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

PER ORBEM

· SMITHSONIAN · INSTITUTION · 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

1909

FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN
PER ORBEM
SMITHSONIAN INSTITUTION WASHINGTON 1846

WASHINGTON
GOVERNMENT PRINTING OFFICE
1910

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

ACCOMPANYING

The Annual Report of the Board of Regents of the Institution for the year ending June 30, 1909.

SMITHSONIAN INSTITUTION,
Washington, June 2, 1910.

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, 1909.

I have the honor to be, very respectfully, your obedient servant,

CHARLES D. WALCOTT,
Secretary.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1909.

SUBJECTS.

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1909, with statistics of exchanges, etc.

2. Report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1909.

3. Proceedings of the Board of Regents for the sessions of December 15, 1908, and February 10, 1909.

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 1909.

CONTENTS.

REPORT OF THE EXECUTIVE COMMITTEE.

LIST OF PLATES.

THE SMITHSONIAN INSTITUTION.

JUNE 30, 1909.

Presiding officer ex officio.—William H. Taft, President of the United States.
Chancellor.—Melville W. Fuller, Chief Justice of the United States.
Members of the Institution:

- William H. Taft, President of the United States.
- James S. Sherman, Vice-President of the United States.
- Melville W. Fuller, Chief Justice of the United States.
- Philander C. Knox, Secretary of State.
- Franklin MacVeagh, Secretary of the Treasury.
- Jacob M. Dickinson, Secretary of War.
- George W. Wickersham, Attorney-General.
- Frank H. Hitchcock, Postmaster-General.
- George von L. Meyer, Secretary of the Navy.
- Richard A. Ballinger, Secretary of the Interior.
- James Wilson, Secretary of Agriculture.
- Charles Nagel, Secretary of Commerce and Labor.

Regents of the Institution:

- Melville W. Fuller, Chief Justice of the United States, Chancellor.
- James S. Sherman, Vice-President of the United States.
- Shelby M. Cullom, Member of the Senate.
- Henry Cabot Lodge, Member of the Senate.
- A. O. Bacon, Member of the Senate.
- John Dalzell, Member of the House of Representatives.
- James R. Mann, Member of the House of Representatives.
- William M. Howard, Member of the House of Representatives.
- James B. Angell, citizen of Michigan.
- Andrew D. White, citizen of New York.
- John B. Henderson, citizen of Washington, D. C.
- Alexander Graham Bell, citizen of Washington, D. C.
- George Gray, citizen of Delaware.
- Charles F. Choate, Jr., citizen of Massachusetts.

Executive Committee.—J. B. Henderson, Alexander Graham Bell, John Dalzell.
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.

THE NATIONAL MUSEUM.

Assistant Secretary in charge.—Richard Rathbun.
Administrative Assistant.—W. de C. Ravenel.
Head Curators.—F. W. True, G. P. Merrill, Walter Hough (acting).
Curators.—R. S. Bassler, A. Howard Clark, F. W. Clarke, F. V. Coville, W. H. Dall, B. W. Evermann, J. M. Flint, U. S. N. (retired), W. H. Holmes, L. O. Howard, Richard Rathbun, Robert Ridgway, Leonhard Stejneger, Charles D. Walcott.
Associate Curators.—J. N. Rose, David White.
Curator, National Gallery of Art.—W. H. Holmes.
Chief of Correspondence and Documents.—Randolph I. Geare.
Superintendent of Construction and Labor.—J. S. Goldsmith.
Editor.—Marcus Benjamin.
Photographer.—T. W. Smillie.
Registrar.—S. C. Brown.

BUREAU OF AMERICAN ETHNOLOGY.

Chief.—W. H. Holmes.
Ethnologists.—J. Walter Fewkes, J. N. B. Hewitt, F. W. Hodge, James Mooney, Matilda Coxe Stevenson, John R. Swanton, Cyrus Thomas.
Philologist.—Franz Boas.
Illustrator.—De Lancey W. Gill.

INTERNATIONAL EXCHANGES.

Chief Clerk.—F. V. Berry.

