for in this region there came to light many unfinished granite pieces to be laid into reliefs, representing wigs, a very beautiful torso of the statuette of a queen, though the wooden head of the queen is unfortunately totally decayed, the baboon's head mentioned above (pl. 6, fig. 1), etc. Only two of these finds will here be specially considered. There is first of all a small limestone mask (pl. 9, fig. 1) doubtless copied from a life-size gypsum mask, many examples of which have been found in the modeling chamber of Thutmes. The wrinkles on the forehead, at the base of the nose and around the nose wings and the mouth are here, and in a non-Egyptian fashion well indicated, though in a more schematic manner than on the large masks.

Only 50 meters from the above there was found another study (pl. 9, fig. 2), a portrait of Amenophis IV, which in its almost incredible delicacy can confidently be placed by the side of the best reliefs of this king. The artist succeeded best in reproducing the eyes, cheeks, and front of the neck. As the main concern was the portrait, the accessories of the royal costume, such as the headcloth, the frontlet, and the asp (uraeus), are treated in a secondary manner and even to some extent merely indicated.

So much concerning the finds of models in this region which, as stated, is in the environs of a new center of sculptural works, not before carefully explored, though it may have been rummaged by our predecessors.

The last find to be mentioned came from an entirely different district, from house Q 48, 1, which is also remarkable for the frequent occur-



IMPRESSION FROM THE MOLDBOARD FOUND IN HOUSE P 47, 25.

Relief model of resin. Back side. About one-half natural size.

1. REDUCED MASK MODEL, FOUND IN HOUSE O 47, 9.

Limestone. Natural size.

2. AMENOPHIS IV. RELIEF STUDY, FOUND IN HOUSE O 47, 13.

Limestone. About one-half natural size.

rence of art finds. The baboon made of gum resin, mentioned above (pl. 6, fig. 1), comes from this house, but the other objects found there are of ivory and as far as they are dated are older than Amenophis IV. Among these is the cover of a box from the time of Amenophis III (1411–1375 B. C.), and the exquisite carving (pl. 10), to be presently discussed, belongs to the time of Thutmosis (Thotmes) IV (1420–1411 B. C.). These dates lead to the assumption that these objects had been collected by some craftsman who inhabited house Q 48, 1, to serve him as copies of patterns.

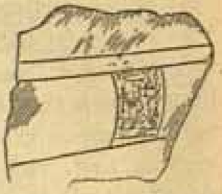


Fig. 1.—Cuff with representation of "King striking down a captive." Fragment of a relief from the mortuary temple of Ne-user-re' at Abusir. Limestone. One-sixth natural size.

The art work in question consists of the outer shell of part of an elephant's tusk, about 12 centimeters long, bisected lengthwise and carved in pierced work. Its surface thus forms the half mantle of an obtuse cone, and it is therefore nearly impossible to reproduce it by photography and by drawing except through unrolling. The work, which was made still more difficult because of the brittleness of the original, was executed by the skillful hand of Mr. A. Bollacher.

The carving shows King Amenophis IV striking with the raised sickle sword a Libyan who fell on his knees before him and whom he grasps by the hair. In addition, the King also grasps a bow and arrows, as customary in this ancient type of representing "a king striking down a captive." This incredible deftness of the hand, which the Egyptian kings displayed at this ceremony, at least on pictorial representations, is already shown in an instance of the Vth dynasty, from the mortuary temple of King Saḥu-re'. Behind the king, over whose head the sun disk is to be noticed, the uraeus serpent rises upon papyrus stalks, the heraldic plant of Upper Egypt. The scene plays before a statue of the god Montu of Thebes, who presents to the king the sickle sword and holds the rib of a palm, the symbol of everlasting duration. In front of the god is inscribed what he is saying to the king: "I hold the sickle sword for you, oh beautiful god! With it thou shalt slay the chiefs of all foreign lands." There is nothing of particular interest either in the composition or the contents of the carving. But the workmanship is finer, particularly the neat execution of the costume of the king and the exquisitely modeled faces of the prostrated Libyan, and still more so of the king.

What purpose did this art work serve, or to what object was it attached? The answer to these questions is furnished by an earlier find from our excavations. In the mortuary temple of Ne-user-re' was found a fragment of a relief (fig. 1) representing the left arm of a king shooting with the bow. The wrist is protected with a cuff against the rebound of the bowstring, and upon the cuff appears in minia-

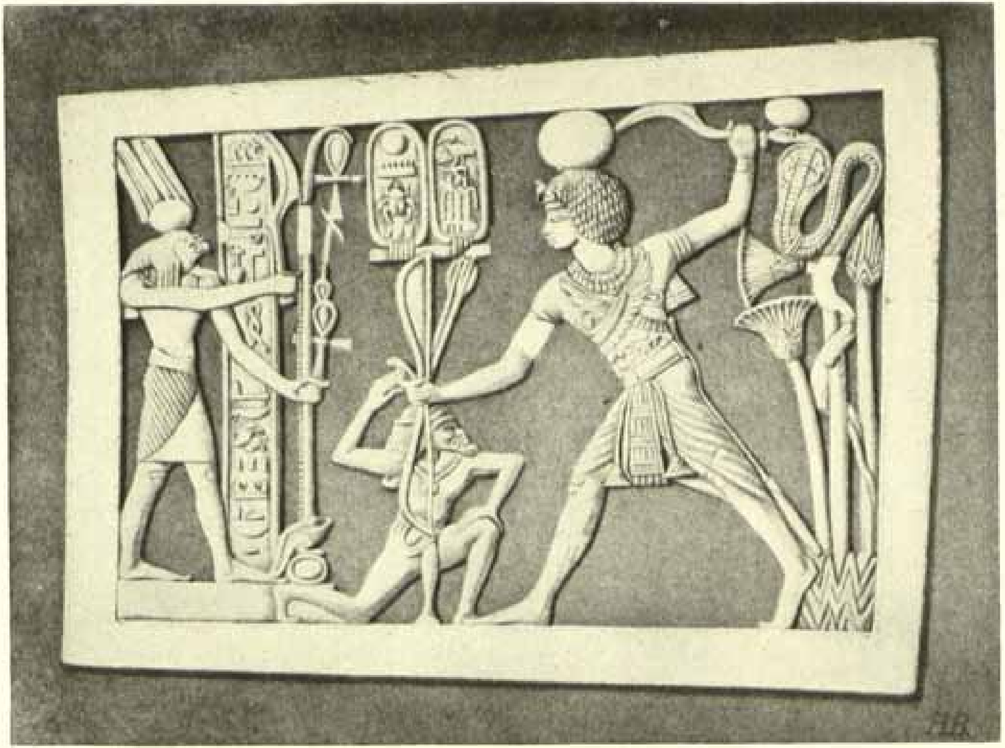
ture the scene of our ivory carving, "the king striking down a captive." In its form the ivory carving, which is to be imagined as backed with some stuff, corresponds exactly to the half shell of such a cuff in natural size. It would comfortably cover the half of an Egyptian slender wrist. But this neat, fragile carving could hardly have stood a practical use. It could only have been put upon a statue of life size; that is, one which according to the inscription of Thutmosis (Thotmes) IV represented the king shooting with the bow.

It is not surprising that an object with the name of Thutmosis IV was found in the city of Amenophis IV. It may not even be assumed that it was brought from Thebes or elsewhere. It has been long known that the city "Horizon of the sun cult" already existed before Amenophis IV, perhaps, even probably, under another name, as was then the case as to personal names, such as Amenophis changed to 'Ich-n-aten and Ptaḥ-mose to Ra'-mose.

On account of the great find of tablets made in 1887 in the "house of the royal letter writer" in the royal archives in the palace quarter, not far from the village Et-Till, the surroundings of this house had been again and again searched throughout by various investigators with the result of adding merely a few unimportant pieces to the original find of upward of 350 tablets, but since the early '90s of the last century hope and further search were given up. So that on December 15, 1913, when Mr. Dubois, the Government's superintendent of buildings and of the excavations, announced the discovery of a clay tablet in house O 47, 2 it seemed scarcely credible (pl. 11; pl. 12, fig. 1). A portion of another tablet was found on December 19 in house N 47, 3 (pl. 12, fig. 2).

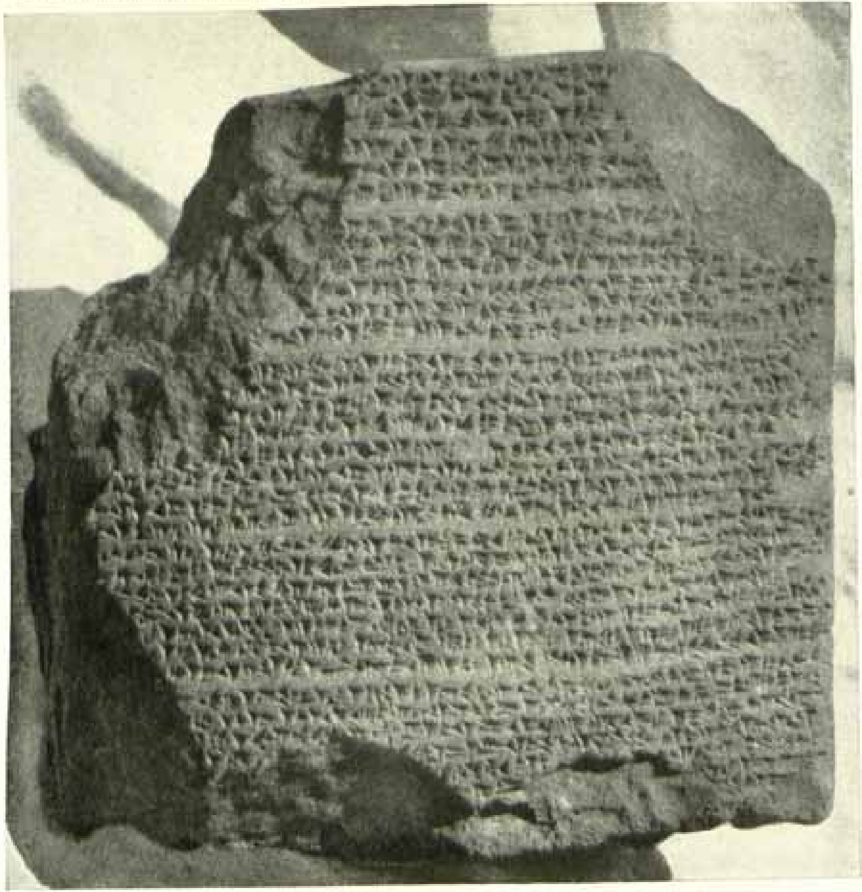
Both these pieces were found in premises which already had been thoroughly excavated, the first near the wall of a courtyard, where it became fastened on the upper edge about 30 centimeters below the surface. Though the surface humidity was slight, yet it caused much flaking of the left margin of the obverse and the corresponding part of the reverse side of the tablet. The second piece lay considerably deeper in the débris, and therefore escaped this damage. The surroundings of both places where the finds were made were diligently dug up in search for other pieces, but without success.

In the division of the finds these two valuable documents fell to the share of the Egyptian Service of Antiquities, and its courtesy in lending them for examination and study is here gratefully acknowledged. Dr. Otto Schroeder of the division of western Asia in the Berlin Museum prepared a provisional translation and explanation of these tablets. The smaller one (pl. 12, fig. 2) is of light-brown clay with darkish spots, probably due to contact with chemical salts. It is 6.1 centimeters high by 3.6 centimeters wide, its greatest thickness 2.65 centimeters. It is inscribed on the obverse only and contains a



IVORY CARVING, FOUND IN HOUSE Q 48, 1.

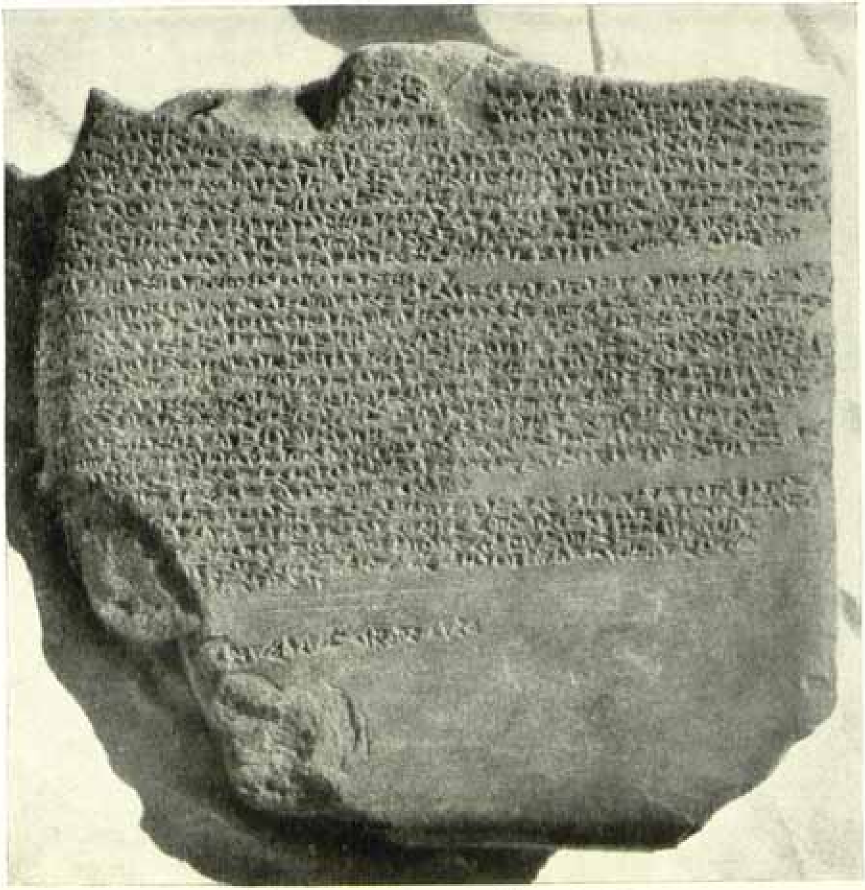
Drawing made from the unrolled carved surface. Natural size.



Obverse. Natural size.

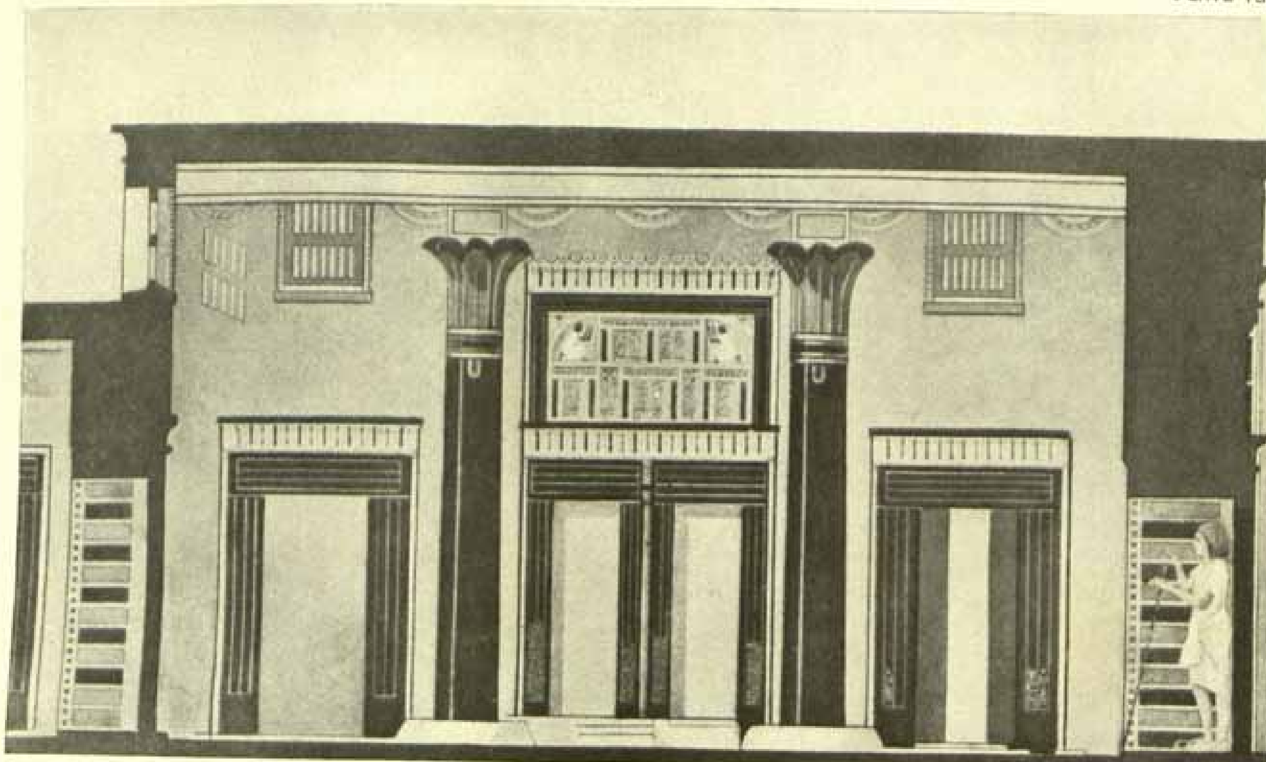
Right edge.

CLAY TABLET, FOUND IN HOUSE O 47, 2.



1. CLAY TABLET, FOUND IN HOUSE O 47, 2.
Reverse. Natural size.

2. FRAGMENT OF A SYLLABARY, FOUND IN HOUSE N 47, 3.
Natural size.



THE "DEEP HALL" IN THE HOUSE OF GENERAL RAʻ-MOSE.

After a provisionally colored reconstruction. Scale, 1:55.

portion of an Assyrian syllabary. Syllabary is the designation of tabular arrangements in different columns of cuneiform characters, their names and values. Usually they consist of three columns. In the middle column are placed the cuneiform signs which are to be explained; the column to the left gives the pronunciation and syllabic value of the character, while the column to the right contains the names of the signs. The present fragment is either the writing exercise of a dragoman who was intrusted with the cuneiform correspondence to western Asia, which the large script would suggest, or a reading exercise provided for such a dragoman in western Asia.

Of much more interest and value is the larger fragment (pl. 11; pl. 12, fig. 1). It is made of a fine light-red clay, with a height and width of 10 centimeters and a thickness not exceeding 2.4 centimeters. It is closely inscribed on both sides with the so-called "Hittite" stroke of the cuneiform script, the several paragraphs being separated by lines. As far as made out, it is the first part of a serial literary work, bearing the title "King of the Battle" (Šar tamḫari), which treated of a military campaign in western Asia, of which the present fragments delineate the causes and the beginning. Unfortunately, the name of the author or scribe, with which Assyrian tablets are usually signed, is here wanting. In its place is some wiped-out Egyptian red ink and the impression of a finger besmeared with red ink, which might suggest that the Egyptian name of the author or scribe in Egyptian script was intended to be placed there.

The first question which pressed for answer was, Did these pieces come from the well-known archives, or are they the harbingers of the existence of deposits of cuneiform tablets apart from the public archives in Tell el-Amarna? The contents of the two tablets do not hinder their having come from the archives, for syllabaries had before that been found in the archives by Professor M. Flinders Petrie and the existence of literary texts in the archives may likewise be asserted. There was found there, belonging to the library of Amenophis III, a faience label of a wooden case of a papyrus which contained, obviously in Egyptian script, the tale of the "Sycamore and the Date Palm." But the great distance of the location of the find from that of the "house of the royal letter-writer," about 1¼ kilometers, would indicate that it did not come from the archives. We should have to assume either that in ancient times pieces from the archives had been scattered over the field of ruins, or that the peasants of Et-Till, who discovered the archives in 1887, have in an incredible manner thrown some of the pieces around. But whatever may have been the origin of the two new tablets, it is certain that there is hope of still further finds of tablets in Tell el-Amarna, where search had been completely abandoned.

VACCINES.[1]

By L. Roger,[2]

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The majority of infectious diseases do not occur a second time; the first attack confers immunity. About a thousand years before the Christian era this fact was known to the Chinese, among whom smallpox made terrible ravages at that time. But all who survived a first attack could live without inconvenience in infected places, so that there was a considerable economic advantage in encouraging the development of the disease during youth. In case the individual died the loss to society was small; in case of survival, the value of that individual immune to a second attack was considerably increased. Such were the reasons given by the Chinese for practising variolation, or inoculation with the disease. It is remarkable that such an idea should spring up and develop at a time when diseases were more often attributed to divine wrath than to contagion, and that it should lead to a prophylactic method which was not taken up again until the end of the eighteenth century.

Variolation was practised by inserting under the skin or in the nostrils of subjects scabs taken from convalescents. This infection through inoculation is much milder than infection contracted spontaneously. This result is easily explained: The pathogenic agent is introduced into regions unfavorable for its development and with a subject in good health, not predisposed to infection, while under ordinary conditions of spontaneous infection it is more often the case that resistance has been lowered through the agency of predisposing or adjuvant causes.

However, variolation is not always harmless; the organism inoculated may be in such a condition of predisposition that infection spreads and takes a serious course, resulting sometimes in death. And even if the inoculated subject resists it, the few pustules which develop are capable of spreading the disease and constitute a danger

[1] Translated by permission from La Nature, Jan. 30, 1915.

[2] The frequency of infections in time of war creating special interest in a study of their prophylaxis, it has seemed to me useful to publish a brief general summary of the whole subject.

for the persons in the vicinity. More than once they have been the starting point of epidemics.

In spite of these limitations, variolation rendered great services. It was introduced little by little into Persia, then into Turkey. In 1721 the wife of the English ambassador at Constantinople, Lady Montague, who witnessed the results obtained by this procedure, made it known on her return to London. The new method spread rapidly and was very happily modified by two Scotch farmers, the Suttey brothers, who invented the subepidermic inoculations.

Variolation has to-day only a historic interest. It has retreated before another procedure which was introduced into science at the end of the eighteenth century. It had been known for a long time that in certain regions in England, and notably in the county of Gloucestershire, that persons who have the direct care of cattle often have on their fingers small pustules contracted by contact with animals attacked by cowpox, and that this eruption gave them immunity against smallpox. In 1768 Sutton and Fewster drew attention to these facts, and it was then that Jenner conceived the idea of practicing systematically, in the interest of prophylaxis, the inoculation of cowpox. In 1798 the results of these researches were made known. It was established that the virus coming from the cow is inocuable in man; that it may be transmitted from man to man, keeping its fundamental characteristics, for when reinoculated in the cow it produced again the characteristic eruption. Finally, inoculation with the virus taken from a cow or from a man previously inoculated, confers immunity against smallpox. The objection was raised that the resistance was not perfect; that several inoculated subjects later contracted the disease. But it came in a mild form and turned off shortly before the period of suppuration, taking a special form, which has given it the name of chickenpox.

The discovery of Jenner brought up an interesting problem which has not yet been solved. Can the disease of the cow, or vaccine (*vacca*, cow), be considered as a special infection, or should it be regarded as a variolous infection modified by a long series of passages through the Bovidæ? The majority of French scholars agree in keeping the two separate. In Germany and Switzerland researches have been carried on tending to establish the fact that the variolous virus can be transformed into vaccinal virus. Whatever solution may be finally adopted, it can be stated that inoculation with vaccine was the first instance of a prophylactic inoculation which was efficacious and harmless. Whether vaccine is a special virus or a modified variolous virus, it produces in man a local eruption which becomes general only in exceptional cases, and in these cases only in a very mild form.

For preventive inoculations the liquid (vaccinal lymph) collected from the pustules of a child or from one of the Bovidæ is used. The animal vaccine is in general use to-day. Young calves are previously inoculated by numerous scarifications on the flanks, and used for the culture of vaccine. It is to be hoped that the attempts now being made will permit the cultivation of vaccinal virus in artificial media so that the passage through animals will not be necessary.

According to their etymology the words "vaccine" and "vaccination" ought to apply only to the diseases of the cow and to its inoculation. But, diverted from their original meaning, they designate to-day a whole series of viruses used for prophylactic purposes. Thus, for instance, the terms anthrax vaccine and antianthrax vaccinations are used. Anthrax vaccine is used only in veterinary medicine, but its study is valuable because the method has been the starting point of numerous discoveries.

To Toussaint, professor at the veterinary school of Toulouse, belongs the credit for having first tried antianthrax vaccination. He subjected anthrax blood to a temperature of about 55° for 10 minutes, thinking in this way to kill the bacilli contained in it. Several animals died on being inoculated with the blood thus prepared, but those which survived became refractory. Toussaint believed that he was vaccinating with the soluble products deposited in the blood by the anthrax bacilli. As a matter of fact he was using weakened microbes. This was shown by Pasteur, who in submitting anthrax cultures to the action of heat, succeeded in producing vaccines which could be accurately graduated.

The most important of the Pasteur vaccinations consists in cultivating the anthrax bacilli at 42°. The microbe develops but does not give off spores, and its virulence diminishes more and more. If, after a certain length of time at 42°, the microbe is placed in a new medium and raised to a eugenesic temperature of 37° or 38°, it develops, gives off spores, but maintains the degree of weakness which it had previously reached. There are two Pasteur vaccines—one called the first vaccine, comes from a bacillus which is kept at 42° for from 15 to 20 days; it is so weakened that it no longer has the power to kill animals except those new born. The second vaccine, which has remained for from 10 to 12 days at 42°, can still kill the adults.

In practice these two viruses, weakened but living, are inoculated successively, and in this way sheep and cattle are rendered immune with no attendant risk. The economic importance of this method is readily seen, and man, who contracts anthrax only by contact with animals, is indirectly protected.

Since antianthrax vaccinations are a protection against possible contamination, it will be asked if a similar method would not be effective during incubation—that is, between the time when the virus is introduced into the organism and the time when the symptoms appear. It was also Pasteur who brought up and solved this problem.

It was already known that it was possible to confer immunity against rabies. A professor at the veterinary school of Lyon, Galtier, had shown that the saliva of a mad dog injected in the veins of a sheep or goat did not provoke symptoms, but conferred a powerful resistance against a later inoculation of the virus. The discovery was important but was devoid of practical interest, as the method was uncertain and dangerous.

Taking up the study of this question, Pasteur, in collaboration with Chamberland, Roux, and Thuillier, recognized that inoculations performed under the cerebral duramater with the emulsion of a fragment of bulb taken from a dog which had died from rabies were certain to transmit the disease. Using a rabbit, if the inoculations are made in series, the virulence increases—that is, the time of incubation diminishes: it becomes only 6 or 7 days after a hundred passages, and from this time it no longer varies; from then on the virus is fixed.

If the spinal marrow of a rabbit which has succumbed to an inoculation of the fixed virus is suspended in a sterilized flask containing a substance free from water, such as fragments of potassium, it was learned that under the influence of drying the virulence diminishes, and at the end of 14 days the organism becomes accustomed to supporting viruses more and more active. As the incubation of the disease—that is, the time which elapses between the bite and the first symptoms—lasts a very long time, and as the process of rendering immune is relatively rapid, the refractory state is successfully reached before the appearance of symptoms.

The treatment varies according to the location, the extent, the depth, and the number of bites. It lasts from 15 to 22 days and consists essentially in injecting at different intervals fragments of marrow, beginning with those dried for 14 days and gradually progressing to those dried only 3 days.

It is useless to dwell on the results obtained. Pasteur's method is causing the gradual disappearance of rabies, and the time can be predicted when this terrible infection will join smallpox and anthrax in the group of historic diseases.

Against smallpox, anthrax, and rabies immunity is secured by means of living virus. It is known to-day that all the effects produced by microbes are due to substances which they contain or which they secrete. Experience shows that it is possible to obtain

immunity by introducing into the organism either sterilized cultures, liquids of the culture free from microbes, or extracts of the bacteria. Each of these different methods has to its credit a certain number of experimental successes and admits of practical application.

The prophylaxis of typhoid fever has attracted special attention and incited numerous researches. After the first attempts of Chantemesse and Widal, it was established through the work of Wright that cultures sterilized by heating can be used. It is only necessary to take care not to exceed a temperature between 53° and 56°. Even within these limits heating has the drawback of weakening the ability to render immune. It has also been proposed to sterilize the cultures by the antiseptics phenol, chloroform, ether, and iodine. And for some time there have been used in practice the autolysats of microbes. It is known that the protoplasm of bacteria, as all living protoplasm, contains digestive ferments. Left to themselves under unfavorable conditions the cells are digested—that is, liquefied by the ferments which they contain. This autodigestion is given the name autolysis. On this principle is based the vaccine of M. Vincent. But as among the higher plants innumerable varieties of a single species are known (it will be recalled what the horticulturists have obtained in growing roses or chrysanthemums), so in each microbe species we should distinguish the varieties or races which close study permits us to differentiate. That is why, in the preparation of vaccines, bacilli from different sources have been used. The polyvalent vaccine of Val de Grâce is prepared with 10 different specimens. They are sprinkled on a liquid solidified by agar-agar, and after 48 hours in the incubator the cultures are taken out and their surface scraped. The bacilli thus collected are put in salt water to be macerated. The liquid is agitated at different intervals, then at the end of 36 to 40 hours it is submitted to electric centrifugalization to be clarified, and finally it is sterilized with ether. Four injections with this vaccine must be made at intervals of eight hours to confer absolute immunity against typhoid fever.

The different antityphoid vaccines give excellent results. The trials made in the Army have demonstrated their efficacy and their harmlessness. The only effects observed during the time following their application are a slight discomfort and a small rise of temperature. But these manifestations are light and passing. So it is with good reason that compulsory antityphoid vaccination has been decreed for the whole French Army. This measure is the more important since in time of war the rate of sickness and death from typhoid fever is extremely high. Even with the precautions taken there is a large number of cases, but these occur only among those not vaccinated or insufficiently vaccinated. However, even among those who have received the necessary inoculations, infections simi-

lar to typhoid fever, but milder, occur quite often. These are paratyphoid fevers. They are due to the paratyphoid bacilli, of which two principal varieties are described, designated by the letters A and B. These two types are related to each other and also on the one hand to the typhoid bacillus, on the other to a microbe very widespread, the colon bacillus, by a series of intermediary forms. The antityphoid vaccines are powerless against these microbes, and a study is now being undertaken to find means of preparing either a single active vaccine for the whole group or a special paratyphoid vaccine.

It has been thought that, instead of injecting the vaccine under the skin, it would be simpler to introduce it by the digestive tract. This new method is too recent to permit of a final judgment. Whatever its lot may be in the future, it would be hazardous to use it at present; during a war is not the time to begin such an experiment. Prudence demands that we use only methods of procedure whose efficacy is indisputable.

The less the condition of the microbe in use is altered, the stronger and more lasting is the immunity obtained by vaccines. For this reason the heating of cultures has been gradually diminished. Attempts have been made to replace the heating process by antiseptic substances; and, finally, the systematic use of living cultures has been proposed.

M. Nicolle advises introducing into the veins living microbes freed from all soluble matter by a prolonged washing. It has been made certain that this method is innocuous and that the bacteria injected remain in the organism and are there destroyed. This discovery is important because it might have been feared that a person vaccinated, like one having the disease, would throw off living elements and become a source of contamination. This method of procedure admits of numerous applications; it is successful in giving immunity against cholera, dysentery, and whooping cough, as well as against typhoid fever.

If we seem to be especially occupied with this last infection it is because its frequency and its seriousness hold first place, especially in our lands. In countries with a warm climate vaccines are frequently used against cholera and against the plague.

The study of anticholera vaccine, begun by Ferran and Gamaléia, has been continued by Haffkine. The living microbe is generally used. On the contrary, Haffkine uses against the plague, cultures sterilized by heating to 70°.

The immunity created by the passage of an infection or by the introduction of a vaccine is chiefly characterized by cellular modifications which lead to humoral modifications. A vaccine does not act

like an antiseptic or an antidote. The organism itself, under the influence of the vaccine, secretes certain substances, or, better, modifies the condition of the blood, and this liquid is given new properties. Immunity results not from a simple impregnation by useful products, but from a reaction against harmful products. For this active immunity to be established, a certain amount of time must be allowed after the time of vaccination. When it is necessary to act quickly—for instance, when a foreigner arrives in a country swept by cholera or the plague—instead of a bacterial vaccination, it is preferable to use serum from an animal rendered immune. The two methods must not be confounded. Serotherapy, or serovaccination, consists in treating or rendering a person immune by means of a blood serum of an animal previously vaccinated. The animal has received the microbe-bearing product and has reacted from it; he has acquired active immunity. The serum of his blood acts almost like an antiseptic or a specific antidote. From the time that it impregnates a new organism it protects it from infection and the organism does not need to react; it takes no part in the action. Thus, it is said, as opposed to the preceding case, that a serum produces a passive immunity.

Passive immunity develops rapidly but is not lasting. The two methods of procedure may be combined—the serum in alcohol may be injected, followed by the vaccine, or, better, an injection of a mixture of the serum and vaccine may be made.

Starting from these results M. Besredka has proposed a new method—vaccination by sensitized virus. The microbes placed in contact with the serum from a vaccinated animal are impregnated with this serum and lose their means of defense. They can no longer resist the phagocytes—that is, the cells capable of absorbing and destroying them. At present they are called sensitized. But an excess of serum is more harmful than useful. So it is necessary to take care, before injecting the microbes impregnated with the serum, to wash them carefully in salt water. This is a new method which has already been applied to a large number of diseases. Metchnikoff and Besredka recommend it as efficacious against typhoid fever, and after experiments made by them on chimpanzees they conclude that it is superior to all other methods of procedure.

The bacterial vaccines serve, as we have said, in rendering normal organisms immune from danger of infection. It has been asked why they would not be useful in fighting an existing infection. As a result there has arisen a new method given the name of vaccinotherapy, or, better, bacteriotherapy.

The first trial is due to Koch, who proposed to combat tuberculosis by injecting into subjects a special product, tuberculin, which is only

an extract of the cultures and the protoplasm of tuberculosis bacilli. The results have been widely varying—often bad, sometimes favorable. It may be that at first too strong doses were used. In any case the product has not the effect of vaccination and its therapeutic use is not free from danger.

The work of Wright especially has attracted attention to bacteriotherapy. The Wright vaccines are used against typhoid fever, melitococcus, infections of streptococcus, and of staphylococcus. A certain quantity of microbes killed by heating is injected into the subject. When it is possible a specimen taken from the sick person himself is used, autovaccines producing appreciably better results. By thus introducing bacterial products into a diseased organism the cellular reactions are stimulated. Thus, by the indirect process of favoring the development of an active immunity, the means of resistance against infection are augmented.

This brief summary shows the important results obtained by practical medicine from experimental researches. Prophylaxis and therapeutics have been completely revised by the vaccines and serums. But it is important not to confound these two terms, and to distinguish clearly the methods which they designate. The word "vaccine" should be reserved for products of bacterial origin—that is, for living microbes, weakened or modified—for bacterial autolysats, and for soluble matter secreted by the bacteria. Serum, on the contrary, is a product of animal origin coming from an individual previously rendered immune. Vaccine arouses in the organism defensive reactions; it creates an active immunity. Serum impregnates the organism and establishes a passive immunity.

Active immunity requires several days to develop, but lasts a long time. Passive immunity is immediate, but quickly disappears. Vaccine is especially a prophylactic means, used more often to prevent than to combat infection. Serum is at the same time a therapeutic and a prophylactic medium.

Thanks to serotherapy, mortality from infections and especially from diphtheria has greatly diminished; owing to vaccination, sickness has declined. Smallpox, rabies, and anthrax have almost passed out of existence, and the time can be predicted when other infections, especially typhoid fever, will in their turn disappear.

PROGRESS IN RECLAMATION OF ARID LANDS IN THE WESTERN UNITED STATES.[1]

By J. B. Beadle,
U. S. Reclamation Service.

[With 13 plates.]

The reclamation of arid lands by the Federal Government has moved steadily forward since the passage of the Newlands Act in 1902, in spite of the numerous and intricate problems arising, many of which could not be foreseen prior to the enactment of the fundamental law governing the operations of the Reclamation Service.

The Service has added some notable structures to the engineering monuments of the country. It has built the highest dam in the world on the Boise River, Idaho, and the one storing the greatest quantity of irrigation water on the Rio Grande, New Mexico. Its reservoirs are capable of holding 6,500,000 acre-feet, or two thousand billion gallons of water. It has excavated 130,000,000 cubic yards of earth and rock, placing 12,000,000 yards in dams and forming conduits aggregating 10,000 miles in length, including 25 miles of tunnels and 85 miles of flumes. Its canals placed end-on would circle the United States. Its structures of all kinds, large and small, dams, bridges, canal drops, checks, and the like total over 70,000 in number.

The works so far constructed make water available for 1,500,000 acres, and the projects under way when completed will provide for nearly as much more. For this greater area the principal works have in large measure already been built, such as storage reservoirs, diversion dams, and main canals, leaving to be added the necessary extensions to the distribution systems.

As incidental to the construction of large irrigation works the Service has engaged in a wide variety of engineering effort, including the construction and operation of roads, telephone systems, power plants, transmission lines, and even railroads. On one project Portland cement was manufactured and on several others the material known as "sand cement" has been produced and used to advantage.

But as varied and intricate as are the engineering problems involved in Government reclamation work, of even greater difficulty

[1] This article is in continuation of papers printed in the Smithsonian Reports for 1901, pp. 407 to 423; 1903, pp. 827 to 841; 1904, pp. 373 to 381; 1907, pp. 331 to 345; 1910, pp 169 to 198.

are the succeeding problems of settlement and utilization of the works. These later problems, involving the human element, less susceptible of mathematical statement, require correspondingly more judgment, as well as patience and tact.

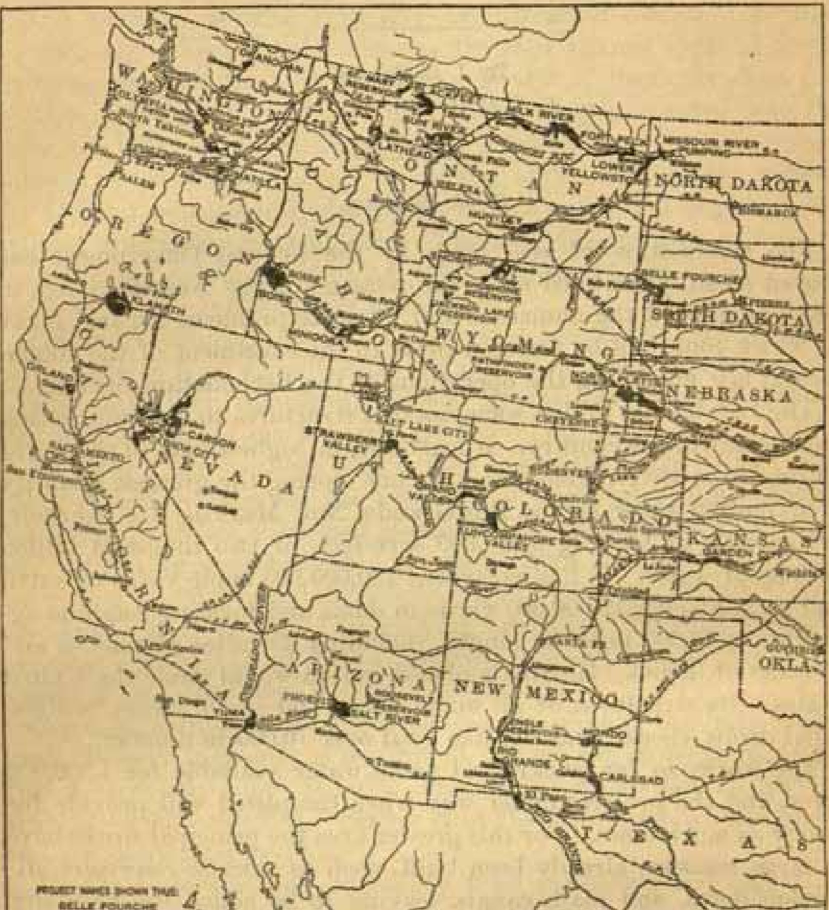


FIG. 1.—Principal reclamation projects.

The physical management and operation of an extensive reservoir and canal system, in which the quantity of flow is regulated at all points and all times according to design, is in itself an intricate problem, akin to railroad management, but in addition this already involves dealing with 25,000 individuals who are dependent on the Government systems for the most vital requisite in their daily occupation of irrigation farming and who are depended upon in turn

to repay to the United States the large investment made in building the works. Thus, in a sense, the Reclamation Service stands midway between the water users and the Nation, owing a duty to each and responsible for the protection of interests that may sometimes appear antagonistic, making the service a natural target for criticism from one quarter or another. However, a broad view of the relations between the Government and the irrigators will usually show their interests to coincide, since the Government has made large investments in reclamation works, the return of which to the National Treasury is directly dependent upon the success of the settlers.

Among those entering public lands are many with no experience in irrigation and often little or none at farming of any kind. Even with water brought to the edge of his farm, the pioneer irrigator has much hard work not common to farming in older humid settlements. The land must be cleared, ditched, and carefully graded to receive the irrigation water, which must be manipulated with skill to prevent loss and damage. Capital is necessary to prepare the land, erect buildings, equip and stock the farm. Many of the problems attending a new agricultural community brought quickly into being relating to crop selection, disease prevention, transportation, and marketing of crops, call for cooperative effort and must be worked out for each project.

In many of these matters the Reclamation Service can act only by suggestion, being limited rather narrowly in the powers given by law.

RECLAMATION LAW.

What may be regarded as the "organic act" governing the operations of the Reclamation Service became law in June, 1902, and is commonly called the reclamation act. This remains the principal legislation, but has been amended and supplemented from time to time in important details, particularly by what is called the reclamation extension act of August 13, 1914. The broad features of the existing law provide for the following:

1. A reclamation fund composed of the receipts from the disposal of public lands in the arid States under the provisions of the various land laws. The fund now approximates a hundred million dollars.
2. The construction of irrigation systems to water public and private lands.
3. Practically free entry to the public lands under the irrigation projects, limiting any one citizen to a farm of such size as is capable of supporting a family.
4. Subdivision of the private lands by sale in small tracts, limiting the area to which water will be furnished one individual to 160 acres.
5. Repayment in easy terms, extending over a long period, of the cost of building the works by the holders of the lands benefited, the money going back into the reclamation fund for use on other projects.

One feature of the law that has been criticised is the absence of any test or qualification for settlers on the reclamation projects. Any citizen who has not exhausted his homestead right may take up a farm unit. Many come in who are unfitted for the arduous task of developing the raw land or who lack the necessary capital to develop their farms and tide them over the nonproductive period at the start. The result may be disastrous to the individual and postpones until his successor is established the payments to the United States for building the works.

Another point of weakness relates to the private lands within the Government projects. There is naturally a tendency to hold these for high prices, such that large owners may realize great profits or "unearned increment" due to the Government construction. The reclamation act sought to force subdivision of large holdings by limiting to 160 acres the area for which any person could acquire a water right. This did not prevent the owners from holding the excess at high prices, and the reclamation extension act seeks to meet the situation by providing that to be included in a project the excess areas must be sold at a price fixed by the Secretary of the Interior. The efficacy of this provision has yet to be demonstrated.

The principal change in the law made by the extension act, however, was to provide easier payments and extend the time in which the irrigators are required to refund the project costs. The act of 1902 provided for repayment in 10 annual installments. The extension act spreads the payments over 20 years. In the case of a new entry or application only an initial payment of 5 per cent is required in the first five years. This gives the settler a liberal period in which to put his farm on a producing basis, during which he may apply his capital to that end unhampered by the necessity of meeting payments on the water-right charges. A liberal extension was undoubtedly needed in a great many cases and the first effect of this recent legislation has been to create a better feeling between the water users and the Government with the increased hope of success in establishing permanent homes.

Another important feature of the extension act, in line with the policy of the fullest possible cooperation between the water users and Reclamation Service, is the provision that after the construction cost is once fixed by public notice it may not be increased through additional construction except after approval by the water users, expressed through individual vote or contract.

COMPLETED WORK.

The Reclamation Service has completed 23 projects or units to the point where the systems are operated and water supplied the farmers for crop production.

In this connection it is well to note the difficulty of fixing an exact time when a large reclamation project is physically completed. Irrigation may start with the completion of the first portion of the canal and laterals, but the construction of the rest of the system may extend over a number of years and yet keep well in advance of settlement and development of the irrigable lands. A better knowledge of the dependency of the water supply gained during these years by further measurement and study may warrant additions to the canal system and the area covered. Or the development of the new community may sufficiently advance land values to justify further expense to increase or conserve the water supply, as by building added storage works or lining the canals with concrete to prevent seepage losses, in either case permitting additional land to be served.

Thus the project as a whole becomes a growing thing, and is not to be compared to a single definite piece of construction, such as a dam or office building, but is similar to a city or railroad system that in a sense may be regarded as never complete.

Nor is the matter of completion made definite by reference to the plan before construction, for we commonly find that during the early history of a large project, while it is being investigated for construction, the conception of what the project finally will be suffers radical changes with the surveys of canal lines and irrigable areas and the accumulation of information regarding the water supply, soil quality, and other factors.

The Government projects now operated are listed in Table 2, which shows that the Reclamation Service delivered irrigation water to 760,000 acres during 1914, but that the systems were constructed well in advance of this, as noted above, being capable of serving 1,240,000 acres. In subsequent pages the principal projects are briefly described with an outline of the work done since former reports. The following tabulation gives some idea of the quantity and diversity of construction work done by the Service on these projects:

Table I.—*Brief summary of construction results.*

[To June 30, 1915.]

Item.	Unit.	Number or quantity.
CONSTRUCTIONS.		
Dams		100
Canals	Miles	9,683
Tunnels	do	25
Dikes or levees	do	91
Irrigation and drain pipe	do	300
Flumes	do	86
Canal lining (concrete)	do	140
Roads	do	784
Railroads	do	82
Telephone lines	do	2,554
Transmission lines	do	429
Canal structures		64,847
Bridges		4,622
Culverts		5,714
Buildings		1,068

TABLE I.—*Brief summary of construction results*—Continued.

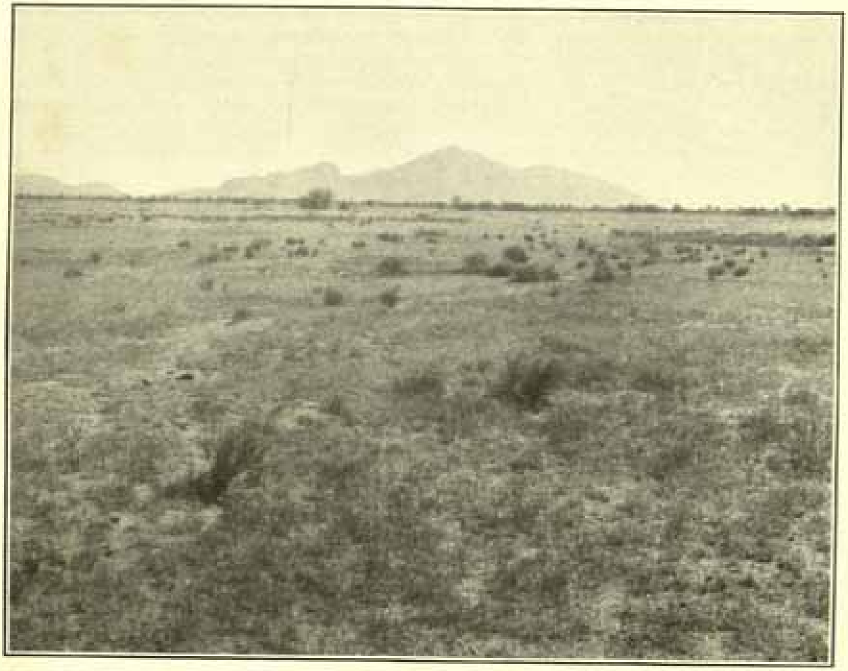
Item.	Unit.	Number or quantity.
MATERIALS HANDLED.		
Excavation:		
Earth	Cubic yards	115,599,284
Indurated	do	7,585,948
Rock	do	6,964,136
Total	do	130,149,368
Volume placed in dams:		
Masonry	do	1,992,502
Earth	do	9,231,109
Rockfill and crib	do	978,474
Total		12,202,085
Riprap	Cubic yards	1,023,398
Paving	Square yards	615,583
Concrete	Cubic yards	2,674,977
Cement	Barrels	2,501,382

CROPS.

The irrigated lands are already producing an annual crop worth upward of $16,000,000, which should be steadily increased by more intensive farming as well as by the development of additional land. In 1914 the farmers on the Government projects harvested irrigated crops from over 700,000 acres. The 60,000 acres listed as irrigated, but not cropped, represent mainly young fruit trees and newly seeded alfalfa.

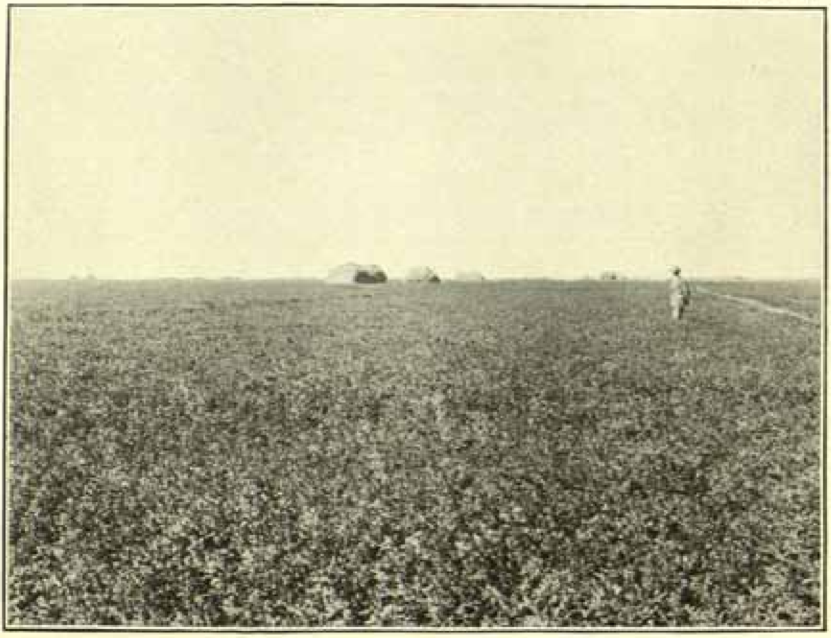
Alfalfa dominates all crop statistics from the irrigated areas (pl. 2, fig. 1). It occupies nearly half the cropped acreage and yields over one-third the total crop value. Its many virtues readily explain this popularity. Once established, or a "stand" secured, it is a hardy plant and continues almost indefinitely to furnish good annual yields without reseeding. It gives several yields or cuttings each year. It is a legume with the peculiar power of drawing from the atmosphere the nitrogen in which the soils of the arid region are often deficient, and leaves behind more than it found of this most valuable of plant requirements. It is the deepest of subsoilers, penetrating with its many roots to a remarkable depth for the other essential elements of plant growth and improving the physical condition of the soil. It furnishes a hay of superior quality for conditioning and fattening stock, so effective in fact that its medicinal value is now being utilized for humans.