NATIONAL ZOOLOGICAL PARK.

Superintendent.—Frank Baker.
Assistant Superintendent.—A. B. Baker.

ASTROPHYSICAL OBSERVATORY.

Director.—C. G. Abbot.
Aid.—F. E. Fowle, Jr.

BUREAU OF INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

Chief Assistant.—L. C. Gunnell.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION.

CHARLES D. WALCOTT,

FOR THE YEAR ENDING JUNE 30, 1909.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit a report showing the operations of the Institution during the year ending June 30, 1909, including the work placed under its direction by Congress in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, and the regional bureau of the International Catalogue of Scientific Literature.

In the body of this report there is given a general account of the affairs of the Institution, while the appendix presents more detailed statements by those in direct charge of the different branches of the work. Independently of this the operations of the National Museum and of the Bureau of American Ethnology are fully treated in separate volumes.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

By act of Congress approved August 10, 1846, the Smithsonian Institution was created an establishment. Its statutory members are "the President, 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."

There has been no change in the personnel of the Board since my last report.

Meetings of the Regents were held on December 15, 1908, and on February 10, 1909, the proceedings of which will be printed as customary in the annual report of the Board to Congress.

GENERAL CONSIDERATIONS.

I deem it proper here to point out the fact that the activities of the Institution are greatly restricted by the very limited annual income at its disposal.

The influence of the Institution in the development of science in this country is too well known to require comment. Its advice is daily sought on scientific matters, not only by other establishments of learning but by individuals all over the land, and that its usefulness has been by no means restricted to this country is evidenced by the fact that the name of the Smithsonian Institution is equally as well known and respected abroad as at home.

But the means derived from the interest on the Smithson fund and other private funds for keeping up the work of the Institution proper have not kept pace with the growth of the country and the constantly increasing demands upon them. The original amount of the Smithson fund of about half a million dollars meant many times over in 1846 what it does to-day, even with the half million which has been gradually added since then. Its income has been economically administered, but it is too limited to carry on any extensive investigations. There are many researches and explorations which the Institution is peculiarly well fitted to organize and supervise, on which the income from an endowment of twenty millions could be wisely and effectively expended.

The Institution has in the past few years received a number of noteworthy gifts in the Harriet Lane Johnston, Freer, and Evans art collections, and an endowment for the fine arts would give a great return for centuries to come by making possible the fostering and stimulating of the fine arts in all its branches.

Under the general plan of organization adopted by the Board of Regents in 1847, the work of the Institution in the "increase of knowledge" is not limited to investigations in the field of science and art, but historical and ethnological researches, and statistical inquiries with reference to physical, moral, and political subjects, are enumerated as objects for which appropriations should be made.

In the humanities there is need of a fearless, thorough, scientific study of the elements entering into the great race problems of the Americas. Until the fundamental tendencies of the differing races now within these areas are intelligently understood, not only by the few, but by the many, a practical understanding of threatening social

conditions is impossible. The uplift of the physical, mental, and moral nature of the peoples of the Americas will come only through the increase and diffusion of such knowledge as will stimulate sound reasoning on existing conditions and racial limitations. Ethnology, anthropology, psychology, preventive medicine, education, are some of the tools that must be used in the shaping of the national, community, and individual life of the future. In this great work the Smithsonian Institution will take such active part as opportunity and means permit.

An article on "The Smithsonian Institution," published in the North American Review, summarizes the history and work of the Institution, and concludes as follows:

> Such has been the result of a single benefaction of half a million of dollars, and perhaps no such result has ever been accomplished by so limited an endowment. Were the great sums given to swell the almost infinite endowments of some of our universities diverted to this unostentatious establishment, its power for good would be immeasurably increased, but, as it is, the bounty of a stranger and an alien has given the American people an agency for good whose influence is incalculable. It presents an opportunity to those who wish to bestow money for some beneficent purpose such as is given by no other on earth, and its scant means and petty endowment are a reproach to our rich and generous nation.[a]

ADMINISTRATION.