A wide variety of other crops are grown on the Government projects—hays, cereals, fruit, sugar beets, and cotton, as well as garden products. Barley is the leading cereal, largely replacing corn in importance in comparison with middle western farming. A considerable area is devoted to grains little seen in the humid States

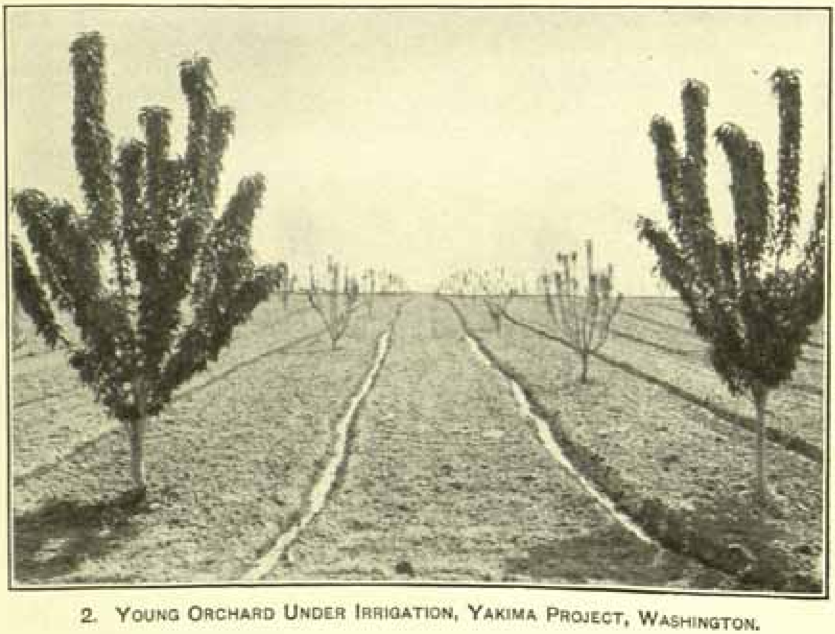


1. ARIZONA DESERT BEFORE RECLAMATION.

2. ARIZONA DESERT RECLAIMED.



1. AN ALFALFA LANDSCAPE, SHOSHONE PROJECT, WYOMING.



2. YOUNG ORCHARD UNDER IRRIGATION, YAKIMA PROJECT, WASHINGTON.

and belonging to the sorghum-corn family, including Kafir corn and milo maize. Beet-sugar factories have been established on a number of the projects, contracting with the farmers for a profitable crop on a large acreage. Cotton has furnished an industry of importance on the southern projects, but this has been set back by the adverse market condition following the outbreak of war in Europe.

Fruit growing is naturally slow to become general, owing to the capital required and postponement of returns; but the industry is making steady progress and has become of major importance on the projects peculiarly suited to it. The Sunnyside Unit in Washington is the home of the famous Yakima Valley apples, and in 1914 produced over a million dollars worth of fruit (pl. 2, fig. 2).

TABLE 2.—*Irrigation and crop results on Government reclamation projects, 1914.*[1]

State.	Project.	Irrigable acreage.	Irrigated acreage.	Cropped acreage.	Value of crops.	
					Total.	Per acre cropped.
Arizona	Salt River	187,112	[2] 173,030	169,719	$4,039,079	$23.80
Arizona-California	Yuma	60,000	25,207	22,568	709,409	31.43
California	Orland	14,300	7,354	6,540	176,331	26.99
Colorado	Uncompahgre Valley	52,338	33,873	33,091	870,381	26.30
Idaho	Boise	207,000				
	Farms reported		64,767	58,064	1,033,447	17.80
	Farms not reported [3]		18,823	16,868	300,140	17.80
	Minidoka	117,090				
	Gravity unit		45,730	39,138	661,796	16.91
	South side pumping unit		35,788	33,512	558,059	16.65
Montana	Huntley	28,808	17,068	17,068	454,583	26.63
	Milk River	13,440	2,201	2,163	34,618	16.00
	Sun River	16,346	6,613	6,561	106,594	16.25
Montana-North Dakota	Lower Yellowstone	36,250	5,743	5,621	96,707	17.20
Nebraska-Wyoming	North Platte	91,504	60,532	59,536	890,202	14.95
Nevada	Truckee-Carson	52,039	39,516	39,285	441,018	[4] 11.23
New Mexico	Carlsbad	20,261	12,690	10,731	237,663	22.15
Do.	Hondo	1,224	1,224	1,172	21,458	18.31
New Mexico-Texas	Rio Grande	40,000	28,442	27,302	1,160,720	42.51
North Dakota	North Dakota Pumping	12,239	1,056	1,045	36,440	34.87
Oregon	Umatilla	17,000	5,102	3,013	88,614	29.41
Oregon-California	Klamath	38,000	24,440	24,440	347,344	14.22
South Dakota	Belle Fourche	68,852	37,454	36,709	461,188	12.56
Washington	Okanogan	10,099	7,740	3,180	104,575	32.88
	Yakima:					
	Sunnyside unit	81,807	64,052	49,273	2,858,845	58.02
	Tieton unit	34,000	20,600	15,920	472,480	29.60
Wyoming	Shoshone	41,166	22,226	20,965	313,826	15.01
	Total	[5] 1,240,875	761,271	703,424	16,475,517	23.50

[1] Data are for calendar year (irrigation season) except on Salt River project, Arizona, data are for corresponding agricultural year, October, 1913, to September, 1914. Figures are for reclamation projects only, excluding three Indian projects in Montana, partially completed and under construction by the Reclamation Service for the Indian Service.

[2] Government project only, exclusive of towns and Tempe Canal lands.

[3] Except irrigated acreage, estimated from figures for reported farms.

[4] $18.22, excluding 19,000 acres native pasture land, at $1.21 per acre, and 4,908 acres otherwise not in full production.

[5] Area Reclamation Service was prepared to supply water during season of 1914.

SEEPAGE AND DRAINAGE.

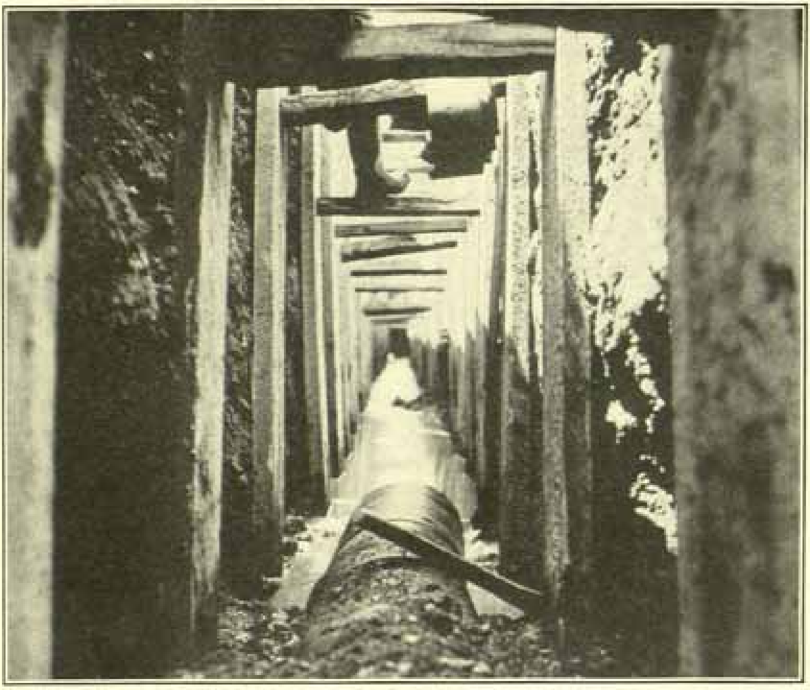
When work in the nature of supplemental construction, already referred to, becomes desirable, it is usually for the purpose of draining the irrigated tracts of excess water.

One of the important things to which attention must be given after an irrigation system is completed and put in operation is the protection of the irrigated lands from becoming seeped and water-logged, destroying their productivity.

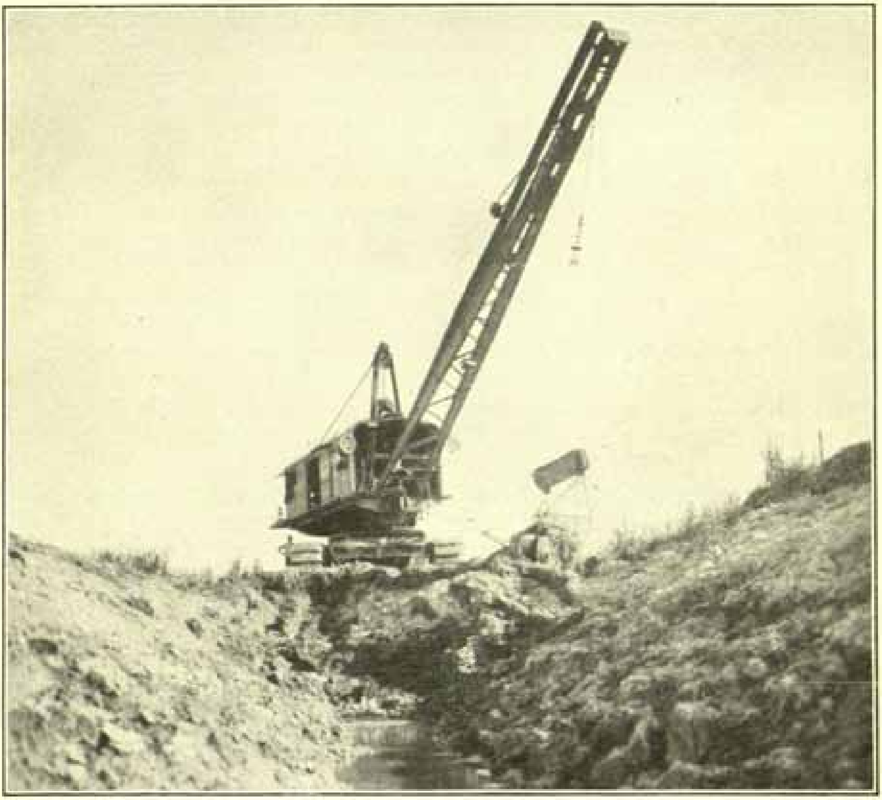
In the use of the irrigation water, there is more or less loss due to the application of a larger quantity than can be retained by the soil and given up to the plants. The amount of water which sinks below the zone of plant growth and is wasted in this manner depends upon the perfection with which the land is graded and ditched and the care and skill used by the irrigator in handling the water. Until the processes have been sufficiently perfected to distribute the exact quantity of water required for the growing crop, some underground wastes are to be expected from this cause. Where, as is ordinarily the case, earthen canals are used for carrying or distributing the water, there is more or less loss by seepage from these channels. This loss, together with the underground waste from irrigation, tends to fill the soil and raise the water plane or height of free water. When this is raised above certain limits the irrigability of the land is destroyed, since plants can not thrive in a soil the interstices of which are filled with water.

To protect lands from becoming thus seeped and water-logged, it is essential that the position of the ground waters be known in order to prevent their rise to or near the surface, rendering the lands unfit for cultivation. Occasional observations must be made at various points to determine the elevation of the ground water and whether or not it is rising. This is done through the medium of wells. When a rise in the water plane is noted and there is danger of it coming too near the surface, action must be taken to prevent it. The means employed to lower and control the ground-water aim at the prevention of losses from canals, the reduction of the amount of water applied to the soil in irrigation, or the construction of drains for carrying out excess waters.

Drainage works have become necessary on a number of the Government projects, and a total of 500 miles of drains have been built to relieve or protect about 100,000 acres. The types of drain used include both covered tile lines (pl. 3, fig. 1) and open ditches (pl. 3, fig. 2). The latter largely predominate, as they have been found through experience to give very satisfactory service, while the efficiency of the tile lines may be seriously impaired by accumulations of sand or by moving out of line.



1. LAYING TILE DRAIN, HUNTLEY PROJECT, MONTANA.



2. DRAGLINE EXCAVATING OPEN DRAIN DITCH, BOISE PROJECT, IDAHO.

ROOSEVELT DAM, WITH FULL RESERVOIR AND WATER PASSING OVER SPILLWAYS.

SALT RIVER PROJECT, ARIZONA.

In Arizona the flow of Salt River has been utilized to irrigate nearly 200,000 acres of fertile land surrounding the State capital. Storage is provided about 80 miles above Phoenix by the famous Roosevelt Dam, a rubble masonry arch in the river canyon 280 feet in maximum height and 1,125 feet along the crest. This gives a reservoir capacity of 1,367,300 acre-feet, or over 400,000,000,000 gallons. A notable event in the history of the project occurred in April, 1915, when, four years after completion of the dam, the reservoir was filled and for the first time water passed over the spillways (pl. 4). The structure stood the test perfectly, and, excepting some erosion of the spillway channels, the excess flood water was discharged without harmful effect, leaving sufficient storage to insure the project water supply for several years. Stream flow records for 25 years indicate that, with the erratic run-off of Salt River, the reservoir may be expected to fill by floods at irregular periods, but that an occasional series of years of lean run-off will empty it again, causing a temporary shortage of water, followed by another period of heavy run-off and a full reservoir. The study of the discharge of the streams of our arid region shows a tendency to these cycles of relatively wet and dry periods, but with records of 30 or even 50 years it is quite impossible to formulate any law as to their recurrence or predict the time when strict economy in the use of water will next be necessary. Some broad-minded men regard these occasional years of scarcity as a benefit. A plentiful supply of irrigation water tends to encourage overuse and careless handling, resulting in waste and rise of ground water, often ruining the lower farm lands by seepage and resultant concentration of alkali. The periodic year of scarcity may therefore be a blessing in disguise, forcing better practice in the use of water and demonstrating the truth that beyond a certain moderate use a greater supply means an actual reduction in the crop value.

From Roosevelt the stored water is passed 60 miles down the river channel to Granite Reef, where the diversion dam turns it into canal systems north and south of the stream. Over 700 miles of main canals and laterals have been excavated to distribute the water to the farmers. The opportunities for hydroelectric development created by the construction of the irrigation works have been utilized by building power plants at the base of Roosevelt Dam and at several points in the canal system where necessary drops afford good heads. Transmission lines have been built, delivering power to the several towns on the project, including the city of Phoenix, where it is used for lighting and manufacturing, and to near-by mining industries, to which the surplus is sold. The receipts from power sales are credited to the project, working a reduction in the total

amount eventually to be repaid by the irrigators for the construction and operation of the project works.

Except for a few minor details the project is regarded as complete, and in 1915 about 190,000 acres were actually irrigated. Crops worth from four to five million dollars are annually harvested from the irrigated lands, the cultivation of which is practically continuous, permitting the sowing and harvesting of two different crops in the same field within the year. A wide variety of products are grown. Alfalfa occupies about one-half the producing acreage, yielding as many as five or six cuttings annually. For this the farmer may secure an average price of $6 per ton, but it is better practice for him to feed the hay and market his output in the more concentrated and profitable form of live-stock products. In 1914 cotton growing had reached extensive proportions on the project, the crop from 11,500 acres bringing a return of $715,000, but the drop in price attributed to the European war has led to the substitution of other crops. Of the grains, barley, wheat, and the sorghum corns are the largest producers. The warm climate lends itself to the growth of citrus as well as deciduous fruits and producing trees have been established on a considerable acreage, which is expected to increase materially in future years with a gradual development toward intensive agriculture.

YUMA PROJECT, ARIZONA AND CALIFORNIA.

Above Yuma, Arizona, has been constructed the Laguna Dam, a low overflow structure of the Indian weir type, 4,780 feet between abutments and 260 feet up and down stream, with a maximum height of 40 feet. This turns the water into canals on both sides of the river for irrigation in Arizona and California. The main canal heads on the California side, and after covering lands on that side crosses the river by means of an inverted siphon. This structure, completed in 1912, consists of two circular concrete shafts connected by a circular concrete-lined tunnel 14 feet inside diameter and 930 feet long. The siphon delivers water to the canal system covering the largest portion of the project in the Yuma Valley, Arizona. On account of the low elevation of the irrigable lands and their consequent liability to overflow from the Colorado River it is necessary to provide an extensive system of river-front protection. The principal work during recent years has been on this feature and the extension of the canal system, which is now competent to water 70,000 acres. This will be extended to cover about 90,000 acres, and an additional 40,000 acres on the Yuma Mesa may be reached by pumping.

About 30,000 acres have been irrigated and the annual crop yield is approaching a million dollars. As at Salt River alfalfa is the

principal crop and a large acreage is here permitted to ripen for seed, which in 1914 brought the farmers $160,000 from 5,500 acres. Cotton has also proven very profitable on this project and with the aid of the Department of Agriculture varieties particularly suited to the locality have been imported or evolved. The cotton industry, now temporarily suspended by the abnormal market conditions, is bound to revive when these return to normal. Other profitable crops include the cereals, sorghum corns, cane, vegetables, and truck. Fruit, especially of the citrus varieties, will undoubtedly increase in importance with development of the project, particularly on the mesa lands yet to be reached by the canal system.

ORLAND PROJECT, CALIFORNIA.

Near Orland, California, has been completed a relatively small project, or what may be regarded as a separate unit of a large Sacramento Valley project. The East Park Dam on Little Stony Creek forms a reservoir storing the water of that stream and of Stony Creek, the latter brought to the reservoir through a feed canal. By means of two diversion dams near Orland the water is taken out of the stream channel into canal systems supplying an area of 20,000 acres favored by exceptional soil, location, transportation facilities, and climate.

The project has been enlarged since former statements by improving the water supply and extending the distribution system to cover an additional 6,000 acres. A diversion dam has been built in Stony Creek near the headwaters and a feed canal excavated to convey the water thus developed to East Park Reservoir. Near Orland separate diversion works have been built for north and south side canals. In accordance with the plans for the present the system is now practically complete and ready to serve the entire 20,000 acres.

In 1914, 7,300 acres were watered, producing crops worth $176,000. High priced products are grown on this project, including almonds, olives, oranges, grapes, and other citrus and deciduous fruits, nuts, and garden truck, as well as hay and forage crops.

GRAND VALLEY PROJECT, COLORADO.

The plan for this project was briefly outlined in the Smithsonian report for 1910, since which construction has been undertaken and about 60 per cent of the work completed.

The diversion dam has been built in Grand River about 8 miles northeast of Palisade. The presence of a railroad along the river bank and the great expense involved in moving this to a higher level led to a somewhat novel construction. It was necessary to control the stage of the stream closely and on the approach of floods be able to release quickly the back water caused by the dam. For this purpose a roller crest structure was built, one of the few and the longest

that has been constructed in this country (pl. 5, fig. 1). The permanent crest of concrete is erected at a relatively low level and above this at 60 and 70 feet intervals rise concrete piers containing the operating mechanism for the structural steel rollers. The latter extend between the piers and may be lowered to form a water-tight junction with the concrete crest, diverting water into the project canal, or may be quickly raised to pass flood water over the weir.

From the diversion dam the main canal follows what is locally known as the "high line," and piercing several hills by tunnels, proceeds in a general westerly direction, passing north of Grand Junction, Fruita, and Mack, and supplying about 43,000 acres of land above the older private canals of the valley. An additional 10,000 acres may be watered by pumping with power developed at drops in the canal. The land is particularly suitable for fruit growing and capable of producing crops of high value.

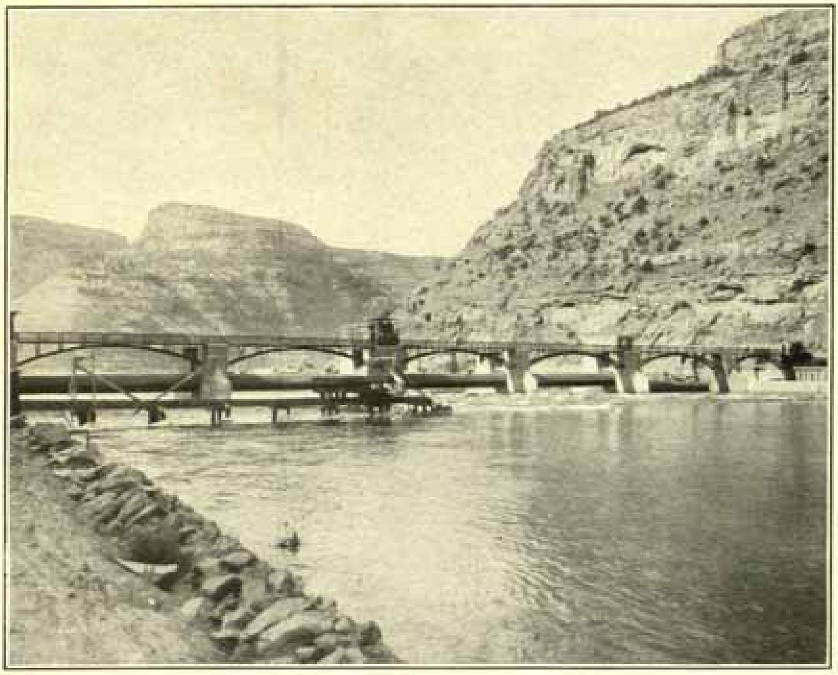
There remain for construction part of the main canal and distribution system, the power and pumping works, and possibly some drainage works. Irrigation will begin on this project in 1916.

UNCOMPAHGRE VALLEY PROJECT, COLORADO.

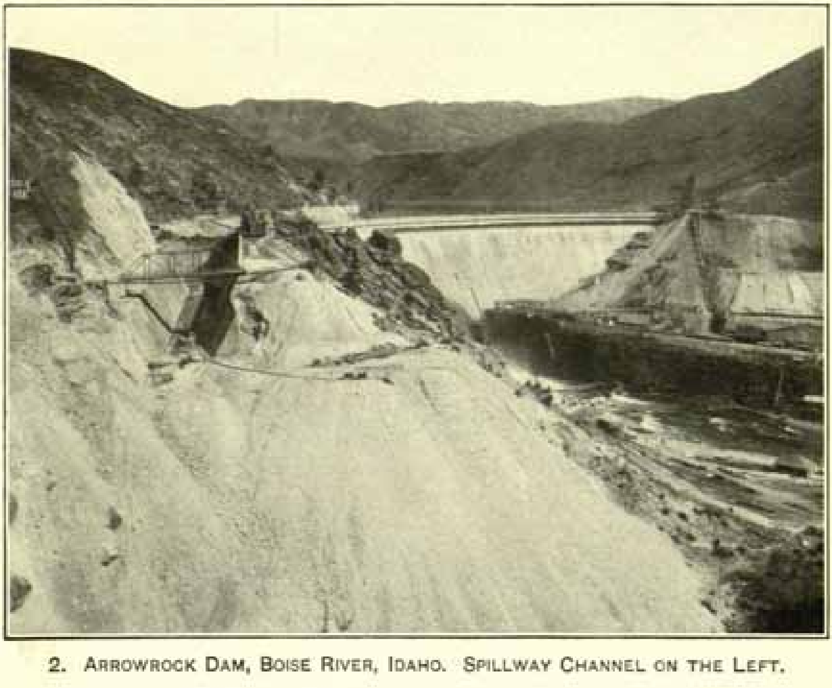
Here the Reclamation Service has built the Gunnison Tunnel to bring water from the Gunnison River to the valley of the Uncompahgre to supplement the meager flow of the latter stream. A number of canal systems heading in the Uncompahgre will distribute the water to about 140,000 acres. Irrigation has been practiced here for many years and the principal private canals have been purchased or absorbed in the Government system to permit change or enlargement in a comprehensive development of the possibilities for irrigation in the valley. Work is in progress on the canal system and this now reaches 65,000 acres, of which 40,000 are being irrigated. The crop production has steadily grown, approximating a million dollars in value in 1915. Deciduous fruits are successful on the irrigated lands and good yields are obtained from alfalfa, potatoes, wheat, and oats (pl. 13).

BOISE PROJECT, IDAHO.

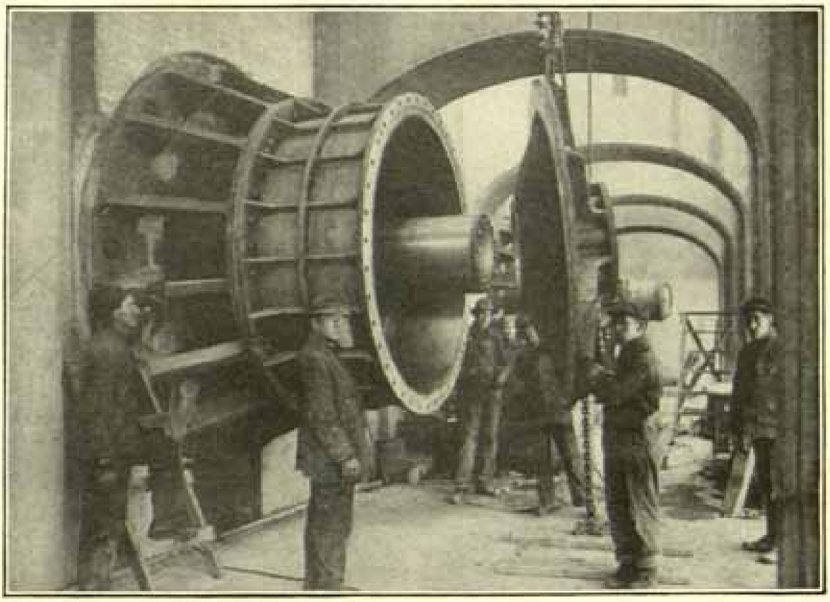
One of the largest projects nearly completed is the Boise in Idaho. This is about equal in area to the Salt River and involves the storage and diversion of the waters of Boise River. The reservoir is formed by the Arrowrock Dam (pl. 5, fig. 2; pl. 6, figs. 1 and 2), the highest in the world, a rubble concrete arch rising 350 feet above the lowest point of the base and measuring 1,075 feet along the crest. The inaccessibility of this site and the large amount of material to be hauled in for the construction made it economical to build a 17-mile railroad



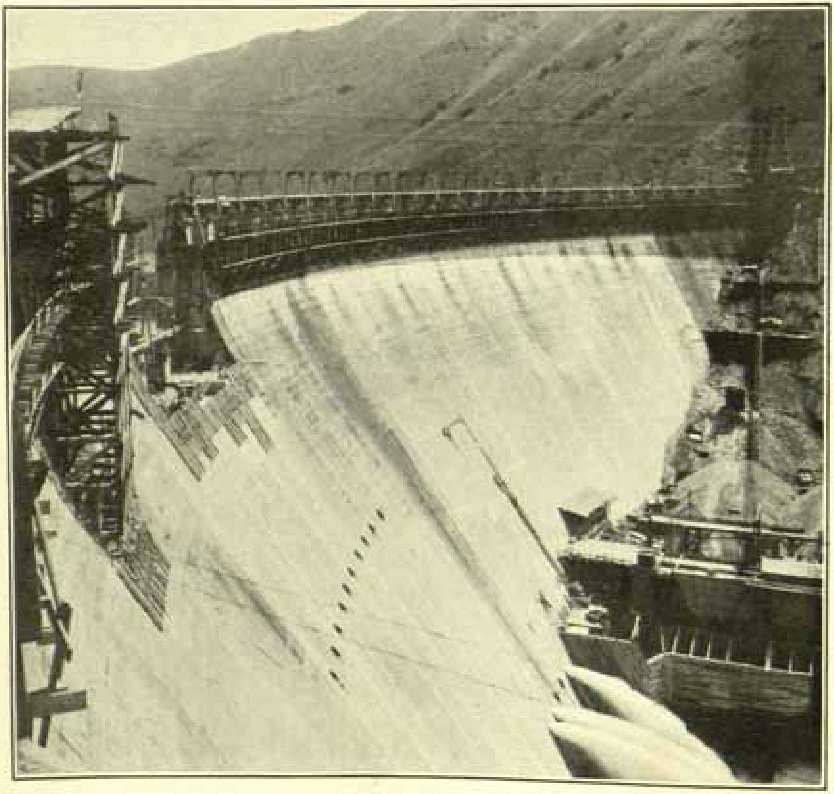
1. DIVERSION DAM, WITH ROLLER CRESTS IN GRAND RIVER, COLO.



2. ARROWROCK DAM, BOISE RIVER, IDAHO. SPILLWAY CHANNEL ON THE LEFT.



1. PLACING VALVES IN ARROWROCK DAM.



2. NEAR VIEW OF ARROWROCK DAM, THE HIGHEST IN THE WORLD.

(pl. 7, fig. 2) connecting the site with the nearest railroad at Barberton. This short railroad, built, owned, and operated by the United States, does a small commercial business in addition to the carriage of freight for building the dam, and the road shows a profit when due credit is allowed for the material carried for the Government construction. This credit represents a substantial saving over what it would have cost to haul the necessary material overland.

About 12 miles below Arrowrock and 8 miles above Boise is the diversion dam of the project (pl. 7, fig. 1), turning the water into the canal system, which includes a main canal carrying the water to the Deer Flat Reservoir, another storage basin formed by several large earth embankments, closing a natural depression some distance from the river.

As on the Salt River project power is developed in connection with the Boise, but in smaller amount. A hydroelectric plant was built at the diversion dam and the power here developed was transmitted to Arrowrock, where it was used to build the larger structure.

In addition to the Arrowrock Dam the principal work since the report of 1910 has been the completion of the distribution system, comprising 1,000 miles of canal and 12,000 structures, together with drainage works. The project embraces two old irrigation districts, which have contracted for supplemental water supply from Arrowrock Reservoir and for drainage work done by the Reclamation Service for the benefit of considerable areas of the district lands that have been rendered temporarily unfit for cultivation by seepage and alkali.

Nearly 100,000 acres of the Boise project are now in crops and the annual production already exceeds a million dollars. Alfalfa, clover, cereals, and potatoes are the leading products.

MINIDOKA PROJECT, IDAHO.

In Snake River Valley a project has been built, involving storage in Jackson Lake, Wyoming (pl. 8, figs. 1 and 2), and a distribution system near Minidoka, Idaho. The Minidoka Dam diverts water to north and south side canals and furnishes a head of 46 feet, which is used to drive a 7,000 kilowatt power plant erected at the dam. The power is utilized to lift irrigation water to additional land not accessible by gravity flow and the excess energy is sold for the benefit of the project.

The power is produced at a cost averaging slightly over one mill per kilowatt-hour, including all operating expense and plant depreciation. This low cost makes it possible to sell the energy for varied and novel uses, such as operating washing machines, flat-irons, and other utensils of the small home. Considerable is used for heating. One of the project towns has recently erected a schoolhouse

that is pointed out as a building without a chimney or a gas pipe, electricity being used for heating, lighting, and operating all the devices necessary in a modern high school that includes physical and chemical laboratories.

The Minidoka Project is practically complete as now planned, and it is possible to water 120,000 acres, of which 82,000 are under irrigation, including 35,000 acres supplied by pumping. Forage crops, grain, potatoes, and sugar beets are the principal products.

HUNTLEY PROJECT, MONTANA.

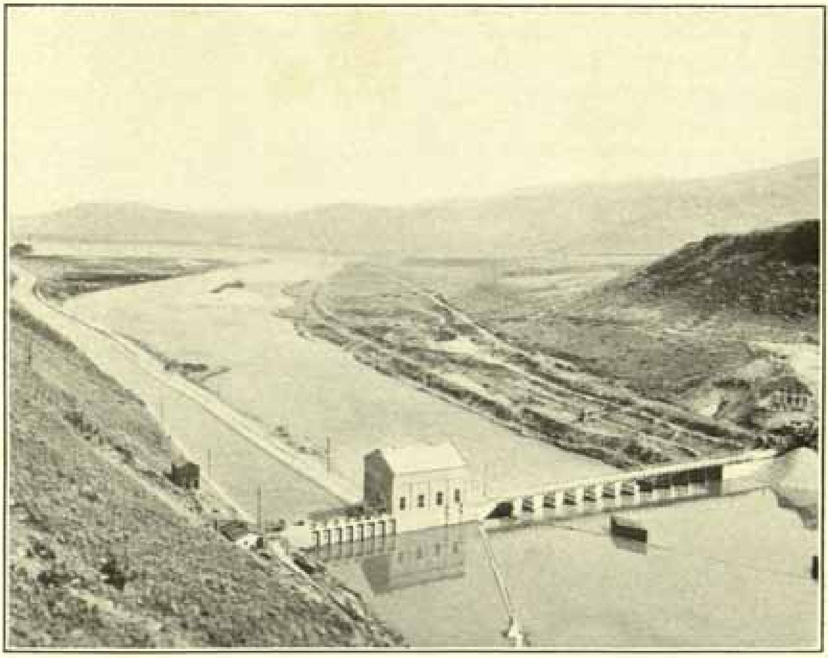
This is one of the few projects that requires no storage works, being located on the Yellowstone River at a point where the natural run-off from a large drainage area provides a sufficient water supply. The main canal and lateral system now cover 30,000 acres, which may be increased by small extensions. The most novel construction feature is a hydraulic pumping plant on the main canal where the bulk of the water, dropping through turbines, operates centrifugal pumps that lift part of the supply to a high-line canal, the whole operation being automatic and requiring almost no attention from the operating force.

The project is one of the most successful in operation and about 20,000 acres are now in crop, yielding products averaging in value over $25 per acre. Sugar beets have become the most important crop (pl. 9, fig. 1). A company has erected and operates a beet-sugar factory, contracting with the farmers for a certain acreage to be planted with seed supplied by the company, which pays for the beets according to their sugar content. Over 4,000 acres are now utilized in this way, returning to the farmer nearly $60 per acre. Alfalfa, grain, and garden truck are the other important products.

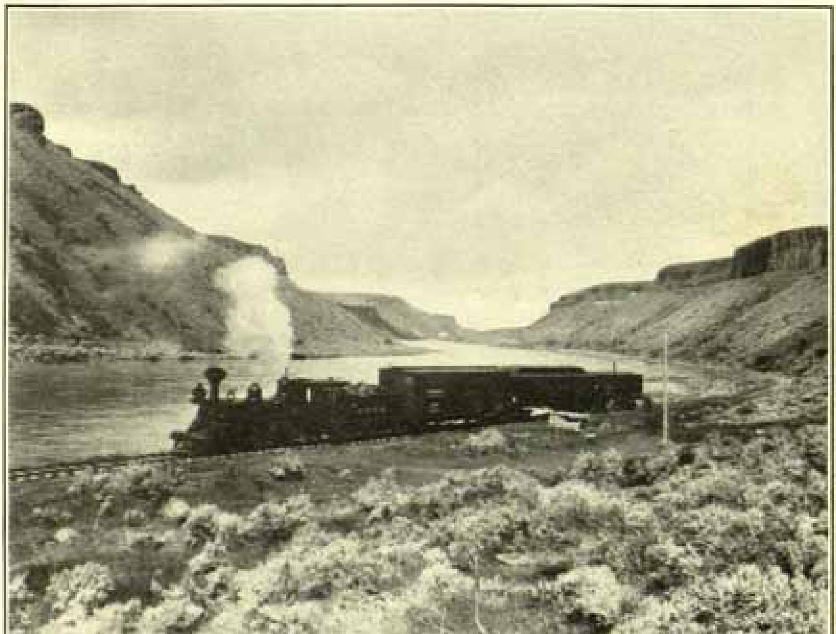
MILK RIVER PROJECT, MONTANA.

Ever since the passage of the reclamation act the effort has been made to develop along broad lines the irrigation possibilities of the Milk River drainage. The situation is much complicated and delays have been caused by the fact that the river is an international stream, rising in the United States, entering Canada, and returning to this country. Thus between the storage sites and irrigable lands in the United States the river passes through lands that may be watered in Canada, leading to conflicting interests in the limited water supply. After years of negotiation a treaty with Great Britain was finally proclaimed in 1910 for the distribution of the water, but its interpretation in detail is still subject to adjustment, which is now in the hands of a joint commission representing the two Governments.

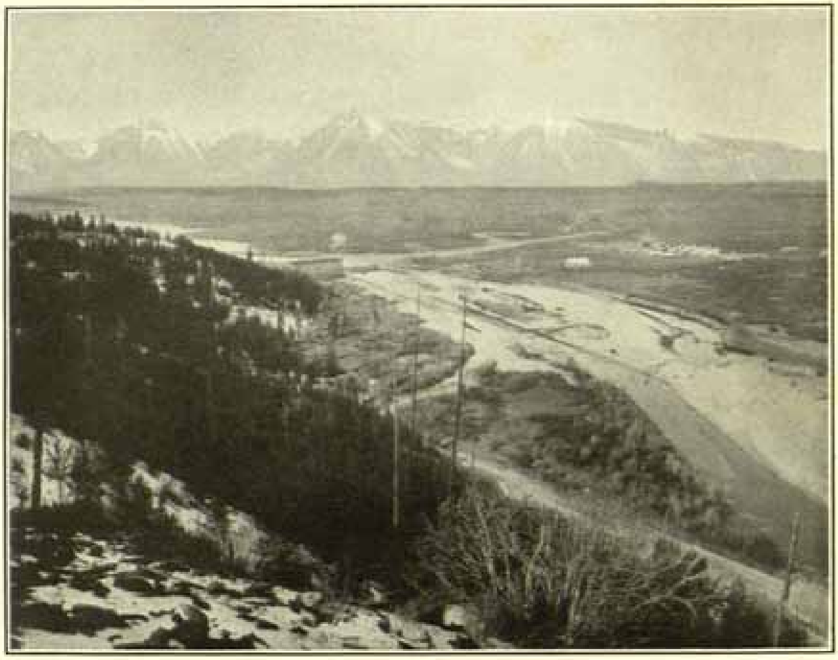
Meanwhile the Reclamation Service has built certain features of the American project, permitting irrigation of a portion of the lands.



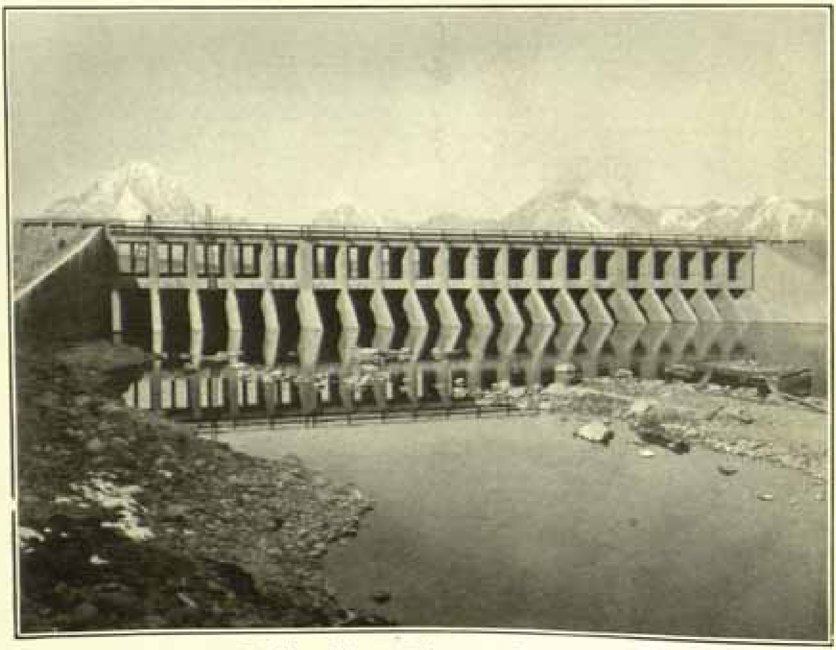
1. DIVERSION DAM IN BOISE RIVER, POWER PLANT AND HEAD OF MAIN CANAL.



2. BOISE AND ARROWROCK RAILROAD, BUILT TO CARRY FREIGHT TO ARROWROCK DAM. DIVERSION DAM AND POWER PLANT IN DISTANCE.



1. DAM AT JACKSON LAKE, WYO., MINIDOKA PROJECT.



2. NEAR VIEW OF JACKSON LAKE DAM.

A canal 25 miles in length has been excavated to supplement the flow of Milk River from that of St. Mary River, thus diverting water through the divide separating the Hudson Bay drainage from that of the Mississippi and Gulf of Mexico. Work is now under way on a storage dam at Sherburne Lakes and additional storage may be provided by a dam at the outlet of Lower St. Mary Lake. Three to four hundred miles below in Milk River Valley, distributing systems are planned, heading at three diversion dams near the towns of Chinook, Dodson, and Vandalia, with supplemental storage in a reservoir fed by one of the main canals. The Dodson and Vandalia dams have been built and distributaries for 40,000 acres. Grain and hay are the staple crops. The rainfall is sufficient to permit dry-farming, but the yield is doubled or trebled with irrigation. Ultimately 200,000 acres or more may be watered.

SUN RIVER PROJECT, MONTANA.

Near Fort Shaw the Reclamation Service has built and operated for several years a unit covering 16,000 acres, and work is now under way on larger features of a project that may eventually comprise 175,000 acres. A diversion dam (pl. 9, fig. 2) has been recently built in the Sun River near Elizabeth and a distribution system for lands north of the river is under construction. A storage reservoir will be built on the north fork of the Sun.

The irrigable lands are within 50 miles of Great Falls, which supplies a market for the farm products. Grain, hay, and vegetables are the principal crops.

LOWER YELLOWSTONE PROJECT, MONTANA AND NORTH DAKOTA.

About 18 miles below Glendive, Montana, the Yellowstone Dam diverts water into a canal that covers a strip of land west of the river in Montana and North Dakota. About 35,000 acres can now be supplied. The cold climate and short growing season limit the crops mainly to hay and grain, which give enhanced yields under irrigation, but the rainfall is sufficient to encourage dry farming and renders it difficult to secure uniform support for irrigation among the settlers. No construction work has been done on this project in recent years.

NORTH PLATTE PROJECT, NEBRASKA AND WYOMING.

This is another interstate project, utilizing the flow of the North Platte River to irrigate lands in Wyoming and Nebraska. Storage is provided near the headwaters by the Pathfinder Dam, a masonry

arch 218 feet high and 432 feet along the crest. Near Whalen, Wyo., a diversion dam supplies the Interstate Canal, a notable irrigation conduit with a capacity of 1,400 cubic feet per second at its head. The canal is over 100 miles long and serves 130,000 acres in the two States. It takes several days for water entering the headgates to reach the end of the ditch, and several small reservoirs have been constructed along the canal to provide temporary storage and better regulation of the flow. These reservoirs, the lower part of the canal, and related distributaries have been built since the former reports in this series. Other construction has included drainage works, and work is now starting on a large unit on the opposite side of the river. Here the Fort Laramie Canal will take out from the river at the Whalen Dam. It will exceed the Interstate Canal in length and furnish water to an area of 100,000 acres.

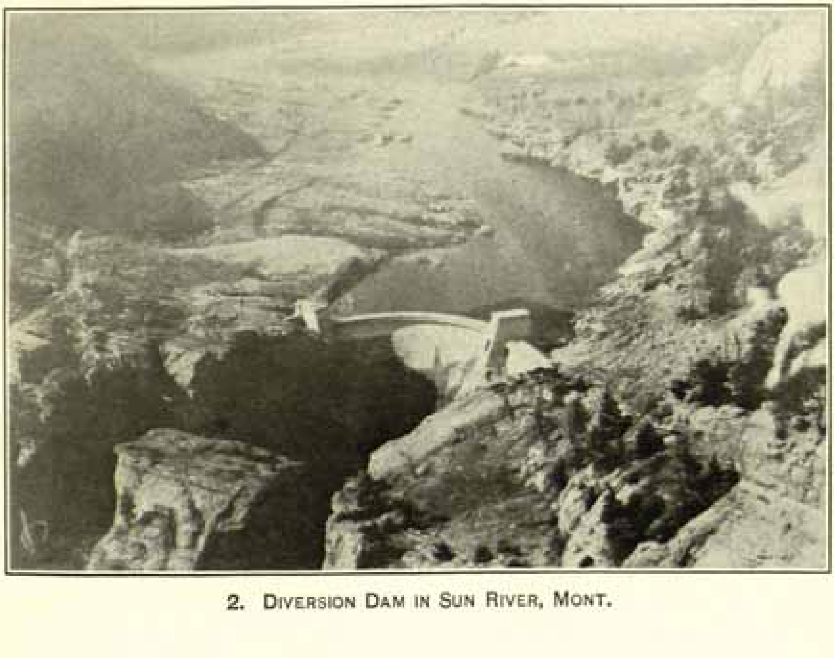
In addition to supplying the Government project of 230,000 acres, the Pathfinder Reservoir provides sufficient stored water to supplement the supply of a number of private canals along the river to which rights have been sold under the provision of the Warren Act of February 21, 1911, the receipts entering the reclamation fund.

The area actually irrigated by the North Platte project is now increasing about 5,000 acres each year, and the annual crop value reached $1,000,000 in 1915, when 70,000 acres were harvested. Alfalfa and grain are extensively grown and used to fatten stock for market. Hog raising has become an important and profitable industry; during the last six months of 1914 shipments to market averaged over 20 carloads, representing monthly receipts of $30,000 from this industry alone.

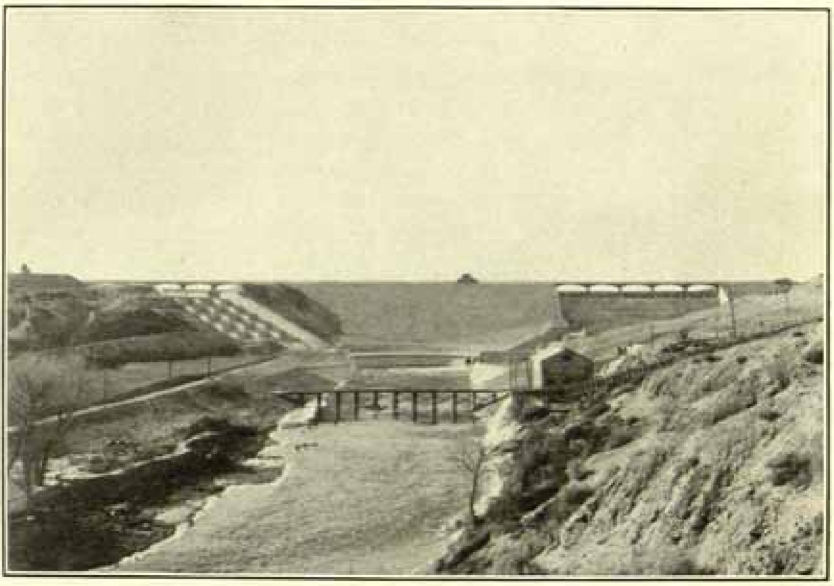
TRUCKEE-CARSON PROJECT, NEVADA.

On this project the Lahontan Dam has been recently built, being completed in 1915 (pl. 10, fig. 1). The structure is a large earth embankment, with rock and gravel paving, 124 feet in maximum height and 1,400 feet long. The most interesting feature of the structure is the provision for passing excess flood water without injury to the dam directly or by erosion of the relatively soft material composing the river channel and canyon walls. For this purpose concrete spillway channels leading from each end of the dam are built in steps, dropping the water to a concreted stilling pool below the structure (pl. 10, fig. 2). The reservoir impounds the flow of Carson River and also receives the water brought from the Truckee through the Truckee Canal, built some years before. Prior to building the reservoir a hydroelectric plant was erected to utilize the drop from Truckee Canal to Carson River and the power thus developed was used in the construction of the dam.

1. HARVESTING SUGAR BEETS, HUNTLEY PROJECT, MONTANA.



2. DIVERSION DAM IN SUN RIVER, MONT.



1. LAHONTAN DAM, TRUCKEE-CARSON PROJECT, NEVADA.

2. STEPPED SPILLWAY CHANNELS AND POOL AT BASE OF LAHONTAN DAM, NEVADA.

Other recent work includes smaller structures, drains, and extension of the distribution system, which serves lands near the town of Fallon. About 65,000 acres are now under ditch and the area may be considerably increased. With additional storage and canal systems 200,000 acres may ultimately be reclaimed. The locality is extremely arid, with an annual rainfall of about 4 inches, insufficient for any crop growth. Under irrigation the soil gives good yields of alfalfa, grain, and vegetables.

CARLSBAD PROJECT, NEW MEXICO.

Near Carlsbad, New Mexico, two dams have been built across the Pecos River, forming storage basins, and from the lower one of these a canal system has been excavated to supply 25,000 acres of land surrounding Carlsbad. The project was completed in 1912, since which about 13,000 acres have been irrigated, producing good yields of alfalfa, cotton, grain, truck, and fruit.

RIO GRANDE PROJECT, NEW MEXICO AND TEXAS.

This is an interstate and international project, using the waters of the Rio Grande to irrigate land in New Mexico and Texas and supplying Mexico at the international boundary a quantity of water fixed by treaty.

The largest irrigation reservoir in the world is formed by the recently completed Elephant Butte Dam (pl. 11, fig. 1), spanning the river canyon near Engle, N. Mex. This structure is of rubble concrete, 300 feet from the bottom of the foundation to the crest, which extends 1,250 feet between abutments. This gives a reservoir capacity exceeding 2,500,000 acre-feet, or 800,000,000,000 gallons. One of the problems connected with storage on the Rio Grande is due to the great amount of silt carried by the stream, and this large reservoir capacity is expected to care for years of silt accumulations, which are further provided for by numerous openings through the dam for sluicing (pl. 11, fig. 2).

From the reservoir the water passes down the river channel to the irrigable lands, which are located in a series of narrow valleys along the stream in New Mexico and Texas. The development of each valley involves a diversion dam, main canals on either side of the river, and the necessary distributaries and structures. A number of private canals watering small areas will be embraced in the general development.