The affairs of the Institution proper have progressed in a satisfactory manner during the year. All communications have received prompt administrative consideration, and everything possible has been done to carry out the fundamental purposes of the Institution, "the increase and diffusion of knowledge."

In the administrative work of the various branches of the government service placed under the direction of the Institution, it has been the custom to fully avail myself of the assistance of the officers in charge of those branches, and I am glad to say that the business of the year has been carried on vigorously. The extended and complicated operations of the National Museum, including the National Gallery of Art and the erection of the new building, have been effectively managed by the assistant secretary in charge, Mr. Richard Rathbun. The International Exchanges, the library, and the International Catalogue of Scientific Literature continued under the efficient charge of Dr. Cyrus Adler, until his resignation on October 1, 1908, when he removed to Philadelphia to assume the presidency of the "Dropsie College for Hebrew and Cognate Learning." Doctor Adler entered the service of the Institution in 1888 as an assistant

[a] The Smithsonian Institution, by Charles Minor Blackford, jr., M. D., North American Review, January, 1909. Reprinted as Senate Document No. 717, Sixtieth Congress, second session.

curator in the National Museum. In 1892 he was appointed librarian of the Institution, and in 1905 became assistant secretary. His service of twenty years was marked by a remarkable grasp of the affairs of the Institution, in the administration of which his advice has been of great assistance to the secretaries.

The affairs of the Bureau of American Ethnology have continued in charge of Mr. W. H. Holmes, as chief, who has also acted as curator of the National Gallery of Art. Mr. C. G. Abbot, director of the Astrophysical Observatory, has carried forward the work of this branch both in Washington and on Mount Wilson, California, where duplicate observations have been carried on at a branch station, and the care of the National Zoological Park has continued under the management of Dr. Frank Baker, its superintendent. Although greatly hampered for adequate funds the Park has proved a great attraction to the people of Washington, over 125,000 persons having visited it in a single month.

The advisory committee on printing and publication, appointed in pursuance of executive order of January 20, 1906, is composed of representatives from the Institution and its branches, and has rendered valuable assistance in examining manuscripts proposed for publication, and in the consideration of various matters connected with printing and publication.

The current business of the Institution has been conducted with promptness, and it is gratifying to note that no arrearages in the work of the government branches under its direction were reported in the quarterly statements to the President and in the annual statement which, in accordance with law, accompanied the estimates transmitted to Congress.

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 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
Deposit 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		7,918.69
Total amount of fund in the United States Treasury		944,918.69

Held at the Smithsonian Institution.

Registered and guaranteed bonds of the West Shore Railroad Company (par value), part of legacy of Thomas G. Hodgkins	$42,000.00
Total permanent fund	986,918.69

In addition to the above there are four pieces of real estate bequeathed to the Institution by the late R. S. Avery, some of which yield a nominal rental and all are free from taxation.

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 $84,769.82, was derived as follows: Interest on the permanent fund, $58,375.12; contributions from various sources for specific purposes, $20,250, and from other miscellaneous sources, $6,144.70; all of which was deposited in the Treasury of the United States to the credit of the current account of the Institution.

With the balance of $18,766.41 on July 1, 1908, the total resources for the fiscal year amounted to $103,536.23. The disbursements, which are given in detail in the annual report of the executive committee, amounted to $71,359.53, leaving a balance of $32,176.70 on deposit June 30, 1909, in the United States Treasury.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1909:

International Exchanges	$32,000
American Ethnology	42,000
Astrophysical Observatory	13,000
National Museum:	
Furniture and fixtures	50,000
Heating and lighting	22,000
Preservation of collections	190,000
Books	2,000
Postage	500
Rent of workshops	4,580
Building repairs	15,000
National Zoological Park	95,000
International Catalogue of Scientific Literature	5,000
Transfer of Greenough statue of Washington	5,000
Temporary occupancy of government buildings for tuberculosis congress	40,000
Total	516,080

Estimates.—The estimates forwarded to Congress in behalf of the government branches of the Institution and the appropriations based thereon for the fiscal year ending June 30, 1910, are as follows:

	Estimates.	Appropriations.
International Exchanges	$32,000	$32,000
American Ethnology	52,000	43,000
Reimbursement of Bell & Co.	525	....
Astrophysical Observatory	17,000	13,000
National Museum:		
Furniture and fixtures	200,000	200,000
Heating and lighting	62,000	60,000
Preservation of collections	400,000	250,000
Books	5,000	2,000
Postage	500	500
Rent of workshops	[a] 4,580	....
Building repairs	15,000	15,000
Moving collections	10,000	4,000
National Gallery of Art	60,000	....
National Zoological Park	110,000	95,000
Readjustment of boundaries	40,000	....
Aviary building	80,000	....
Roadways and walks	12,000	....
International Catalogue of Scientific Literature	7,500	6,000
Total	1,108,105	720,500

[a] The request was made to the Appropriations Committee that this item be eliminated, as rented buildings would be vacated by June 30, 1909.

The Institution is required each year to submit to Congress, through the Secretary of the Treasury, estimates for the support of the several branches placed by the Congress under its administrative charge. The estimates for the fiscal year ending June 30, 1911, were submitted to the Secretary of the Treasury on May 1, 1909, instead of in the fall of the year as heretofore, it being the desire of the President, expressed through the Treasury Department, that more time be given to their examination.

In preparing these estimates I found it imperative that considerable increases should be made in several directions, as follows:

For the Bureau of American Ethnology I have asked an increase of $10,000, to be allotted for the exploration and preservation of antiquities, researches among the tribes of the Middle West, and for researches in Hawaii and Samoa.

To properly carry on the work of the Astrophysical Observatory likewise requires a greater appropriation. The furnishing and maintenance of the new building for the National Museum necessitates, in general, a large increase in annual appropriations. For the National Zoological Park I have asked a considerable increase, in order that it may be properly maintained and become in greater measure what its name would lead the public to expect and demand in a national park.

Estimates for the year ending June 30, 1911.

International Exchanges		$32,000
American Ethnology		52,000
International Catalogue of Scientific Literature		7,500
Astrophysical Observatory		18,000
National Museum:		
Furniture and fixtures	$125,000	
Heating and lighting	60,000	
Preservation of collections	400,000	
Books	5,000	
Building repairs	15,000	
Postage	500	
		605,500
National Zoological Park:		
Maintenance, etc	$110,000	
Aviary building	80,000	
Roadways and walks	14,000	
Readjustment of boundaries	40,000	
		244,000
Printing and binding for the Institution and its branches		72,700
Total		1,031,700

EXPLORATIONS AND RESEARCHES.

The resources of the Smithsonian Institution are at present too limited to permit of large grants for extensive explorations or investigations, but as far as the income allows aid is given in various lines of research work, and it is sometimes found possible to engage in expeditions likely to accomplish important results. If funds could be obtained to be administered under the Institution, the scientific work of the Government might often be supplemented by original researches of a character that would hardly be undertaken by the Government, and which would be of great service to humanity and to science.

Through the National Museum, the Bureau of American Ethnology, and the Astrophysical Observatory the Institution has been enabled to carry on various important biological, ethnological, and astrophysical researches, which are mentioned elsewhere in this report.

SMITHSONIAN AFRICAN EXPEDITION.

Through the generosity of friends of the Smithsonian Institution, there was provided during the past year a special fund to pay for the outfitting and to meet the expenses of the naturalists on a hunting and collecting expedition to Africa under the direction of Col. Theodore Roosevelt. No part of the fund was derived from any government appropriation or from the income of the Institution. The special interest of the Institution in the expedition is the collection of biological material for the United States National Museum.