In the Mesilla Valley the Leasburg Dam and main canal have thus been built to connect with several community canals covering about

35,000 acres. An additional diversion is now under construction in this valley controlling 60,000 acres.

In El Paso Valley the old Franklin Canal has been purchased and enlarged. This passes through the city of El Paso, where it has been concrete lined to give increased capacity. About 29,000 acres will eventually be watered.

Other tracts to be reached lie in Rincon and Palomas Valleys. In all, the project contemplates the irrigation of about 155,000 acres in the United States. The soils are very fertile and the market facilities unusually good. Alfalfa yields 3 to 6 tons per acre and the price averages above $10 per ton, reaching at times as high as $15 or $20. Vegetables, truck, and fruit are very successful, and the 27,000 acres harvested in 1914 under the Government works yielded crops worth well over a million dollars.

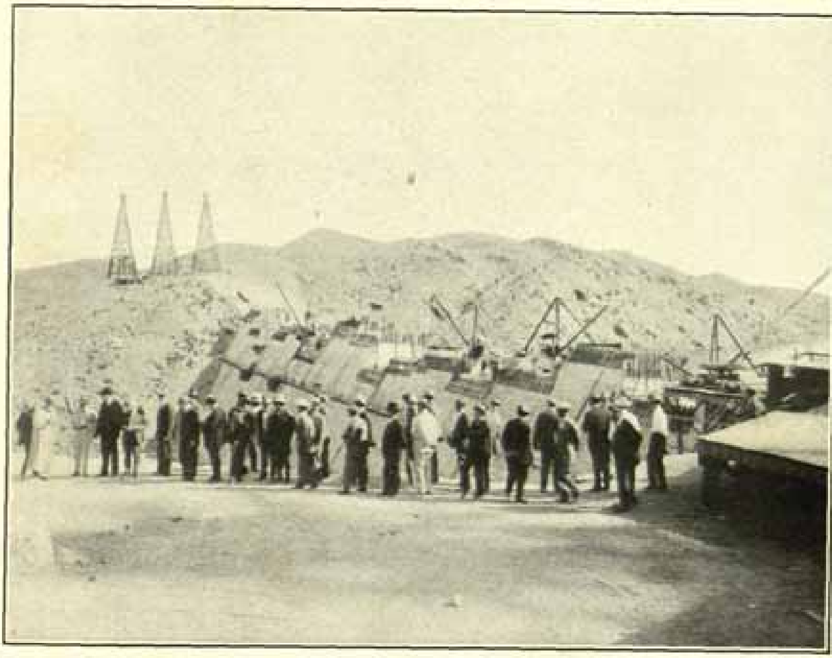
UMATILLA PROJECT, OREGON.

Former reports have described the portion of the Umatilla project lying east of the Umatilla River, supplying 25,000 acres by means of a canal system heading in Cold Springs Reservoir, which is filled by a feed canal from the Umatilla. Recently an extension to the project has been under construction west of the river, adding about 11,000 acres to the irrigable area. The work includes the Three Mile Falls Diversion Dam, a main canal heading at the dam, and a system of laterals carrying water to each farm.

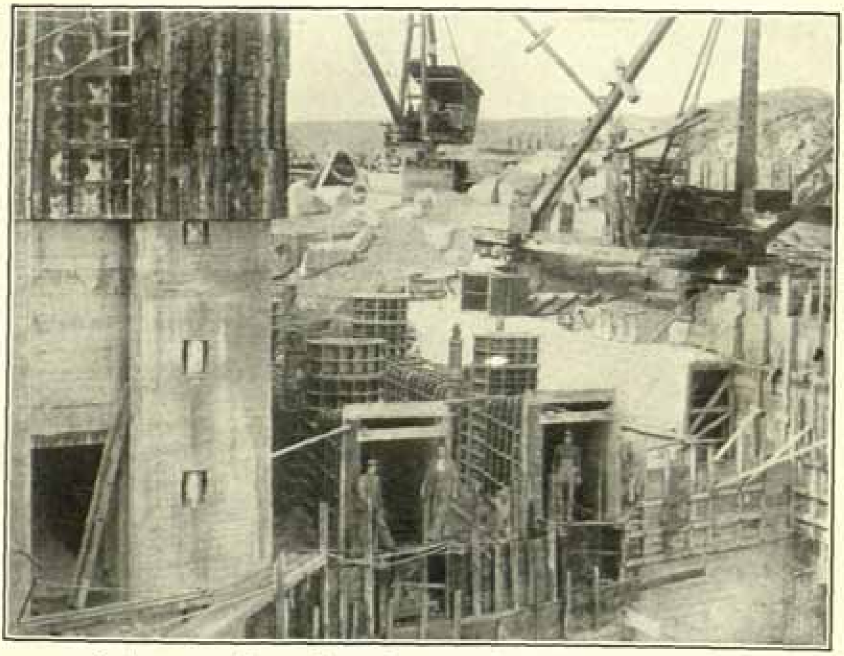
On the older part of the project about 5,000 acres are now in crop. The conditions are favorable for the growth of fruit, which is gradually becoming the principal product. Good yields are also obtained from alfalfa, grain, vegetables, and truck crops.

One of the difficulties encountered in the operation of the Umatilla project is due to the fact that portions of the irrigable land are very sandy, causing the irrigation water to escape rapidly to a depth where it is not available to the plant roots. To sustain crop growth on such land it is necessary to irrigate it frequently and the "duty" or quantity of water required per acre is excessive. In some cases the duty may be as low as 15 or even 20 acre-feet per acre, i. e., during the irrigation season the total application to the field is equivalent to a depth of 15 or 20 feet. The average duty on the Umatilla project is now about 7 acre-feet, and for all the reclamation projects the average is between 2 and 3 acre-feet per acre.

The great importance of this subject is realized when it is remembered that usually the available water supply and not the available land limits the extent of a project and largely determines the cost per acre. Also the cost of operating the works and guarding against

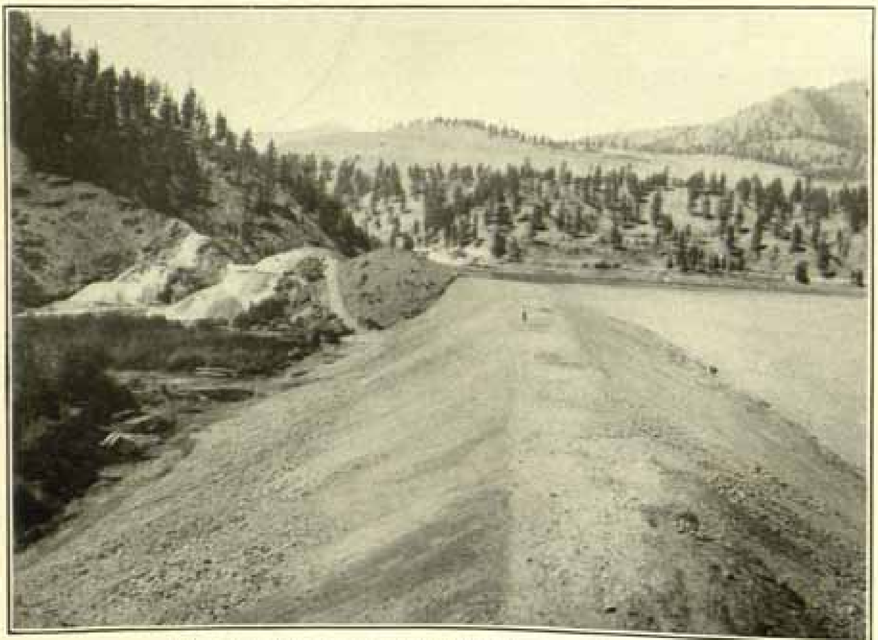


1. ELEPHANT BUTTE DAM IN THE RIO GRANDE, NEW MEX. CONGRESSIONAL PARTY ON TOUR OF INSPECTION, JUNE, 1915.



2. INSTALLING SLUICE GATES, ELEPHANT BUTTE DAM, NEW MEXICO.

1. CLEAR CREEK DAM, TIETON UNIT OF YAKIMA PROJECT, WASHINGTON.



2. CONCONULLY DAM, OKANOGAN PROJECT, WASHINGTON.

breaks in the canals is increased as the quantity of water to be carried is made larger and the annual charge for operation and maintenance against each irrigator is in proportion to the amount of water delivered to him.

The permanent cure for excessive use imposed by sandy land lies in the addition of vegetable matter to the soil. With the growth of each crop the condition improves through the addition of humus. Another influence for a better duty, applicable to all soils, is the use of relatively large irrigation heads; that is, supplying the fields by using a large stream of water for a short time rather than allowing a small head to run to the fields during a longer period. To improve the duty by this means requires proper ditching and grading as well as skill in handling the water.

By these means the average duty on the Umatilla project was improved more than an acre-foot per acre in 1914 over the previous year, and it is believed that with the gradual addition of humus to the sandy portions of the area the problem will be satisfactorily solved. The farmers on the sandy tracts require every encouragement in establishing normal conditions and provision has been made for a relatively low charge per acre-foot for such lands for a period of years during which opportunity may be had to put the soil in proper condition.

KLAMATH PROJECT, OREGON AND CALIFORNIA.

In the Klamath country of southern Oregon and northern California a plan has been partially carried out for utilizing the run-off of Klamath Lakes and Lost River to water areas that may eventually total 200,000 acres. As described in former statements certain units of the project have been constructed, making water now available for 40,000 acres, of which 25,000 are being irrigated. In its entirety the project is an intricate one, involving a number of unusual features, of which perhaps the most novel is the dewatering and subsequent canalization of the Tule Lake bed. For this purpose its supply from Lost River is cut off by building a dam at Clear Lake, the head of Lost River, forming a large shallow basin in which evaporation practically equals the inflow, and largely diverting into Klamath River the run-off that reaches Lost River below Clear Lake. By evaporation the bed of Tule Lake is gradually uncovering and irrigation of the exposed land has begun along the edge of the lake. Construction work in recent years includes the Lost River diversion dam and channel to Klamath River, enlargements and extensions of canal systems and drains for the lands already watered.

The Klamath area receives an average annual rainfall of 14 inches, permitting some crop production by dry farming, but the

yields are doubled with irrigation. Forage crops predominate, but potatoes are successfully grown and small areas of fruit trees have yielded well.

BELLE FOURCHE PROJECT, SOUTH DAKOTA.

Near the town of Belle Fourche, S. Dakota, the river of the same name has been utilized to irrigate lands east of the town. A diversion dam in the river turns the flow into a feed canal supplying a reservoir on Owl Creek, formed by a large earth dam from which canal systems distribute the water to the irrigable lands. Since former reports the distributaries have been extended to serve an area of 78,000 acres, about half of which is producing crops. Cereals predominate, including wheat, oats, corn, rye, and barley. Alfalfa is generally grown, and potatoes and garden truck occupy small tracts.

STRAWBERRY VALLEY PROJECT, UTAH.

This contemplates the irrigation of 50,000 acres east of Utah Lake. Storage is provided by a dam on Strawberry River. By means of a tunnel nearly 4 miles long the water is carried through the rim of the Great Basin and delivered to Spanish Fork River. Here it is turned into the canal system by means of a diversion dam. The main canal serves also as a power conduit, supplying a hydroelectric plant, built early in the construction work, to furnish power for driving Strawberry tunnel. A permanent use of the power is planned for pumping water to tracts inaccessible by gravity flow and for drainage. Surplus power is now sold the towns of Payson, Salem, and Spanish Fork. The canal construction has recently been actively pushed and the project as a whole is regarded as 85 per cent completed. A number of old canals in the valley will be supplied from the Government works, and the delivery of stored water began in June, 1915. The principal products are alfalfa and other hays, cereals, sugar beets, and vegetables.

OKANOGAN PROJECT, WASHINGTON.

In Okanogan County, Washington, the Reclamation Service has built works to serve 10,000 acres of land along Okanogan River within 50 miles of the Canadian border. Storage is provided in Salmon Lake and by an earthen dam on Salmon River near the town of Conconully. (Pl. 12, fig. 2.) The water is turned into a canal system about 12 miles below the Conconully Dam by means of a weir across Salmon River. The gravity system was completed in 1910 and the water has been used by the farmers each year on an increased acreage. The area irrigated has now reached about 8,000

THE DESERT TRANSFORMED.

Harvest scene on irrigated land, Uncompahgre Valley Project, Colorado.

acres, making it desirable to build a pumping plant that has been regarded as a part of the general plan, and this has recently been constructed. Small hydroelectric plants have been erected at drops formerly provided in the project canals and the power thus developed is used to operate the pumping plant, which is located near Omak. This lifts water from the Okanogan River to supplement the supply from the Salmon. It is not necessary to run the pumps every year, but they provide capacity to water about 1,000 acres during seasons of lean runoff in Salmon River.

The project lands are excellently suited to the production of fruit, particularly apples. Peaches, apricots, pears, prunes, and various small fruits are also grown. Hay, forage, and vegetables are produced on smaller areas.

YAKIMA PROJECT, WASHINGTON.

As described in former reports considerable work has been completed toward the execution of a comprehensive development of the Yakima Valley, including storage reservoirs at the headwaters of the Yakima River and its tributaries, and distributing systems at various points lower down in the valley. Since former statements a permanent dam has been built at the outlet of Kachess Lake and a similar structure is under way at Lake Keechelus. Kachess Dam is an earth and gravel fill 1,400 feet long and 65 feet in maximum height. On the Tieton River a relatively small reservoir has been formed by the construction of Clear Creek Dam (pl. 12, fig. 1) to serve a novel purpose. The Tieton is fed by melting snow, causing a large diurnal variation in the flow so that the discharge at its peaks could not be taken into the main canal and some of the needed water was lost. The Clear Creek Dam provides the necessary reservoir capacity to correct this daily fluctuation and store a small quantity of water.

The principal distribution systems are the Sunnyside and Tieton units. In 1906 the United States purchased the old Sunnyside Canal, then watering 40,000 acres, and this has been extended and enlarged to supply 82,000 acres, including several small tracts to which water is pumped, using power developed at plants built at drops in the canal system. On the Tieton water is provided for 33,000 acres by a system including a main canal of difficult construction through Tieton Canyon, involving several tunnels and long stretches of open canal made up of concrete shapes.

Nearly 100,000 acres are now under irrigation on these two units, growing crops each year worth three to three and a half million dollars. The section has become a well-known apple producer and through cooperative organizations has made great progress in de-

veloping a uniform product and in advertising and marketing it. In addition to apples and other fruits excellent yields are obtained from alfalfa, cereals, and vegetables. Indian corn is successful here; in 1914, 7,500 acres of this crop yielded an average of about 50 bushels per acre.

SHOSHONE PROJECT, WYOMING.

In Wyoming the Shoshone River is being utilized to develop a project of 150,000 acres. In the canyon above Cody has been built the Shoshone Dam, a rubble concrete arch 328 feet high and 200 feet along the crest. This was the highest dam in the world when constructed, but has since been exceeded by the Arrowrock Dam, also built by the Reclamation Service. Eight miles below Cody a diversion dam turns the stored water into Corbett Tunnel, which delivers to the main canal. Recent work has extended the distribution system to reach 41,000 acres. Slightly over half of this is now being irrigated so that the canal system is constructed well ahead of the farming development. Agriculturally the project is essentially a hay and grain producer, with small tracts devoted to vegetables and garden truck. Alfalfa is the principal crop, exceeding all others together in planted area and value of product.

SUMMARY.

Under the reclamation act of June, 1902, with later amendments, the work of redeeming our arid lands has gone steadily forward to the point where 23 projects or units have been completed so that the problems of construction have been succeeded by those of operating the works for agricultural production. A million and a half acres can now be supplied with water through the Government systems, and half of this area is actually producing crops totaling nearly $20,000,000 in yearly value. In effect a State has been added to the Nation in that the annual production from the irrigated lands already exceeds that of a number of the smaller States.

SOME RECENT DEVELOPMENTS IN TELEPHONY AND TELEGRAPHY.[1]

By Frank B. Jewett,
Assistant Chief Engineer Western Electric Co. (Inc.).

With an art such as that of telephony and telegraphy which has been either wholly or in large part developed within the last 30 years, it is difficult to cover in an article of a few thousand words all that might be construed under the term "recent developments." It is even difficult to determine what should be classified as recent developments.

As soon as the researches and discoveries of scientists and inventors along any line show signs of developing into an art which will aid in the every-day life of mankind, a great stimulus is given, not only to a betterment of the physical means for affording the service, but also to the development and exploitation of the commercial possibilities made available by the new art and to the production of an operating organization which will render the physical equipment most fully available for the commercial needs. Thus, it happens that in the field of telephony and telegraphy, both wire and radio, great strides have been made during the past few years in perfecting the commercial and operating organizations which have been found necessary to make the work of the scientist and engineer fully available to the public. In what follows no attempt has been made to cover any features of these latter developments. This seemed the more necessary since the commercial and traffic needs of no two countries are exactly alike and a full presentation of the subject would require more space and more particularly larger knowledge than the author possesses. In limiting the paper to the physical and engineering aspects of telephony and telegraphy an attempt has been made further to confine it to those developments which have brought about rather radical changes in the existing state of the art or which bid fair to bring about such changes in the future.

Before passing on to a consideration of these recent physical and engineering developments, it might be well to point out that, contrary to a more or less general belief, most of the physical developments have followed as a direct result of commercial or traffic operating requirements rather than as the result of a priori considerations on the part of the scientist and the engineer. Although not

[1] Read at the Second Pan American Scientific Congress, at Washington, Dec. 27, 1915–Jan. 8, 1916. Printed by permission of Executive Committee of the Congress.

universally true, a large majority of the radical physical changes have resulted from studies and developments made with a view to extending the existing possibilities of telephony or telegraphy to cover some new or more promising field.

In selecting the items to be considered the endeavor has been to touch upon those changes in the physical art of telephone and telegraph transmission which would be of interest to all of the members of the Pan American Scientific Congress, irrespective of any commercial, geographic, or climatic conditions which might be peculiar to any given locality. In other words, the attempt has been to select those developments which tend to improve or modify fundamental considerations in the application of the art of transmitting intelligence electrically. The only exception to this is in the brief discussion of apparatus intended primarily for use under tropical and semitropical conditions. To a large proportion of the members of the congress this is really a fundamental consideration which must underlie the proper engineering of the physical plant needed to give service.

Although the present state of the art has closely interlaced the requirements of wire and radio telephone and telegraph developments and although the future seems to indicate an even closer tying together of all phases of electrical intelligence transmission systems, it is difficult in a short paper to treat the important advances, except in relation with the particular field to which they most closely pertain. For this reason the discussion has been divided into three main parts:

1. Wire telephony,
2. Wire telegraphy, and
3. Radio communication, both telephonic and telegraphic.

1. WIRE TELEPHONY.

Since the whole present art of wire telephony is the result of only 40 years' work, almost anything might be construed as a "recent development." Ten years has, however, been taken as the period to be covered, and since any major development in the art requires considerable time for its working out, the results of the work during the past 10 years can only be properly appreciated by considering the state of the telephone art some time prior thereto—for example, about 1900.

Let us review, therefore, the situation in the telephone field at the beginning of the present century.

By 1900 the telephone art was rapidly emerging from the era when the inventor rather than the engineer was supreme in the field. The experience gained during the preceding 25 years, supplemented

by the application of sound engineering principles, had indicated certain things as being fundamental to the proper extension of commercial telephony. The trend of further development and the correct methods to be followed were also becoming clear.

Among other things, the necessity for using metallic circuits had been proven beyond peradventure. So, too, the employment of the relatively high-priced, hard-drawn copper line wire had been shown to be economically cheaper and more satisfactory, all things considered, than the inexpensive iron and steel wire originally employed for both telephone and telegraph circuits. Moreover, the fallacy of building expensive long-distance, open-wire pole lines and terminating them in the cities in small wire cables was beginning to be fully appreciated, and the engineering of the wire plant was already being done on a scientific basis. This basis was that the wire plant as a whole should be in cost equilibrium when considered from a transmission standpoint. In a plant where such cost equilibrium exists, the increased annual charge required to give a fixed increment of improvement in transmission is the same, irrespective of the part of the plant in which the improvement is made. The full appreciation of this fundamental requirement and its extended application has probably done more than any one thing to eliminate gross variations in the grades of transmission furnished in different localities and greatly to reduce plant costs.

Fifteen years ago the possibility of improving the transmission efficiency of telephone circuits by the periodic introduction of loading coils was not commercially known. Little or no progress had as yet been made in the art of securing a third or "phantom" metallic circuit from two ordinary metallic circuits. Amplifying devices, which were among the earliest dreams of the telephone inventor and engineer, were still in a crude state of undeveloped laboratory equipment. Fifteen years ago the telephone engineer, except in a few localities, had had relatively little experience in the problem of operating in close proximity to electric power circuits of extra high potential. To be sure, the introduction of street railways and low-tension lighting and power circuits had already brought with them the necessity for radical changes in the telephone art. But the single-phase railway and the high-potential transmission circuit employing hundreds of thousands of volts did not then exist.

In the matter of substation apparatus—that is, transmitters, receivers, and associated devices—the telephone art had become somewhat stabilized. The bipolar type of receiver was in general use, as was also some form of multicontact microphone. In America, where the ultimate scope of telephony was recognized to include a universal long-distance service as well as purely local service, the solid back, granular button type of carbon transmitter had come to

be standard. In Europe, where the conditions of a purely local or at best a very short-distance transmission seemed to prevail, a more microphonic type of instrument was preferred. In both continents there was already a drift away from the earlier forms of fixed or wall type subscribers' instruments, and the desk stand and hand set were beginning to appear.

In the central office the myriads of inventions which had been proposed and tried out were gradually giving way to apparatus which embodied the best of all that had been suggested. So-called automatic systems for central office operation were beginning to be exploited, but the great bulk of telephone engineering was on the basis of manual switchboards, which, to be sure, involved many functions not manually performed. In fact, nobody as yet had had sufficient experience to say definitely where the ultimate development of central office switchboards was likely to lead.

Such, in brief, was the state of the art in the more important parts of wire telephony 15 years ago. A comparison of the then existing art with that of to-day and a statement of what has been done in the last 10 years can best be made by a statement of the improvements in each principal line. This survey will also permit of making some sort of a hazard as to the future development which may be expected in the field of wire telephony.

PHANTOM CIRCUITS.

As is well known, so-called "phantom" circuits are those metallic telephone circuits which are obtained by combining two ordinary metallic telephone circuits in such a way that a third metallic telephone circuit is secured without producing any mutual interference with either of the component circuits and without causing any mutual interference between these component circuits. Considered from the theoretical standpoint alone, the problem is a simple one, since it consists merely in so arranging the circuits and the terminal apparatus that the current in one side of the phantom divides equally between the two wires of one physical circuit, while the current in the other side of the phantom divides equally between the two wires of the second physical circuit, a further proviso being that the arrangement shall be suitably balanced both electromagnetically and electrostatically. Under these conditions, there is no tendency for currents in the phantom circuit to produce circulating currents in the component physical circuits, nor do circulating currents in the latter tend to produce a circulating current in the phantom.

Technically the realization of this theoretical ideal is extremely difficult. Since in the transmission of speech we are dealing with a band of high-frequency alternating currents, it does not suffice to

have the circuits and terminal apparatus balanced merely with regard to their ohmic resistance. They must also be balanced with regard to mutual capacities and inductances, not for a single frequency alone but for a multiplicity of frequencies, if the necessary freedom from cross interference is to be obtained.

With the conditions which existed at the beginning of the present century, neither the lines themselves nor the terminal apparatus were suitably balanced for the introduction of the phantom principle. All of the cables then in service were constructed with a view to securing freedom from interference between simple metallic circuits. So also with open-wire lines, which, although transposed according to definite rules, were designed merely to provide freedom from cross interference between circuits operated on an ordinary metallic basis. The terminal apparatus in general use at that time, although reasonably satisfactory for the services originally intended, was even more hopeless than the lines from the standpoint of phantom operation.

During the years between 1900 and 1906 or 1907 great strides were made in the application of phantom operation. A transposition system, permitting the use of phantom circuits on open-wire lines, was developed and the necessary mechanical details for interchanging the wires were worked out. Phantom repeating coils were designed and the art of their manufacture developed. Little or no progress, however, was made in the matter of successfully adapting cable construction to the requirements of phantom operation.

The condition at about the beginning of 1907 was, therefore, one in which there was a fairly large and successful application of the phantom principle on nonloaded open-wire pole lines which terminated directly at central offices or terminated through relatively short lengths of cable. Where the toll lines had to be brought into the central offices through long lengths of cable, it was necessary either to place the phantom repeating coils at the junction of the cable with the open wire toll line or to endeavor, by a process of experimental selection, to find a sufficient number of interference-free pair combinations in the cable. The first of these alternatives was highly objectionable, both from the standpoint of maintenance on the coils and more particularly because it practically eliminated half of the wires from the possibility of use for superimposed telegraphy. The second alternative was almost equally objectionable because every repair to the cable required a reselection of pairs.

At this time (1907) there were no means known for combining the phantom principle with the benefits from loading, now to be described.

LOADING.

Although Oliver Heaviside had shown mathematically in the early days of telephone development that material improvements in the transmission efficiency of circuits would result from increasing their self-inductance in a uniform fashion, it was not until the latter part of the last century that any scheme was suggested for the practical application of Heaviside's work. During the two or three years immediately preceding 1900, Prof. M. I. Pupin, of Columbia University, and Mr. George A. Campbell, of the American Telephone & Telegraph Co., working independently, showed that by the insertion of suitable inductance coils at intervals regularly spaced over the length of the line the effect of a distributed inductance could be simulated to any desired degree of precision.

This invention of so-called "lumped" or "coil" loading came at a most opportune time in the development of the telephone industry in the United States. By 1900 telephone service requirements within the larger urban areas and on the long-distance toll lines were taxing the then known methods of transmission to the limit. In cities such as New York the number of circuits required for interoffice trunk purposes had become so great that it was no longer feasible to carry them on open-wire pole lines in the streets. The only known alternative was the employment of heavy-gauge conductor cables, whose use would entail vast expenditures for copper and conduit space and which even then would provide an inferior grade of transmission. For this service the benefits to be derived from loading offered a most welcome relief by insuring the possibility of obtaining the necessary grade of transmission through cables with small-gauge wires.

The problem in the long-distance toll line field was somewhat different. Here it was not so much a question of securing more circuits but of extending the range of transmission or bettering the service over existing circuits. With the large size of copper conductors then in use on the longer lines it was clear that no practical transmission benefits would be derived from a further increase in the weight of metal, while such an increase would necessitate a large addition to the item of line costs. It was seen at once that if coil loading could be applied to open-wire lines the effective range of the circuits could be very greatly increased.

Under the economic spur of these two requirements, the engineers of the Bell system attacked vigorously the problem of producing inductance coils which would fulfill the requirements set forth by Pupin and Campbell. Although the mathematical solutions had been obtained and their accuracy demonstrated in the laboratory, the practical problem of physical application to existing telephone circuits had yet to be completed.

To be effective, loading coils must provide the required inductance, without at the same time too greatly increasing the effective resistance of the line. With the materials at first available it was feared that the only feasible way of obtaining the desired transmission results would be through the employment of air-core coils. Coils of this type were actually constructed and installed during some of the early experiments. While fairly efficient in the matter of the ratio of inductance to effective resistance, these coils were abnormally large and had the very serious defect of producing a large stray magnetic field, so that it was impossible to locate more than a few coils in close proximity to one another without encountering serious cross interference.

This early work showed the absolute necessity of producing a magnetic core type of inductance coil. The solution of this problem led ultimately to the development of the fine iron wire toroidal core type of loading coil which is now standard.

By 1906 suitable coils had been developed for loading both cable and open-wire circuits of the ordinary metallic type. In the cable plant loading was common for all of the longer interoffice trunks in cities and loaded underground toll cables between cities were beginning to be installed. In the open-wire plant loading was common for everything except the larger sizes of copper wire which were employed in the very long distance services. The loading of such wires had not as yet proved feasible, due to the fact that with the construction then standard the reduction in transmission efficiency in times of wet weather was so great that the loaded circuit was at times actually poorer than a corresponding nonloaded circuit.

At the time in question (1906–7) no progress had been made in the application of loading to circuits operating on the phantom principle. In laying out the plant the telephone engineer was consequently confronted with the necessity of choosing either to avail himself of the benefits of better or more extended transmission through loading or of greater circuit facilities through phantoming—he could not obtain both.

In this connection it is interesting to note that whether the choice was loading or phantoming, the successful operation of plant necessitated a very much higher degree of line construction and maintenance than had hitherto been deemed necessary.

DEVELOPMENT OF PHANTOM LOADING AND DUPLEX CABLE.

The engineers of the Bell system were fully alive to the disadvantages of the conditions just described and at once commenced developments looking to their elimination. The result has been that during the past eight or nine years the problem of loading large-gauge open-wire circuits has been solved, the use of loading has been

extended to circuits operating on the phantom principle, and the method of manufacturing cable has been completely revised, so that to-day practically no large-gauge telephone cables are constructed except those in which all of the wires are available for loading and phantom operation.

Incidental to these developments but of a practical importance almost equal to the major developments themselves has been the working out of the methods necessary properly to install and load this new or so-called "duplex" type cable.

PRESENT STATE OF THE ART WITH REGARD TO LOADING, PHANTOMING, AND DUPLEX CABLES.

Coincident with the successful adaptation of loading to phantom circuits and the production of a cable suitable for loaded phantom operation came a rapid application of these developments in the extension and betterment of long-distance service. While these applications were made principally in the United States, they have also been put into use in Europe and in some parts of South America, notably at the Isthmus of Panama. At the present time it is standard practice in the United States to have all of the longer open-wire lines equipped with phantom loading, to have these lines enter the central offices through loaded phantom cables, and to connect the principal cities with loaded phantom circuits in underground cable. The most noteworthy application of phantom loading to the open-wire plant is in the transcontinental telephone circuits between New York, Boston, and other Atlantic seaboard cities and the Pacific coast, while the most noteworthy application of loaded phantom cables is between Boston and Washington, where the circuits are carried in loaded underground cable pairs for a distance of approximately 500 miles. In England an underground loaded phantom cable between London and Liverpool is now nearing completion.

As illustrative of the extent to which loading has been applied to telephone circuits in the United States within the last 10 or 12 years, it might be noted that there are to-day in service approximately 350,000 miles of loaded inter-office trunk circuit, 34,000 miles of loaded underground toll circuit, and 200,000 miles of loaded open-wire lines. The average extension in the range of transmission by the use of loading is from two to three times.

TELEPHONE AMPLIFIERS.

While the idea of telephone amplifying devices is almost as old as the telephone art itself, it has been only within the last four or five years that anything approaching successful application of this idea has been made.

Two problems are involved in the application of amplifiers to ordinary two-way telephone circuits. One is the problem of the amplifier instrument itself and involves fundamentally the construction of an instrument which will add energy from a local source to the telephone circuit under the control of the attenuated telephone current from the distant transmitting station. To be successful the instrument must have such characteristics that no appreciable distortion of the speech is produced in its operation.

The other is the problem of so inserting the amplifying device in the telephone line that it will work equally well in both directions and without any tendency to "sing," i. e., to operate in a local closed cycle.

Both of these problems were for many years formidable and unsurmounted obstacles. Recently, however, both have been solved, and the engineers of the Bell telephone system have developed a number of types of amplifying devices capable of application to either nonloaded or loaded circuits in cable or open wire. All of these different types are in successful operation to-day. The application of amplifiers to loaded circuits is particularly difficult on account of the peculiar characteristics of such circuits, and the solution has involved many radical changes in the previously existing art of loading.

TRANSMITTERS AND RECEIVERS.

Although the fundamental principles employed in the manufacture of commercial transmitters and receivers have not undergone radical change within the past 10 years, there have been marked advances in the construction of the apparatus. In particular, transmitters have been adapted for use interchangeably on local and common battery systems. They have been made much more rugged, with better "quality" and louder volume than the instruments standard 10 years ago.

An even more marked improvement has been made in connection with receivers due to the employment of pole pieces which are electrically welded to the permanent magnet portion of the receiver.

Special transmitters and receivers for a variety of services have been developed. In particular, throat and chest transmitters, which operate directly from the muscular movements caused by the operation of speaking, have been constructed for aeroplane and mine-rescue work, where ordinary type instruments can not be employed. Special transmitters have also been developed for employment in theaters, churches, and other auditoriums for the purpose of enabling partially deaf persons to understand better what is being said. Special telephones have also been developed for stethoscopic and cardiographic observations.

LOUD-SPEAKING TELEPHONE APPARATUS.

While the successful completion of the loading and amplifier developments which have made transcontinental telephony possible have completely eliminated the necessity and desirability for loud-speaking telephone apparatus for general telephone service, the last three or four years have seen material progress in the development of such equipment for specialized services. In particular, there has arisen a demand for loud-speaking telephonic equipment for announcing purposes, for passing signals and orders to switch towers along railway lines, and for use in connection with moving pictures. While active development work on this kind of apparatus is still in progress, much has already been done to meet the demands which have arisen. For many of the services amplifying devices are used in conjunction with special transmitters and receivers.

TELEPHONE CIRCUITS WITH SUPERIMPOSED TELEGRAPH.

While the original application of ordinary ground-line telegraph operation to wires normally employed for telephone service was made a good many years ago, notable improvements in the equipment have been made during the last 10 or 12 years. The development of phantoming and loading, and particularly the combination of the two, introduced many difficulties into the successful operation of superimposed telegraph circuits. Within the last few years it has been necessary to redesign completely the terminal apparatus used at the central office. In addition, the presence of the telegraph current necessitated a special design of loading coil for use on very long circuits in order to avoid impairment of speech quality.

All of these difficulties have been overcome and the situation to-day is one in which every wire in a modern telephone toll plant is available for operation as a grounded telegraph circuit, irrespective of whether the wire forms part of a loaded circuit or a loaded phantom circuit and irrespective of whether it is in cable or open wire. Further, the telegraph circuit so produced is suitable for the highest class of duplex operation. In the United States there are thousands of miles of such superimposed telegraph circuits in daily operation.

INTERFERENCE FROM HIGH-TENSION LIGHTING, POWER, AND RAILWAY CIRCUITS.

Within the last 10 years the art of electric transmission of power has undergone radical changes and the whole art of single-phase alternating-current railway operation has come into existence. Developments of a protective nature for telephone and telegraph circuits have kept pace with the developments in the disturbing circuits.

The most notable results have been obtained in connection with the operation of telephone and telegraph lines in proximity to single-phase alternating-current railways. In this type of power transmission circuit the inductive effects may be felt at distances measured by miles rather than by feet, while on wires in close proximity to the railway line the induced potentials may at times reach hundreds or even thousands of volts. The problem of protecting low-voltage circuits against these excessive potentials led to the development of what are known as compensating transformers, which, although causing some transmission loss when introduced into the telephone circuit, serve effectively to limit the voltage rise in the circuit to a point which endangers neither the operation of the circuit nor the lives of those employing it.

In connection with high-tension interference, it is interesting to note that in the United States the difficulties from interference which beset the telephone and telegraph engineer have reacted to produce material alterations in the methods of power circuit operation originally proposed. Further, there is to-day a concerted desire on the part of telephone, telegraph, and power engineers to introduce methods of operation which will be productive of minimum inconvenience to all concerned.

The great growth in the high-tension network which covers the country, particularly in the thickly settled commercial sections, has added hazards to life and property as well as inductive disturbance troubles to the problem of the telephone and telegraph engineer. With the increasing complexity of the aerial line plant and more particularly through the economic and legislative necessity for reducing the number of pole lines to a minimum by joint occupancy of low and high-tension wires, the possibility of physical contact, particularly in times of storm, has been greatly enhanced. One of the very great advances which has been made in the last few years has been in defining proper specifications for joint use construction, proper specifications for safe construction at crossing points of low and high-tension wires, and the formulation and adoption of proper types of pole-line construction for low and high-tension wires in general.

TELEPHONES FOR TRAIN DISPATCHING.

In the railroad field the use of the telegraph for controlling train operations is rapidly giving way to the telephone. Up to a few years ago the telegraph offered the only feasible means for handling this class of service, which required the dispatcher, located at a central point, to keep in constant touch with a large number of stations along the line. There were frequently as many as 50 or 60 of these stations, and each office had a predetermined call or code which enabled the dispatcher to call in the particular operator wanted.

During the last few years thoroughly reliable mechanisms have been produced for selectively signaling a large number of telephone stations on the same line. With this mechanism the dispatcher, by the simple process of turning a particular key at the central point, operates a signal, usually a bell, at the desired station without signaling any of the other stations on the line. As soon as the called operator picks up his telephone he, and he alone, is in direct communication with the dispatcher over a high-grade telephone circuit.

The development of this effective signaling apparatus has removed the principal obstacle to the general adoption of the more effective and flexible telephone and it seems only a question of time when practically all train dispatching will be done by this means rather than by telegraph.

TELEPHONE APPARATUS.

Because of the rapid development of the telephone art it has actually been difficult, at times, to produce the new apparatus needed to keep pace with the service requirements. This was particularly true in the period preceding 1905. The result was that 10 years ago the telephone system was employing a great variety of apparatus performing almost identical functions and consequently the quantity of each special type of apparatus required was small and the manufacturing costs correspondingly high.

With the telephone industry assuming gigantic proportions this state of affairs obviously could not continue indefinitely without entailing great monetary waste. About eight years ago, therefore, the matter of unifying telephone apparatus as much as possible was undertaken with the result that there are to-day lines of apparatus with but slight differences in structure which are capable of performing a variety of functions. This has been brought about largely by the employment of unit types of constructions capable of being assembled in a variety of ways.

All this has resulted in the adoption of more effective methods of manufacture with a consequent reduction in cost. One of the most noteworthy results of this general development has been the substitution of parts punched and formed from sheet metal for parts previously made from castings or machined from solid stock. This use of sheet metal has also resulted in lighter and simpler apparatus, occupying less space in the switchboard or substation.

A noteworthy example of this standardization of types is found in relays, of which hundreds of thousands are employed in central office equipments. A few years ago there were almost as many types of relays as there were individual service requirements. To-day this has been changed and the number of types reduced to very small proportions—the necessary service requirements being obtained by

special windings and special arrangements of contact springs assembled from standard parts.

Another striking change in telephone apparatus has been the substitution of metal for wood, particularly in connection with the housing of substation apparatus. Where formerly the subscriber's set and the apparatus box were made from wood, the standard practice now is to employ drawn-steel housings, properly japanned.

2. WIRE TELEGRAPHY.

LAND SYSTEMS.

Although the telegraph was the first of the electric intelligence transmission systems in the field, progress in the art during the 20 years following 1885 was not as great as the progress in the telephone field. Recently, however, great activity has been shown in the matter of utilizing the telegraph-wire plant to better advantage. Not only has the use of the superimposed telegraph been greatly extended in the telephone plant, but there have also been striking developments in the realm of printing and high-speed telegraph systems.

The primary object of these developments has been economy in the wire plant and in operating costs. As a result of what has been accomplished it is probably an underestimation to state that one telegraph circuit can now be made to carry as much traffic as four or five circuits operated by hand-speed Morse. It should be noted in passing that this statement is not intended to convey the idea that all telegraph circuits should be so operated.

Two radically different fundamental ideas have been developed in the last decade, namely, the high-speed and the multiplex. In the high-speed printing system the messages are first prepared on perforated tape by a number of operators, and these tapes when collected are fed into a transmitting machine in sequence. This transmitting machine converts the perforations in the tape into telegraph signals, which pass out over the line. At the receiving end the messages may be printed directly on a paper tape or they may be received as perforations in a tape, which is later fed into a special typewriter designed to translate the perforations into Roman characters.

In high-speed systems the printed tape at the receiving station is gummed to the telegraph blanks. Thus the operations at the sending station of bringing the perforated tapes to the high-speed transmitter and at the receiving station of distributing the messages and gumming the tapes are manual, and a natural development would be toward performing these operations automatically or else eliminating them altogether.

The multiplex type of printing telegraph accomplishes this purpose, and the present indications are that it will become the preferred scheme for handling the heavy telegraph traffic which obtains between large cities.

In the multiplex system the line is switched to each operator in turn and at each switching the electrical signals, forming a one-letter combination, are transmitted over the line. The switching mechanism operates with such rapidity that it is possible to obtain a speed of from 40 to 50 words per minute from each sending operator. Thus in the case of a quadruple duplex—that is, a circuit transmitting four messages in each direction simultaneously over one wire—the total carrying capacity of the circuit would be from 320 to 400 words per minute.

In the multiplex system the messages are perforated on a paper tape, as in the case of the high-speed systems, but instead of one transmitting machine and one printing machine operating at a high speed a number of separate transmitters and printers are used at each end. These transmitters and printers are connected to the switching mechanisms, and by means of properly designed synchronizing apparatus the instruments at either end of the line are kept in proper relation to one another, so that each printer is always associated with its own transmitter.

One great advantage of the multiplex from an electrical and mechanical standpoint lies in the relatively long time intervals which obtain. Thus, after a letter combination has been sent out by a transmitter to the distant printer, the transmitter has ample time to set up another letter combination and the printer to print the letter and to restore to normal before the machines are again connected to the line.

The multiplex printing telegraph system now being manufactured by the Western Electric Co. has shown traffic loads per circuit averaging nearly one-third greater than those carried by previous multiplex systems using the same number of operators. As compared with high-speed systems, the traffic handled by this multiplex is probably 40 per cent greater per average circuit, although the number of operators required is less.

An outgrowth of the work on multiplex printers has been the development of electrical printing mechanisms which bid fair to have a wide field of application in other services, such, for example, as in the operation of large commercial and manufacturing establishments.

TELEGRAPH FOR RAILWAY SERVICE.

As noted in connection with telephone developments, the production of suitable selective signaling apparatus has made possible the substitution of the telephone for the telegraph in the handling of train movements on railways.

As this railway service has been one of the principal uses of the telegraph for more than 50 years, its abolition would appear to make the handling of commercial messages for business not conducted by telephone and the transmission of press dispatches and other matter which can be done most economically in this way the principal future field for land telegraphy.

SUBMARINE TELEGRAPH CABLE.

For many years developments in the submarine-telegraph field were practically confined to improvements in the types of cable employed and to minor improvements in the terminal apparatus. During the last few years there has been renewed activity in this highly important branch of communication.

In particular much has been done in the way of amplifying the feeble currents received through long ocean cables, thus rendering legible current fluctuations which would otherwise be too feeble to produce readable signals on a siphon recorder tape. A direct result of amplifying the signals has also been increased speed of transmission.

Within the last two or three years experiments have likewise been made with a view to recording cable signals as dots and dashes on a sounder, so that they can be read by ear, as is done in the case of Morse telegraphs. Just how far this line of development, which would permit connecting together submarine cables and land telegraph lines, will succeed commercially is a question yet to be determined.

The most recent work on submarine telegraphy has been that of Col. Squier, of the United States Army, who has designed a system of alternating-current cable signaling which gives promise of considerable application.

3. RADIOTELEPHONY AND TELEGRAPHY.

Since the whole life of the art of radiocommunication is scarcely more than 15 years long, everything which has been done is in a sense a recent development. The physical phenomena involved in radiocommunication are so spectacular and weird that more attention on the part of the general public has probably been accorded the progress of the art than is usually given to the commercial de-

velopments of electrical science. For this reason it will doubtless suffice to confine our consideration to what has been done during the last five years.

At the beginning of the present decade, radiotelegraphy, although serving a useful purpose in connection with ship-to-ship and ship-to-shore services, was still in a very unsatisfactory condition. Very little had as yet been done in the matter of developing successful long-distance communication. With one or two minor exceptions of what were in reality experimental installations, practically all radio-communication was on a spark-system basis. Continuous wave train systems were beginning to loom up as possibilities of the future, and controversies as to the relative merits of such systems and the already known spark systems had already begun.

At the time in question—say, 1900—radiotelephony, except as a theoretical possibility supported by a few rather unsatisfactory demonstrations of an experimental character, did not exist. Certain things had, however, been reasonably well determined as essential to any future development along this line; for example, the necessity for a continuous or almost continuous form of wave train and something other than the direct insertion of a telephone transmitter in the antenna circuit for modifying the high-frequency waves.

By the first of 1913 what was termed commercial trans-Atlantic communication by radiotelegraphy had been accomplished, and although spark systems were still in the great majority, continuous-oscillation systems were beginning to come into favor, particularly for long-distance service. In a practical sense, radiotelephony had not, however, made very much progress.

GENERATING APPARATUS.

During the past five years most of the progress in the field of generating apparatus has been in the direction of producing continuous oscillations of large power. In this connection should be mentioned the Goldschmidt generator, the static frequency changers of the Telefunken Co., improvements in the Poulsen arc intended to give a larger output and more stable operation, the high frequency alternators developed by the General Electric Co., and thermionic devices. Some of this apparatus has reached the stage where it is in everyday commercial service, while the rest is still largely in the experimental stage.

RADIATING SYSTEMS.

During the past few years practically nothing of importance has been published on the fundamental principles of radiating systems. The general trend of commercial or experimental radio station con-

struction has been toward the use of larger antenna structures at the sending station with a corresponding lengthening of the most efficient wave length to be used. Although present knowledge is still very meager, this tendency to large antenna systems at the sending station is the result of the general experience in long-distance radiotransmission, which appears to show that the lower frequencies, that is, the longer wave lengths, are more readily and efficiently transmitted than the higher frequencies or shorter wave lengths.

For receiving, the use of amplifying devices has permitted the adoption of very cheap and simple structures. Experience has shown that the reduction in receiving efficiency by the adoption of small antenna systems is compensated for by the reduction in atmospheric disturbances—this making possible the use of a high degree of amplification of the received signals.

TRANSMISSION.

The most important data on the laws governing the strength of received signals which has been published during the last few years are those obtained by Dr. Austin, of the United States Navy Department. This data was in process of being augmented by a comprehensive series of simultaneous observations at widely separated stations under the direction of an international organization at the time present hostilities in Europe commenced. Until such international cooperation can be reestablished little of value is likely to be done.

RECEIVING APPARATUS.

As inferred above, the sensitiveness of receiving apparatus has been very greatly increased during the past few years. This has been accomplished largely through the employment of detectors of the so-called Fleming, De Forrest, and Von Lieben types, together with the use of locally generated oscillation methods of receiving continuous wave-train signals. The introduction of continuous wave-train systems and the improvements made in spark-sending apparatus have also made possible a decided increase in selectivity at the receiving stations.

ATMOSPHERIC AND INTERFERENCE DISTURBANCES.

Although so-called atmospheric disturbances and interference from other radio stations have always been recognized as one of the serious limitations to the successful employment of radio and although a vast amount of labor has been expended during the past four or five years, the actual progress toward better conditions has been relatively small.

In the matter of station interference the improvements in transmitting and receiving apparatus just noted have, of course, tended to decrease the amount of trouble from this source.

Despite all endeavors atmospheric disturbances of various kinds are still a vast obstacle to the successful use of radio in some localities, and in all localities at certain seasons of the year. Many schemes for the elimination or reduction of these disturbances have been proposed and tried out, but none have as yet shown themselves to be even measurably successful.

OPERATING METHODS.

By far the larger part of radiotelegraph messages are handled at comparatively slow speeds with hand sending, although automatic machine sending has been tried out to a limited extent. The receiving is done largely by ear. Duplex operation involving the use of two antennæ at each end has come into use to a limited extent—the sending system being under some form of distant control by the receiving operator.

TRAFFIC.

The present commercial traffic is largely special in nature, such as ship-to-shore and ship-to-ship service. Where land business is involved the messages are collected largely by the telegraph companies and passed on to the radio companies for transmission. In addition to this special service for which no wire competition is possible, several regular transoceanic services are being maintained, notably those from Tuckerton and Sayville in the United States to Hanover and Nauen in Germany and that between San Francisco and Honolulu.

REGULATION.

With the rapid growth in the number and power of radio stations during the past few years, conditions of operation under a system of no control became so difficult that the whole matter of radio regulation by law has received a great deal of attention, not only in individual countries but also through cooperative international action. The importance of radio communication in matters of hazard to life at sea and in matters of maritime warfare tended to augment the necessity for rigid control of commercial radio systems.

Although much has been done to ameliorate the state of affairs existing some years ago, further extensions of radio service and further improvements in radio transmitting and receiving apparatus will undoubtedly necessitate further action by governments, both individually and collectively. It is to be hoped that legislation will be based on actual physical possibilities rather than on what might be.

RADIOTELEPHONY.

While the foregoing comments on recent developments pertain mainly to radiotelegraphy, many of them apply equally to radiotelephony. At the same time it can be said that up to within the last year or 15 months very little of practical importance had been done in the field of radiotelephony.

During 1915 very considerable progress has been made and as is well known, successful radiotelephony has been carried on between the Naval Radio Station at Arlington and such distant points as the Isthmus of Panama, San Francisco, San Diego, Honolulu, and Paris. An important part of this work has been a demonstration of the practicability of directly connecting long-distance telephone and telegraph wires to the radio system at either the transmitting or receiving end, thus making possible a continuous communication channel involving one or more wire and one or more radio links.

The success of these recent improvements in long-distance radiotelephony has been made possible not only by improvements in the receiving apparatus but more particularly by improvements in the transmitting apparatus and in the means for influencing and modulating the radiation of large amounts of energy from the antenna system.

APPARATUS FOR THE TROPICS.

In a meeting such as a Pan American Scientific Congress, where many of the delegates are interested in the conditions which obtain in the Tropical Zone, no paper on recent developments in telephony and telegraphy would be complete without some mention of the special developments that have been made to better the operation of apparatus used in such localities.

Roughly speaking, the conditions of telephone and telegraph operation which require special consideration in tropical countries are those arising from:

1. The higher temperature and higher average humidity which obtains.

2. The greater severity of lightning storms and other atmospheric disturbances.

3. The prevalance in some localities of insects which are peculiarly destructive to wood, fabrics, and even to metals.

Trouble in telephone plants from the first of these causes is especially noticeable wherever there is common battery operation. With this system practically all parts of the local telephone plant are subjected to the continuous application of the central office battery voltage. This, obviously, results in increased electrolytic corrosion troubles where there is any chance of such action.