In June, 1908, the following letter was received from President Roosevelt:

THE WHITE HOUSE, WASHINGTON.
OYSTER BAY, N. Y., *June 20, 1908.*

MY DEAR DOCTOR WALCOTT: About the 1st of April next I intend to start for Africa. My plans are of course indefinite, but at present I hope they will be something on the following order:

By May 1 I shall land at Mombasa and spend the next few months hunting and traveling in British and German East Africa; probably going thence to or toward Uganda, with the expectation of striking the Nile about the beginning of the new year, and then working down it, with side trips after animals and birds, so as to come out at tide water, say, about March 1. This would give me ten months in Africa. As you know, I am not in the least a game butcher. I like to do a certain amount of hunting, but my real and main interest is the interest of a faunal naturalist. Now, it seems to me that this opens the best chance for the National Museum to get a fine collection not only of the big game beasts, but of the smaller mammals and birds of Africa; and looking at it dispassionately, I believe that the chance ought not to be neglected. I will make arrangements to pay for the expenses of myself and my son. But what I would like to do would be to get one or two professional field taxidermists, field naturalists, to go with me, who should prepare and send back the specimens we collect. The collection which would thus go to the National Museum would be of unique value. It would, I hope, include specimens of big game, together with the rare smaller animals and birds. I have not the means that would enable me to pay for the field naturalists or taxidermists and their kit, and the curing and transport of the specimens for the National Museum. Of course the actual hunting of the big game I would want to do myself, or have my son do; but the specimens will all go to the National Museum, save a very few personal trophies of little scientific value which for some reason I might like to keep. Now, can you, in view of getting these specimens for the National Museum, arrange for the services of the field taxidermists, and for the care and transport of the specimens? As ex-President, I should feel that the National Museum is the museum to which my collection should go.

With high regard, sincerely yours,

THEODORE ROOSEVELT.

HON. CHARLES D. WALCOTT,
Secretary Smithsonian Institution,
Washington, D. C.

To which I replied from camp in Montana, where I was carrying on geological investigations for the Institution:

BELTON, MONT., *June 27, 1908.*

To the PRESIDENT,
Oyster Bay, N. Y.

DEAR MR. PRESIDENT: Your letter of June 20, with a copy of a letter Dr. Cyrus Adler wrote you in reply, just received.

I am immensely pleased at the thought of your collections coming to the National Museum, and it will give me the greatest pleasure to provide two taxidermists and their kit, and to arrange for the curing and transport of the specimens.

I leave in the morning for the Kintla Lake region and the Continental Divide, as most of the geological work has to be done above timber line.

Thanking you most heartily and sincerely for the opportunity of securing the African material, I remain,

Sincerely yours,

CHARLES D. WALCOTT.

At the next meeting of the Board of Regents on December 15, 1908, the following resolutions were adopted, formally recording the acceptance of the President's generous offer and expressing the Board's appreciation of the contributions of the friends of the Institution which made this expedition possible:

Resolved, That the Board of Regents of the Smithsonian Institution express to Theodore Roosevelt, President of the United States, its appreciation of his very generous offer contained in his letter of the 20th of June, 1908, to the Secretary of the Institution, with respect to his expedition to Africa; and that it accept the same.

Resolved, That the thanks of the Board of Regents of the Smithsonian Institution be conveyed by the Secretary of the Institution to the donors who have so generously contributed funds to meet the expenses of the naturalists who will accompany Mr. Theodore Roosevelt upon his expedition to Africa, the results of which will be presented by the President to the Smithsonian Institution for the National Museum.

The party sailed on March 23, 1909, from New York on the steamer *Hamburg* for Naples, whence steamer was taken to Mombasa, British East Africa. Those accompanying Mr. Roosevelt were his son Kermit and three naturalists—Lieut. Col. Edgar A. Mearns, surgeon, U. S. Army; Mr. Edmund Heller; and Mr. J. Alden Loring. The expedition arrived in Africa on April 21.

A letter from Mr. Heller, dated at Nairobi May 31, announced the shipment of 20 barrels of large mammal skins in brine, comprising Colonel Roosevelt's first month's collection. The shipment consists of 82 specimens, as follows: Lion, 7; leopard, 1; cheetah, 1; spotted hyena, 1; Cape hartebeest, 14; white-bearded wildebeest, 5; Neumann steinbuck, 5; Kirk dik-dik, 1; common waterbuck, 3; Chanler reedbuck, 4; Grant gazelle, 9; Thomson gazelle, 5, impalla, 2; eland, 1; Cape buffalo, 4; giraffe, 3; hippopotamus, 1; wart hog, 6; Burchell zebra, 7; black rhinoceros, 2. While no new species, so far as is known, is included in this first shipment, the collection will supplement materially the specimens already in the National Museum.