Recently switchboard cables, electromagnet coils, switchboard cords, and in general the instruments themselves have been so improved that operation in the tropics is not materially more troublesome than in the Temperate Zones. These improvements, which are largely in the nature of moisture-proofing standard equipment or the production of corresponding moisture-proof types, have resulted from careful studies made by engineers in the Tropics.

A few years ago there were many complaints about apparatus involving wood manufactured in the United States and Europe and installed in tropical countries. These complaints covered the destruction of the wooden portions by so-called "white ants." So numerous did these complaints become that it was clearly evident that some substitute for untreated northern woods would have to be obtained. Two alternatives presented themselves—one, the use of tropical woods which experience had shown to be relatively free from termite attack, and the other, some treatment of the ordinary Temperate Zone woods generally employed by telephone and telegraph companies. While the careful studies which were instituted and which involved subjecting samples to actual exposure to termite attacks have not yet been completed, it is clear that either teak or mahogany is a relatively safe wood to employ. In some cases, of course, the value of the apparatus hardly justifies the expense of these woods, and doubtless cheaper substitutes will ultimately be forthcoming.

While the so-called "lead bug" is not confined solely to the Tropics, its ravages appear to be more widespread there than in Temperate Zone countries, such as the United States. Thus far no very effective economical means has been found for preventing its destructive action, particularly to lead cable sheaths. Numerous experiments are under way at the present time, some of which it is hoped will lead to an amelioration of this trouble.

In the matter of metal finishes, much improvement has been made during the last three or four years particularly where iron or steel parts are involved. Where long life for the apparatus is required it has been definitely proven that the utmost precautions are required in finishing apparatus intended for installation in the Tropics. In general thoroughly satisfactory protective finishes must involve the use of a coating of some nonrusting or rust preventing metal on the iron, either with or without an additional covering of japan or lacquer.

SUMMARY.

Summarized briefly, the principal developments in the field of intelligence transmission during the last four or five years have been the introduction of high-speed and printing telegraph systems; im-

provements in the accuracy and speed of submarine cable telegraphy; very great extensions in the use of loading and phantoming on telephone circuits, both open wire and cable, and particularly in the combination of loading and phantoming; the development of successful telephone amplifiers; and in general the reduction of apparatus manufacture to a more uniform and economical basis. In the field of radio communication the developments have been in the production of better telegraph apparatus; in increased range and reliability of radiotelegraphy, and recently in the successful experiments which have been made in long-distance radiotelephony. Of major importance in this field has been the establishment, beyond question, of the practicability of directly connecting long distance wire telephone and telegraph lines with systems of radiotransmission.

With the developments already accomplished and with the other developments now in progress, it is possible to predict with something of assurance the probable trend of the various services during the next few years. The exact fields of telephony and telegraphy of wire and radio communication are becoming more clearly defined, and it is evident that the whole art of intelligence transmission electrically will develop with the various services acting cooperatively rather than competitively. Telegraphy is essentially not a competitor of telephony in the service it is fitted to render mankind, and the physical limitations imposed on radio communication show that while it has a distinct and valuable place in the art which will be vigorously developed, that place does not involve any active competition with wire telegraphy or telephony.

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SIR DAVID GILL (1843–1914).[1]

By A. S. Eddington.

By the death of Sir David Gill astronomy has lost one of its ablest and best-known leaders. By his widespread activity, his close association with all the great enterprises of observational astronomy, and by the energy and enthusiasm of his character, he had come to hold an almost unique position in astronomical councils; and the withdrawal of his great motive power leaves a universal sense of loss. By his individual achievements and by his leadership he has exerted an incalculable influence on the progress of all that pertains to precision of observation. It will be our task in this notice to give an outline of his work as an astronomer, but to understand his immense influence it is necessary also to realize the personal character of the man. Those who came in contact with him felt the charm of his personality. In some indefinable way he could inspire others with his enthusiasm and determination. Enjoying a life crowded with activity, surrounded by an unusually wide circle of friends, he was ever ready and eager to encourage the humblest beginner. It was no perfunctory interest that he displayed. He was quick to discern any signs of promise, and no less outspoken in his criticism; but, whether he praised or condemned, few could leave him without the truest admiration and affection for his simple-hearted character.

David Gill was born at Aberdeen on the 12th of June, 1843. His family had long been associated with that city, where his father had an old-established and successful business in clocks and watches of all kinds. In due course he entered the Marischal College and University, Aberdeen. At that time J. Clerk Maxwell was a professor there, and his teaching had a great influence on the young student. Judged by ordinary standards, Maxwell was not a successful lecturer; but there were some students who could catch a part of his meaning as he "thought aloud" at the blackboard and feel the impression of his personality in after-lecture conversation, and these found him an inspiring teacher. Gill was among these, and he became imbued with a zeal for experimental science which soon manifested itself in his setting up a small laboratory in his father's house.

[1] Reprinted by permission from Monthly Notices of the Royal Astronomical Society, London, Feb., 1915.

Up to the age of 20 Gill's scientific interests appear to have had no particular inclination to astronomy, but in 1863 he became desirous of securing an accurate time service at Aberdeen. Encouraged by a visit to Prof. Piazzi Smyth at Edinburgh Observatory, he succeeded in interesting Prof. David Thomson in his efforts. There was at that time an old observatory at King's College, Aberdeen. Together the two men unearthed and set up in adjustment a portable transit instrument which had long been disused, the sidereal clock was overhauled and fitted with contact springs for the electrical control of other clocks, and the observations for time determination now became the chief occupation of Gill's leisure evenings.

It was not long before he began to seek for an instrument which would give him a wider scope for astronomical work. He met with a second-hand silver-on-glass mirror of 12 inches aperture and 10 feet focal length. The task of mounting this equatorially gave him the first opportunity of displaying that skill in instrumental designing for which he afterwards became so famous; and the whole mounting was made from his working drawings. He made the driving clock with his own hands.

Among the chief results obtained with this telescope were some excellent photographs of the moon. At that time Lord Lindsay (son of the Earl of Crawford) was planning to erect an observatory at Dun Echt, 13 miles from Aberdeen. Having seen these photographs, he visited Gill in order to see his instruments and methods of work. The acquaintance thus formed led to Gill's receiving early in 1872 an invitation to take charge of the Dun Echt Observatory that was about to be erected.

At this time Gill was actively at work all day, his father having retired, leaving the business in his hands; it was only his evenings that could be devoted to scientific pursuits. He had married in 1870, and was living in Aberdeen near his little observatory. To accept Lord Crawford's offer meant the giving up of a flourishing business and a heavy pecuniary sacrifice; but by now astronomy was claiming him irresistibly, and he made the choice without hesitation. The business that he now relinquished had never been congenial to him; but the time he had devoted to the clockmaker's art had not been wasted, for it is reasonable to believe that his natural mechanical genius was in no small measure fostered by this early training.

Gill's direction of the Dun Echt Observatory lasted from 1872 to 1876. It was his task to design and install the fine equipment that was rapidly acquired—for him a foretaste of the similar work he was afterwards to carry out at the Cape. But this period of his life is chiefly remembered not for observations made at Dun Echt but for an expedition to the island of Mauritius on the occasion of the transit of Venus, 1874. It was in preparation for the work at

Mauritius that he first began to use the heliometer, an instrument with which his most celebrated researches were afterwards made. The 4-inch heliometer of the Dun Echt Observatory (afterwards purchased for the Cape) was made under Gill's superintendence by Repsold; and whilst it was in the course of construction he took the opportunity to visit Hamburg for the meeting of the Astronomische Gesellschaft in 1873. Besides attending this congress, Gill visited several of the continental observatories, and in this way made the acquaintance of the leading European astronomers, and also obtained an insight into the organization of the large observatories.

The Mauritius expedition introduced him to two of the great problems, which more especially he made his life's work—the determination of the solar parallax and the problems of geodetic measurements. Deferring, for the present, consideration of the scientific results of this expedition and of another expedition to Ascension Island in 1877, we pass on to the next great step in his career.

Early in 1879 David Gill was appointed by the admiralty to be Her Majesty's astronomer at the Cape of Good Hope, in succession to Mr. E. J. Stone. Before sailing for the Cape he made another tour of the European observatories, visiting Paris, Leiden, Groningen, Hamburg, Copenhagen, Helsingfors, and Poulkovo. Perhaps the most important fruit of these visits was his acquaintance with Dr. Auwers and Dr. Elkin, which led to much valuable cooperation between them.

On the 29th of May, 1879, he arrived at Cape Town and took up his duties at the observatory. The only instruments which he found in use were the Airy transit circle, a 7-inch equatorial, and a photoheliograph. The observatory, founded in 1820, had fulfilled a useful duty by the regular work of meridian observation, the early Cape Catalogues being a most valuable source for the positions of the southern stars. Its history had also been marked by one conspicuous achievement—Henderson's detection of the parallax of α Centauri, the first proof that the parallax of a fixed star could amount to a measurable quantity. Whilst the instruments and observations might be open to many criticisms, the work was, for that period, fairly efficient. But the standard of precision was being raised, and Gill's standard was the highest of his time. To his mechanical insight the faulty design and unsatisfactory repair of the old instruments was apparent, and he would not rest until the defects were remedied. He was no believer in the Airy type of transit circle, incapable of reversal, but it was many years before he could obtain an instrument according to his ideals. Meanwhile it was necessary to make the best of the existing telescope. The object glass was deteriorated, the micrometer screws were worn, and the whole instrument was in need

of a thorough overhaul. He at once set to work upon it with his usual energy, and so transformed it that for differential work it left little to be desired. The Airy transit circle performed useful service until 1901, when it was replaced by the new reversible transit circle. It is still used at times for special researches. The 7-inch equatorial was likewise submitted to a thorough overhaul.

The only immediate addition to the equipment was the 4-inch heliometer, which was secured by Gill by private purchase. With this provision he was content to spend the first few years of his directorship, until he should be in a stronger position to press his claims on the treasury. The principal additions made during the subsequent years that he spent at the Cape were the 6-inch Dallmeyer lens used for the photographic Durchmusterung, acquired in 1884; the 7-inch heliometer in 1887, the astrographic refractor erected in 1890, the Victoria telescope (a 24-inch photographic refractor with guiding telescope and spectroscopic equipment) in 1898, and the reversible transit circle in 1901. He was thus for his first researches limited to instruments of very moderate size and cost, and the success with which he afterwards obtained an adequate provision for the observatory was due both to the confidence inspired by his brilliant early work and to his pertinacity in pressing the needs of astronomy.

If from his many and varied services to astronomy we were asked to pick out the one in which he arrived at the most striking and complete success, there is little doubt that the answer would be his determination of the solar parallax. At the time when Gill, by accepting the charge of the Dun Echt Observatory, definitely embarked on an astronomical career a celestial event of the first magnitude was approaching—the transit of Venus of 1874. Great expectations were entertained that this would afford an improved determination of the solar parallax, a fundamental constant which was at that time involved in unsatisfactory uncertainty. Preparations were made by the leading observatories and astronomical societies on an unprecedentedly lavish scale, and expeditions were dispatched to different parts of the world. Lord Lindsay was cooperating in the work, and the Dun Echt expedition took up a station at Mauritius. Gill had already formed the opinion (which he afterwards conspicuously advocated) that there were other and better methods of finding the sun's parallax involving far less expense. He believed that the observations of the transit were of such a nature that the results would be inaccurate and capable of more than one interpretation, for too much depended on the arbitrary judgment of those who had to discuss the observations. He determined, therefore, to use the opportunity of the expedition to make trial of another method, namely, morning and evening observations of the minor planet

Juno, which was then favorably situated. He considered that a single observer could by heliometer observations of a minor planet obtain results comparable in accuracy with those derived from all the transit of Venus observations together. Unfortunately, the heliometer was delayed in arrival at Mauritius, and the first half of the opposition of Juno was lost. Observations in the latter half were secured on 12 evenings and 11 mornings, but the parallax factor was then small. The result, $8''.77 \pm 0''.041$, though disappointing owing to the causes mentioned, gave a clear indication of the value of the method, and this pioneer effort served its purpose as a preliminary to a more ambitious attempt. From that time onwards Gill had a strong conviction of the value of the heliometer for work of the highest refinement, and he acquired his remarkable skill in using it. The transit of Venus was observed by the party, but Gill appears to have formed so low an opinion of the trustworthiness of the measures that he took little interest in their subsequent use.

In 1877 an exceptionally favorable approach of Mars to the earth offered a good opportunity for a renewed attack on the problem of the solar parallax. Gill, who had resigned his position at Dun Echt, began to prepare for an expedition to Ascension Island for this purpose. He fully expected that Mars would, owing to its large disk, prove to be a less satisfactory subject for heliometer observation than a minor planet, which is practically indistinguishable in appearance from the comparison stars; but the parallax factor was so much more favorable than for any minor planet then known that the opportunity was not to be missed. His anticipations proved correct. The value of the solar parallax now found showed a great improvement on any previous determination. The result, $8''.78$, with a probable error of $\pm 0''.012$, marks a new stage of advance. But Gill by this work became more than ever convinced that the definitive determination of the constant must rest on minor planets.

For his third and final attempt, in 1888–9, the minor planets Iris, Victoria, and Sappho were chosen. Instead of measuring the diurnal parallax, he proceeded this time by the combination of observations made at widely separated stations. This involved a great scheme of cooperation in which many observatories and individuals took some part. The actual heliometer measures of the planets were made mainly by Gill and Finlay at the Cape, by Elkin and Hall at Yale, and by Peter at Leipzig. Of the many other cooperators Dr. Auwers in particular took a large and important share in the work. Accurate places of the comparison stars were needed, and meridian observations of these were made at a large number of places. In the case of Victoria this was supplemented by a heliometer triangulation in order to avoid the various systematic errors that affect meridian observations. The whole discussion, which forms two

large volumes (vi and vii) of the Cape Annals, is a remarkable record of a thorough and laborious undertaking. It was particularly the kind of investigation to bring out the characteristic qualities of Gill's genius. To plan the work required that perfect understanding of instruments and observations in which he was unrivaled; and to carry it through in its completeness required a dogged persistence which overcame all obstacles, an enthusiasm which shirked nothing, and a power of leadership which inspired all his helpers. There have been other great and successful cooperative schemes since then, but we miss in them the unity of execution which the immense driving force of Gill's leadership supplied.

The final result gave for the solar parallax $8''.804 \pm 0''.0046$, and in due course this value was adopted (as $8''.80$) in the Ephemerides. In so far as a single investigation can be held to settle so important a constant, the solar parallax was now known with all the accuracy required for the calculations in which it plays a part. Subsequent researches have all tended to confirm Gill's value; the discordant results found by other methods are disappearing, whilst the superiority of the minor planet method has become more and more manifest. In the Eros campaign of 1900–1901 the Cape Observatory took no share, owing to the northern declination of the planet, but Gill followed the investigation with keen interest and took part in the arrangement of the work. The results from Eros, whilst diminishing the range of uncertainty, so far as accidental errors are concerned, have not appreciably altered the value. Shortly before leaving the Cape, Gill initiated a determination of the same constant by means of spectroscopic observations, the line-of-sight velocity of the earth relative to a star being measured at opposite seasons, so that the earth's orbital velocity is found. These observations are now yielding excellent results.

We have seen that his measurements during the observations of Juno at Mauritius convinced Gill of the value of the heliometer as an instrument of research. In his hands it was capable of remarkable accuracy. The instrument is peculiarly difficult to use, and the number of those who observe with it has always been few. At the time when the 4-inch instrument was constructed for him the heliometer was usually regarded in England as an exercise for the textbook or the examination question. Even now that its possibilities have been demonstrated it has not been taken up widely. At the present day it is natural to prefer photographic methods, which give equal or perhaps slightly superior accuracy, whilst making far less demands on the observer. Perhaps, too, the prospect for future progress and development is more obvious in the case of photographic than of heliometer observations. Certainly Gill's success with the heliometer never blinded him to the advantages

of the long-focus refractor, and he fully shared the modern tendency to depend more and more on photography. But there is one advantage of the heliometer over the photographic refractor, both for solar and stellar parallaxes, on which Gill strongly insisted—the heliometer measures are independent of the color of the object under observation. He maintained, and confirmed by experimental observations, that the skilled observer in making coincidences of the images matches the colors and not the most intense points of the minute spectrum caused by atmospheric dispersion. This is a refinement obviously impossible in photography, and, for example, it is well known that the doubtful effect of atmospheric dispersion leaves a little uncertainty in the solar parallax deduced from the photographic observations of Eros.

So early as 1872 Gill had begun to plan a series of determinations of stellar parallax with a micrometer attached to his reflector—an investigation which was interrupted by his removal to Dun Echt. On his appointment to the Cape he began to apply his 4-inch heliometer to this work. In this he was joined by Elkin, as a volunteer observer, and they set to work on a program of 9 stars, including Sirius, Canopus, α and β Centauri, with some stars of exceptionally large proper motion. The most important outcome of this work was the parallax of α Centauri, $0''.75$, with a probable error of only a hundredth of a second of arc. The desirability of a larger instrument with some alterations of design soon became apparent, and in 1887 a 7-inch heliometer was constructed at a cost of £2,200. With this, Gill and Finlay, and afterwards De Sitter, measured 17 stars, including 12 of the brightest in the southern sky, in most cases with a probable error as low as $\pm 0''.01$. These results were of great interest, establishing the remoteness and intense luminosity of some of the brightest stars, such as Canopus and Rigel. Whenever they have been put to the test Gill's values have always been confirmed. Spurious parallaxes are a great bane in stellar investigation, and, at least until recently, few observers have escaped an occasional bad error; but Gill's parallaxes can always be relied on. His general accuracy has been equaled, perhaps a little surpassed, by some modern photographic determinations; but when we compare the sizes of the instruments—the 40-inch telescope at Yerkes or the 26-inch at Greenwich with his 7-inch heliometer—we must marvel at the precision he could obtain. The following table (given by him) will show the comparative accuracy of his work. It gives the probable error of the measured position of a parallax star:

Cambridge refractor (19.3 feet focus), 4 exposures	$\pm 0''.048$
Yerkes refractor (63 feet focus), 3 exposures	$\pm 0\ .026$
Heliometer, one complete observation, i. e., 16 pointings	$\pm 0\ .036$

Another application of the heliometer was made in his determination of the elements of Jupiter's satellites and of the mass of Jupiter. The longitudes of the satellites can be found very accurately from the usual observations of eclipses, but the latitudes are more difficult to derive. Heliometer measures had been made before by Bessel and others, but in all cases the satellite had been referred to the limb or center of the disk. Gill's method was to measure the distances and position angles of the satellites relative to one another; for, as he had found in his observations of Mars, the best results are only possible when the objects to be measured have no sensible disks. The observations were carried out in 1891. On each night the measures were reduced to a constant scale by referring them to the distance between two standard stars. The absolute distance between the standards was determined by a lengthy comparison with the distances of stars employed in the Victoria triangulation, whose definitive coordinates had been found with an accuracy quite exceptional. These observations were the beginning of a very thorough investigation of the whole problem; but the further observations and the discussion of the results were placed by Gill in the hands of younger men, who could give a more undivided attention to the problem. The nature of the investigation required a repetition of the observations at a subsequent date. This was made by the late Bryan Cookson at the Cape in 1901–2. Photographic observations were made concurrently in 1891 and 1902, and again in 1903–4. The whole material thus collected formed an exceedingly valuable source for improving the accuracy of our knowledge of Jupiter's system. The detailed discussion was taken up by De Sitter at Gill's suggestion; he reduced Gill's own observations during a visit to the Cape (1897–99), and worked out the elements and masses derivable from the whole work. It is evident that Gill attached the greatest importance to this work, and, though the later stages were in the charge of other workers, he followed its progress to the minutest detail. His stimulating influence carried it to a successful conclusion, if conclusion it can be called, for in his summary of the work in the History of the Cape Observatory he urges the need for an extended program of future work, and appeals to astronomers to carry it out. His last scientific effort, on the day the fatal illness began, was to write an introduction to De Sitter's discussion.

Gill's detection of the existence of magnitude equation in observations of right ascension with the meridian circle was an incidental result of his heliometer observations at Ascension. This definitive discovery of a systematic personality, by which faint stars are regularly observed too late relatively to bright stars, has been of fundamental importance in meridian work. He took great interest in the problem

of eliminating this peculiarly difficult source of error by screens and other methods, and it was a source of great satisfaction to him that the traveling-wire micrometer seems to have successfully accomplished this object.

Reference has already been made to Gill's early photographs of the moon. These were, of course, not by any means the first lunar photographs, but in 1882 Gill made a notable advance in celestial photography by successfully photographing the great comet of that year. Several pictures of this comet had already been obtained, with fixed camera, and the knowledge thus obtained that the light was sufficiently intense encouraged Gill to attempt to obtain images of greater scientific value by guiding the camera in the modern way. He was assisted by Mr. Allis, a local photographer, from whom he borrowed a doublet of 2½ inches aperture and 11 inches focal length. He mounted this doublet on the 6-inch equatorial, which he used as guiding telescope. Excellent representations of the comet were obtained with exposures of from 30 minutes upwards; but, a fact of still greater importance, it was found that, notwithstanding the insignificant size of the apparatus, a great many stars were shown whose images were well defined over a large field. This suggested the practicability of using similar but more powerful instruments for mapping the sky and for other astronomical purposes to which photography is now applied.

We now know how this result has revolutionized the methods of observational work. Gill led the way in turning the new possibilities to a practical account. The immediate outcome was the Cape Photographic Durchmusterung, started in 1885. The survey covers the region of the sky from the South Pole to Dec. $-18°$, and is complete so far as photographic magnitude $9^{m}\!\cdot\!2$ (on the C.P.D. scale). A rapid rectilinear Dallmeyer lens of 6 inches aperture and 54 inches focal length was used for the photography. The work was completed in 1890. Very soon after the start Prof. Kapteyn's offer was received to devote himself for some years to the arduous labor of the measurement and reduction of the plates, a work for which the Cape Observatory was unable to provide. This is a further instance of Gill's success in attracting for his helpers the men best capable of carrying out the work desired. The association of Gill and Kapteyn, which began now, has proved a most powerful influence in the advance of stellar investigation, and, to quote Gill's own words, "probably the most valuable result of the C.P.D. to science is the fact that it first directed Kapteyn's mind to the study of the problems of cosmical astronomy and thus led him to the brilliant researches and discoveries with which his name is now and ever will be associated."

We can only mention briefly the other photographic work with which Gill was associated. When the history of the inception of the

International Astrographic Chart and Catalogue comes to be written it will probably be found that much was due to Gill's initiative. It may be difficult to trace whence the first suggestion arose, but at least we know that he was in its councils from the very beginning and gave his whole-hearted support to the great enterprise. His measuring machine for photographic plates, designed by him and constructed by Repsold, has been very generally copied in its main features. Another work of great value which owes much to his counsel and assistance is the chart of the sky made by the late J. Franklin-Adams. Mr. Franklin-Adams, an enthusiastic amateur, who had only recently applied himself to astronomy, came to the Cape at an early stage of the work to photograph the Southern Hemisphere. It needs little imagination to realize how Gill, by his experienced advice and his insistence on a high standard of quality, helped to make of this the valuable work that it became.

In 1897 the necessary expenditure for a new reversible transit circle at the Cape was at length sanctioned. Since his first appointment Gill had lost no opportunity of urging the need for an instrument which should be free from the defects which were obvious in the old design. For the determination of fundamental right ascensions and declinations the chief requirements are an extreme stability of the instrument, means of eliminating or determining the flexures of the various parts, and of guarding against the effects of temperature changes both in the instrument and in the surrounding air. The problem of equalizing the distribution of temperature was most carefully thought out. The piers were made hollow, covered externally with nonconducting material, and filled with water. The telescope tube was surrounded by a double envelope of copper to minimize the effects of local heating, and the graduated circles were similarly protected by copper disks. Of special interest was Gill's method of obtaining fixed meridian marks for maintaining the azimuth of the transit circle. Four deep pits, reaching down to the unweathered rock, were constructed underneath the long-focus collimating lenses and the marks respectively, and a simple method was devised by which the apparatus above ground could be readily set in a definite position with respect to the vertical collimating lines of object glasses fixed in the rock below. So perfect is the stability of these marks that it has been found possible to measure the movement of the North Pole over the earth's surface by the apparent change of azimuth. It is certain that the device will be widely imitated in future.

On his appointment as H. M. astronomer, in 1879, Gill began to consider the question of a geodetic survey of South Africa. His previous experience of such work had been obtained on the occasion of his visit to Mauritius. In connection with the Transit of Venus expeditions of 1874, numerous longitude determinations were made

by the various parties of observers; and, indeed, these geodetic results proved to be the most important outcome of the whole work. Gill's share was a chain of telegraphic longitudes connecting Berlin with Malta, Alexandria, Suez, and Aden. Before returning home he proceeded to Egypt, in response to an invitation from Gen. Stone, chief of the military staff of the Khedive, in order to measure a base line for the proposed survey of the country. This work made slow progress at first, as Gill had no trained assistance on which he could rely; but in the end, with the help of Prof. Watson, he carried it through satisfactorily. No permanent outcome of this work has survived, for the defining marks of the base line were afterwards destroyed by Arabs.

It would serve little purpose here to enter into the details of the work which Gill succeeded in accomplishing in South Africa. Besides the more practical uses of an accurate survey, Gill kept ever in view the object of the ultimate measurement of the great arc of the meridian of 105° from the North Cape to Cape Agulhas—the longest measurable arc of the meridian in the world. Colonial and foreign Governments, the Chartered Company, and the scientific societies were all in turn pressed and persuaded. Difficulties of funds, of personnel, of war, interposed obstacles; but there was no resisting Gill. His indomitable persistence always won in the end. Worried ministers would ultimately come to terms with their genial persecutor. Still active in this great cause after retirement from the Cape, he had the satisfaction of getting the last link of the South African chain filled in. The great measured arc along the meridian of 30° E. now extends from Cape Agulhas to within a short distance of Lake Tanganyika, near the boundary of British territory, a length of 24°, at which point it awaits the other chain of triangulation that will some day be pushed down from Egypt.

We have now passed in review the most important of Gill's scientific investigations. To these may be added some miscellaneous contributions, of which we can not here give any detail. A triangulation by heliometer of the southern circumpolar stars was made under his direction in 1897–1900, but he was not very satisfied with the consistency of the observations. A series of meridian observations of the lunar crater Mösting A, organized by him jointly with Sir William Christie at Greenwich, led to a good determination of the lunar parallax and figure of the earth. The arrangements for a catalogue of zodiacal stars were placed in his hands by the International Astrographic Congress.

In October, 1906, Sir David Gill left the Cape. Owing to ill health he had anticipated by rather more than a year the date of compulsory retirement. But there were no signs of failing vigor when he returned to England; on the contrary, he plunged into a

strenuous life of scientific activity in London. He became president and afterwards foreign secretary of the Royal Astronomical Society, president of the British Association at Leicester, and on the councils of the Royal and Royal Geographical Societies as président d'honneur of the committee of the astrographic chart, and in numerous other duties he was a center of energy and initiative. For several years he worked at his History and Description of the Cape Observatory, published in 1913. Amid our sorrow at his death, when still in the full vigor of scientific activity, there is cause for thankfulness that he was spared to complete and to see the reception of this retrospect of the work to which he had devoted his life.

To this record of strenuous work in the cause of science must be added some allusion to the other side of his life. There was an ideal background to his public life in the quiet home, always characteristically Scotch wherever he lived. In Lady Gill he found a sympathizer in all his sacrifices and devotion to astronomy. She did not become an astronomer, but she shared all his desires, and it was ever her care to aid him to fulfill his great calling. She was of Scotch birth, like himself, and their home was bright with an indescribable spirit of open-heartedness which seemed to come from his loved Highlands.

In December, 1913, he was seized with double pneumonia, and from the first the gravity of the illness was realized. His magnificent constitution carried him bravely through a long fight with the disease, but heart failure supervened, and on the morning of January 24 he died peacefully.

There is no need to enumerate the honors conferred on him by the British, French, and German Governments, and by numerous academies and universities. Official recognition was generously bestowed; even richer was the tribute of admiration and affection of his world-wide circle of friends.

WALTER HOLBROOK GASKELL, 1847–1914.[1]

By J. N. Langley.

Walter Holbrook Gaskell was born on November 1, 1847, at Naples, where his parents were passing the winter for the sake of his father's health. His father, John Dakin Gaskell, was a barrister, a member of the Middle Temple, who followed his profession for a few years and then retired to private life. His mother was Anne Gaskell, second cousin of his father. Gaskell as a boy lived with his father at Highgate and attended Sir Roger Cholmeley's school at that place. At school he worked chiefly at mathematics, but had considerable interest in natural history, and appears to have made more than the usual schoolboy collections connected with that subject.

He came up to Cambridge in October, 1865, when he was not quite 18, as a member of Trinity College. In his third year he was elected to a foundation scholarship, and proceeded to the B. A. degree in 1869, being twenty-sixth wrangler in the mathematical tripos. After taking his degree he studied for a medical career, and in the course of his preliminary scientific work he attended the lectures on elementary biology and physiology given by Michael Foster, who came to Cambridge as prælector in physiology at Trinity College in 1870. Foster led a considerable number of his early pupils to a scientific career. He first aroused an interest in scientific problems and then, sometimes gradually, sometimes suddenly, suggested that there was no better course in life than that of trying to solve them. Gaskell, as far as my recollection serves, was influenced in the latter way. In 1872 he went to University College Hospital, London, for clinical work. On his return to Cambridge, Foster, in the course of a conversation with him, suggested he should drop his medical career for the time and try his hand at research in physiology. Gaskell, I believe, adopted on the spot this suggestion, and instead of proceeding to the M. B. degree went to Leipzig to work under Ludwig (1874).

At this time Ludwig's laboratory was much the most important school of physiological research in Germany or elsewhere. It attracted students from all parts of the world. All the work was planned by Ludwig, who had an almost unerring sense of the lines

[1] Reprinted by permission from the Proceedings of the Royal Society, London, Series B, vol. 88, no. 606, April 1, 1915.

of work which would yield profitable results. To this the success of the school was mainly due. Its popularity was increased by the method of procedure adopted by Ludwig. This has been described by Sir T. Lauder Brunton, who was with Ludwig in 1869–70. The experiments were carried out by Ludwig with the pupil as assistant; Ludwig wrote the paper and then published it, occasionally as a conjoint work, but more usually in the name of his pupil. As I have heard from Gaskell, the method was the same in his time. The work given him was a continuation of that on the innervation of skeletal muscle already begun in the laboratory. This led him by a series of steps, which were perfectly logical but impossible to foresee, from point to point of scientific inquiry up to his theory of the origin of vertebrates.

Soon after his return to England in 1875, Gaskell married Miss Catherine Sharpe Parker, a daughter of Mr. R. A. Parker, of the firm of Messrs. Sharpe, Parker & Co., solicitors, by whom he had one son, Dr. J. F. Gaskell, and four daughters, two of whom survive him. He settled in Grantchester, about a mile and a half from Cambridge, and in the Cambridge Physiological Laboratory he carried further the investigation on the innervation of the blood vessels of striated muscle. He found (1877), amongst other facts, that stimulation of the nerve supplying the mylohyoid muscle of the frog caused considerable and constant dilatation of the blood vessels, although contraction of the muscle itself was prevented by curare. This was the most decisive instance known at the time of such action in a purely muscular structure. It did not, however, settle the question of the occurrence of vaso-dilator fibers in the nerves of skeletal muscle, the discussion of which was carried on by Heidenhain and others.

From the behavior of the arteries under nervous stimulation he passed to the investigation of the behavior of the small arteries and of the heart with varying reaction of the blood, and, finding that a small addition of alkali increased the tone of both, and that a small addition of acid decreased it, he suggested that, besides the nervous control of the circulation, there was also a chemical control in each organ and tissue by the products set free in activity, so that, for example, the contraction of the muscle by setting free acid led to an increased flow of blood through it. The suggestion was not entirely new, but it was wider in range than any of its kind previously made and rested on more solid facts. This work directed his attention to the heart, and for the next four or five years he devoted his time to the questions of the innervation of the heart, and the cause of the heart beat. With these questions others were busily engaged, notably Engelmann and Heidenhain.

In the early seventies it was universally held that the beat of the heart was due to the nerve cells present in it, and that it was initiated

by the nerve cells of the sinus venosus. There were very varied views as to the method of working of the nervous mechanism, especially as to the parts played by the nerve cells of the septum of the auricle, and the nerve cells of the base of the ventricle. As it became more widely recognized that parts of the heart which had no discernible nerve cells could contract rhythmically, it was felt that the nervous theory did not account for the whole of the phenomena. Moreover, some of the pharmacological results could not be satisfactorily explained on the theory as then put forward. But no one had any more satisfactory explanation to offer.

The question of the action of the nerve cells in the heart was part of the general question of the functions of the peripheral ganglia. In 1869, Engelmann argued that the peristaltic contraction of the ureters did not depend on nerve cells and that the contraction was conducted from one muscle cell to the next without the intervention of nerve fibers. In 1875 he advocated a similar view as regards the passage of contraction from one part of the ventricle of the frog's heart to the rest, and he thought this was probably also the case in the auricle. But in one important point he kept to the old theory and considered that the passage of contraction from auricle to ventricle was brought about by nerve cells and nerve fibers. Gaskell (1881) at first adopted the current theory with some modifications in detail, but in 1883 he abandoned it, and argued that the contraction of the heart was of muscular origin; it started in the sinus and spread as a peristaltic wave to the other chambers, the delay in the passage of the contraction wave from one chamber of the heart to the next being due to a slow conduction in the modified muscular tissue which he found at the junction of the sinus venosus with the auricle, and at the junction of the auricle with the ventricle. In the course of his work Gaskell made a large number of original observations on the behavior of the several parts of the heart and of the cardiac muscle. The term "block" Gaskell adopted from Romanes's account of the passage of contraction waves in Medusæ; the phenomena had been partly worked out in the frog's ventricle by Engelmann, but they were much more completely elucidated by Gaskell's work on the heart of the frog and the tortoise. It was known that the contraction of the ventricle might only occur at every second, third, or fourth beat of the auricle. Gaskell obtained this effect experimentally by varying the degree of block between the two chambers. After the lapse of years the invention of the string galvanometer brought the observation of heart block in man into the region of clinical medicine.

The different effects produced on the heart of the frog by stimulating the vagus nerve were investigated simultaneously by Gaskell and by Heidenhain. Gaskell observed that stimulation of the vagus

sometimes caused an increase in the strength of the beats in addition to the quickening which had been already described by Schmiedeberg and others, and which had been attributed to special accelerator nerve fibers. Heidenhain found that by stimulating the medulla oblongata at different points, acceleration and augmentation, or slowing and weakening, of the heart beat could be obtained. Gaskell traced in the crocodile and frog the origin of the accelerator fibers to the sympathetic system, and this was followed up by a more complete anatomical investigation by Gaskell and Gadow. The innervation of the heart of lower vertebrates was thus brought into line with that of the mammal. In addition, he gave a more complete account than had been given by Heidenhain of the cause of the independence of the slowing and the weakening of the heart beat caused by pure vagus fibers, and of the quickening and the increase of strength caused by sympathetic fibers. A little later Gaskell showed that an electrical change can be produced in quiescent heart muscle on stimulation of the cardiac nerves, and that the change is different according as the vagus or the accelerator nerve is stimulated.

Gaskell's work in this field was of the first importance. His papers are a storehouse of observations of a fundamental nature. He elaborated his theories and gave an admirable account of the whole subject in an article on "The Contraction of Cardiac Muscle" in Schäfer's "Textbook of Physiology," published in 1900. It may be mentioned that the rhythm of the heart was the subject of his Croonian lecture to the Royal Society in 1881, and that on the work mentioned above he was elected a fellow of the society in the following year.

In the course of his dissection of the accelerator nerve in mammals, Gaskell was struck by the overwhelming preponderance of nonmedullated nerve fibers in it, although the nerves centrally of ganglia from which the accelerator fibers arose were mainly medullated, and this determined him to investigate the relation of the sympathetic system to the spinal cord. At this time the question of the relation of the sympathetic and other peripheral ganglia to the cerebrospinal system was in a state of profound confusion, and general agreement had been reached on a few points only. A great number of facts had been described, and they covered a wide area of descriptive anatomy in different classes of vertebrates, of histology of nerve fibers and nerve cells, and of physiology. Few observers covered more than a small portion of the ground. Results were coming quickly and the ground was tilled rather hastily. The practical disappearance of the theory that the "vegetative" nervous system was independent of the "animal" nervous system had led to the peripheral ganglia being less considered as a whole than they had been at an earlier time, and to special explanations being put forward for

the working of the several parts. Thus, those writers who tried to give an impartial summary of the state of knowledge found themselves reduced to stating a number of more or less contradictory facts and irreconcilable theories.

Gaskell did not approach the subject from the point of view of what had already been done or said. He approached it from the point of view suggested by his observations on the accelerator nerves in the mammal. This method had the disadvantage that it led him to leave uninvestigated some of the chief difficulties which were felt at the time, but it had the advantage that it enabled him to come to a rapid decision on certain important points. Gaskell confined his attention to the efferent "visceral" fibers. His most important conclusions were, that all efferent visceral fibers, whether in cranial or in spinal nerves, were small medullated fibers, and that they left the cerebrospinal system in three groups—the cervico-cranial, the thoracic, and the sacral—the thoracic portion being what was ordinarily called the sympathetic. These conclusions reestablished the connection of small medullated fibers with the whole of the "organic" system described by Bidder and Volkmann in 1842, gave an explanation of Reissner's statement in 1862 that the anterior roots of the thoracic nerves contained bundles of small medullated fibers, while those of the cervical and lumbar nerves contained only a few such fibers scattered amongst the larger ones, supported the view which had been held by some anatomists that the white rami communicantes constituted the sole connection between the spinal cord and the sympathetic, and brought all the involuntary nerves of whatever origin into one system of gaglionated nerves as had been recently advocated by Dastre and Morat. In these conclusions there was one weak spot. Whilst it was definitely shown that the outflow of visceral fibers from the central nervous system to the sympathetic was enormously greater in the regions in which there were only white rami, it was not shown that no fibers passed out by the gray rami. Gaskell's observation of the rarity of small medullated fibers in the gray rami was not in accord with earlier observations, and he did in fact underestimate their number. Further, physiologists of repute had described vasomotor, pupil or heart effects as being caused by stimulation of the cervical nerves, which had gray rami only. It might then be said that the few small medullated fibers present in the centrally running branch of the gray rami represented the few scattered small medullated fibers of the anterior roots of the corresponding spinal nerves. Thus the difference between the thoracic and other regions of the spinal cord might be one of degree only. So far, however, as subsequent investigation has gone, Gaskell's conclusion was correct, and the gray rami receive no efferent fibers from the spinal cord.

Gaskell's work clarified the air. It gave anatomists and physiologists a clearer view of the general arrangement of the efferent nerves governing unstriated muscle and glands, and it directed the attention of physiologists to points which they had singularly neglected. It is to be noticed also that Gaskell's earlier theory that the heart beat is not due to the activity of local nerve cells has an intimate bearing on the much-discussed question of the automatic and reflex action of peripheral ganglia.

In the paper setting forth the conclusions given above, Gaskell discussed a number of other problems of the sympathetic system. His theories were based on facts known at the time, but the experiments to test their wider application were few. Some are still under discussion; some are superseded. The most far-reaching of these theories was on the nature of the difference between motor and inhibitory nerve fibers. In 1881 he had advocated the view that the vagus is the trophic nerve of the heart. Löwit, in 1882, had suggested, on the lines of Hering's theory of assimilatory and dissimilatory processes in the body, that the cardiac inhibitory fibers favor assimilation, and that the accelerator fibers favor dissimilation. Gaskell, developing his trophic theory, took a more definite and a wider view and urged that all inhibitory fibers are anabolic, and all motor fibers are katabolic.

Gaskell's microscopical and anatomical observations led him to questions of morphology. He argued that in a typical spinal segment a lateral root was to be distinguished in addition to the ventral and dorsal roots. The lateral root consisted of two parts, one arose from the lateral mesoblast plates of Van Wijhe and supplied the respiratory muscles of Ch. Bell's system, the other formed the ganglionated nerves of the visceral system. On this basis he discussed the homologies of the cranial and spinal nerves, and returned to this subject in a paper published a few years later. For his work on the nervous system he was awarded the Marshall Hall prize of the Royal Medical and Chirurgical Society in 1888, and was elected a fellow of the society.

In 1890 the Nizam of Hyderabad supplied funds to a commission for the investigation of the cause of death under chloroform—the second which he had supported. The commission reported that death was due to an action of the respiratory center, and that if the respiration was carefully attended to it was unnecessary to pay any attention to the pulse. These conclusions were directly opposed to common belief based both on experimental and clinical observation. One of the members of the commission asked Gaskell to criticize their report. Gaskell arranged with Dr. Shore to make a joint experimental inquiry. Gaskell and Shore, employing various methods, notably that of cross circulation from one animal to

another, brought forward evidence which was generally regarded as conclusive that chloroform had a direct weakening action on the heart. Their paper, published in 1893, checked a tendency to regard the respiration as the only factor to be considered in administering chloroform. It was a useful piece of work, but it gave Gaskell the only enemy he ever made.

This investigation was a sidetrack from the main line of the work which Gaskell had been pursuing for some years. His morphological studies on the homologies of the cranial and spinal nerves had led him to consider the problem of the origin of the nervous system in vertebrates, and this again led him to a theory of the origin of vertebrates to which he gave nearly all his time in later years. Dr. Gadow has been kind enough to write the following account of this part of Gaskell's researches:

Gaskell's physiological research has always been to a considerable extent on the morphological side, and this combination of the sister sciences culminated in his inquiry into the origin of vertebrates. He was drawn to this at present hopelessly difficult problem neither by accident nor design but by the complete failure of various morphological friends to account for certain structures the understanding of which was necessary for his research. He therefore determined to find out for himself, and thus it has come to pass that a man between 30 and 40 years of age, M. D. of Cambridge and a physiologist of renown, devoted about 25 years of his life to essentially morphological studies, more than—in the nature of things—applies to some of his rather bitter scientific opponents. Moreover, entering the new field quite unbiased, his critical mind enabled him, when studying, for instance, the best comprehensive textbooks on embryology, to discover the weak sides of that discipline. It was not a question of picking out what suited him; on the contrary there was hardly a point—be it the homologies of the germinal layers, the occurrence of some obscure feature like Reissner's fiber, or some Silurian fossil, which he did not take often infinite pains to examine into. Frequently he enlisted friendly help, as in the case of the digestive properties of the Lamprey's skin.

This is not the place to discuss the strong and weak points of his hypothesis that vertebrates are descended from some Crustacean-like ancestor—i. e., from some vaguely reconstructable stock of which the palæozoic Trilobites, King crabs, and Scorpions are the only known representatives on the invertebrate side, and he bridged the gulf between them and the vertebrates by the Silurian Ostracoderms, of whose internal organization the larvæ of the Lampreys, before their marvellous changes into the present adult forms, seemed to afford a clue. The gulf was great indeed, but his planned bridges were not more hazily sketched than those which pretend to connect the vertebrates either separately or conjointly with Amphioxus, Tunicates, Balanoglossus, etc., with worms and even with Echinoderms. Especially the various worm theories he considered as no solution of the problem, since they would carry the connection so far back as to merge almost into the beginning of the Metazoa, amounting to no recognizable origin. He on the contrary believed that "each higher group of animals has arisen in succession from the highest race developed up to that time.

Further, as the leading motif of the whole course of this solution he discerned the orderly sequence in the development of the central nervous system,

in which no break of continuity can possibly have occurred. The brain and nerves afford the fundamental homologies; the organs which they innervate may fall into line in a surprising way, but they are not the essential comparisons—e. g., a new gut may be formed, as in the transforming Ammocœtes. "The secret of evolutionary success is the development of a superior brain."

The immediate starting point of Gaskell's investigations on the origin of vertebrates was the recognition of the close similarity in structure and function of the different parts of the vertebrate brain with those of Arthropods. The segmental character of the vertebrate central nervous system, so clear to the physiologist, and long before insisted upon by most anatomists, had lost weight for the morphologists, clearly because the C. N. S. appears embryonically as a single unsegmented tube. Here then was the next question forced upon Gaskell's attention. Can not the two opposing views be reconciled by the suggestion that the vertebrate C. N. S. consists of two parts, closely entangled, viz, a segmental nervous system on the same plan as that of the Arthropods, which is outside and has surrounded an epithelial tubular structure?

This idea explained at once the remarkable nonnervous epithelial parts of the tube, which become so conspicuous as we descend the vertebrate phylum, and every part of this tube bears the same resemblance to various parts of the C. N. S. as the dorsal stomach and intestine of an Arthropod. As a crowning of his conception the pineal eyes fit into the right place of the scheme; and the resemblances become greater and more numerous on the one hand in Ammocœtes, as was to be expected in the lowest available vertebrate, and on the other in Limulus, the King crab. In short, there was now a provisional working hypothesis, obtained by a direct logical process from the consideration of the vertebrate nervous system.

After this working explanation of the tubular nature of the C. N. S. the next step was the inquiry into the nature of the cranial nerves and therefore the double segmentation of the vertebrate body in the head region. Now he was in the midst of the most complex and abstruse problem of morphology, involving every organic system. The resemblances between Arthropods and vertebrates—with Limulus and Ammocœtes as the champions—are, indeed, numerous and in many cases perplexingly close. Of course, the more Gaskell became absorbed by his research, the more resemblances he saw, many of which are in all probability mere coincidences, or even erroneous. With great intuition and ingenuity he connected them, and in some of the most important cases his argumentation as to their being homologous structures has remained intact. He knew that if but a few are true homologies, his case would be proven, according to all the accepted canons of the theory of descent, and all the rest could be waved aside as incidental convergences, due to correlations, the possible laws of which we are now only just beginning to speculate about. Hence he felt it necessary to defend, so to speak, his whole extended line; not that the yielding of some point would mean a disastrous breach but because of the lack of criterion to know which of his many points might prove one of his best assets, viz, an absolute homologue.

On the other hand he felt justified in assuming as most unlikely that representatives of two fundamentally different phyla should have produced so very many close resemblances, so close in function, structure, and relative position as to make it impossible to show them up as heterogeneous. He was also fully aware of it that our time-honored conception of homologies versus analogies and their application to phylogeny are under reconsideration. It is a blow to the comparative anatomist and to the constructor of pedigrees, but all the more interesting since it shows that it is life, function, adaptation, and inheritance,

which shape the material, and this being Gaskell's standpoint of view he skillfully worked with the tools of the morphologist as a physiologist. Be his genial hypothesis, elaborate enough for a theory, right or wrong, he has discovered and elucidated many a feature both in vertebrates and invertebrates which without his tireless work would remain still neglected and unexplained.

His book, "The Origin of Vertebrates," published in 1908, has made little impression. Partly, it is to a great extent a reprint of numerous previous papers and series of assays, partly because, instead of pleading, he did not present his views and the long chain of argumentation in an easy manner. Lastly the idea of our descent from "some Crustacean-like ancestors" was so subversive of all the other rival hypotheses (one of which if assumed to be right implies that all the others are wrong) that the unbiassed reader expects at least a clearly summarizing explanation why Gaskell considered the older hypotheses not only insufficient but wrong.

He did not choose this line. He had too noble a character, the respecting admiration of his many friends, ever ready to defend his own, willing to give in to sound argument, but not to be suppressed. "By their fruits you shall know them."

In reviewing Gaskell's work one can not fail to be struck with the carefulness and accuracy of his observations. But the bent of his mind lay in the direction of generalization. A fact once definitely ascertained was never viewed by him as an isolated phenomenon, it was used as a basis for formulating some general rule. If he sometimes generalized too hastily, it was but the defect of his virtue. The value of his work was widely recognized. He was awarded a royal medal of the Royal Society in 1889, and at various times was the recipient of honors both at home and abroad.

One or two further events of his life and some personal characteristics remain to be mentioned. In 1878 he proceeded to the degree of M. D. by thesis, but he did not at any time practice medicine. Two or three years after this he began a lifelong part in the advanced teaching of physiology in the university. His subjects were those on which he had himself worked, viz, the heart, the nervous mechanism of respiration, the sympathetic system, and, at a later date, the origin of vertebrates. In 1883 he was appointed university lecturer. His style was incisive, and he spoke on controversial points with a half-suppressed enthusiasm which was eminently infectious.

In 1888 he left Grantchester and took up his residence in Cambridge. In the following year he was elected a fellow of Trinity Hall, and was appointed prælector in natural science in the college. Living in a town was not to his liking, and in 1893 he built a house (The Uplands) on a hilltop in Great Shelford, opposite that on which perched Michael Foster's house. Here he remained for the rest of his life.

Gaskell attended but little the congresses of scientific associations, though he did not altogether shun them. He was president of Section I of the British Association in 1896 at Liverpool, and attended

the meetings of the association in Canada in 1897, and in South Africa in 1905, and took the opportunity of seeing a good deal of these countries. He was present also at one or two of the earlier triennial meetings of the International Congress of Physiologists.

He did not take much interest in the ordinary business of the university, but he served on the university council (1907–1910), and if any broad question came before the senate he was fairly certain to be found on the Placet side. When there was real need of his services he did not grudge them. He served on the Royal Commission on Vivisection, which was appointed in 1906, and the final report of which was not issued until 1912; and he was a member of the Mosely Commission on Education in America.

As an undergraduate he rowed in the May races, played cricket and racquets, and frequented the bathing sheds. Later on he enjoyed an occasional set of lawn tennis, but, in general, active exercise did not greatly attract him. In recreation, as, indeed, in work, he took throughout life a somewhat leisurely course. He liked both work and play, but not to the stage of exhaustion. For some years he spent part of the long vacation yachting and fishing with his brother. His hobby was gardening. He converted a large part of his 15 acres of sloping hillside at Shelford into a charming terraced garden, the early summer display of which was the occasion of an annual reception to Cambridge residents. He was always glad to receive physiologists visiting Cambridge, and his bluff, hearty greeting left no doubt of their welcome. In the evening he liked a game of whist or bridge, and after college feasts he was among the first to settle down to a rubber.

In the year preceding his death he was a little troubled about his health, but his customary course of life was hardly affected. He was writing a small volume on the "Involuntary Nervous System," and on September 3 revised the last sheets. Early on the following morning he had a cerebral hemorrhage, and died on September 7 without recovering consciousness.

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