Together with this shipment are expected a large number of specimens of small mammals, and also of birds gathered by Lieut. Col. Mearns and J. Alden Loring, of the expedition party.

Through the Smithsonian African expedition the National Zoological Park has been presented by Mr. W. W. McMillan, of Juja farm, near Nairobi, British East Africa, with an exceptional collection of live African animals. A letter from Lieut. Col. Edgar A. Mearns, dated May 20, states that the collection includes 11 large mammals and 3 large birds, all in fine condition and for the most part well broken to captivity, as follows: A male and female lion, 2 years old; a male and two female lions, 17 months old; a female leopard, a pet of Mrs. McMillan; two cheetahs; a wart hog, 2 years old; one Thomson and one Grant gazelle, well grown; a large

eagle of unusual species; a small vulture; and a large buteo. Specimens of none of these, except the lions and leopard, are at present contained in the park.

STUDIES IN CAMBRIAN GEOLOGY AND PALEONTOLOGY.

In my reports for the past two years reference has been made to studies of the older sedimentary rocks of the North American Continent, which I have been carrying on as opportunity offered for more than twenty years. This work was continued in Montana and the Canadian Rockies during the field season of 1908.

Outfitting at Belton, Mont., the last of June, 1908, the party proceeded with saddle horses and pack mules north past Lake McDonald and on up the valley of the North Fork of the Flathead River to the Kintla lakes. From the Continental Divide northeast of Upper Kintla Lake beautiful views were obtained of the higher peaks, deep canyons, and snow fields north and south of the international boundary. Numerous photographs and notes on the geology were taken.

The party crossed the forty-ninth parallel and moved north up the valley of the Flathead, in British Columbia, making several side excursions into the mountains. The farthest point reached toward the northeast was about 20 miles south of Crows Nest Pass. From there the route led along a trapper's trail up Johnson Creek to the Continental Divide, thence to the town of Pincher Creek and south to Waterton Lake. An examination was made of the oil fields west of Waterton Lake on Cumberland Creek, which is about 15 miles north of the international boundary. From this point the party followed a trail along the western side of Waterton Lake and thence up Little Kootna Creek to the Continental Divide at the head of Mineral Creek, a tributary of McDonald Creek. A few days were spent in taking photographs and examining the geological structure in this vicinity before returning to Belton, on August 1, for supplies.

A trip was next made by the way of Lake McDonald to Gunsight Pass on the Continental Divide, above Upper St. Mary Lake. But smoke from forest fires became so dense that the party returned to Belton and proceeded southward up the South Fork of the Flathead River for about 100 miles. Examinations were made of Gordon Mountain and vicinity and during the return journey several geological sections were examined along the western side of the Continental Divide. Belton was again reached early in September and a trip was made to Marias Pass, which afforded a very fine view of the main range of the Rocky Mountains along the line of the Great Northern Railway.

The scientific results of the 950-mile trip through the forests and on mountain trails will aid materially in the solution of several problems connected with the stratigraphy and structure of the main ranges

of the eastern Rocky Mountains and of the geological position and age of many thousands of feet of the sandstones, shales, and limestones forming the mountains in northern Montana, British Columbia, and Alberta.

On the return an examination was made of the geological formations in the vicinity of Helena, Mont., and of the Wasatch Range, southeast of Salt Lake City, Utah.

Three additional papers giving a summary of the results of my studies in Cambrian Geology and Paleontology were published during the year: No. 3, Cambrian Brachiopoda: Descriptions of new genera and species; No. 4, Classification and terminology of the Cambrian Brachiopoda; and No. 5, Cambrian sections of the Cordilleran area.[a]

GEOLOGICAL INVESTIGATIONS IN THE FAR EAST.

In May, 1909, a Smithsonian grant was made to Prof. Joseph P. Iddings, of the United States Geological Survey and the University of Chicago, for geological investigations in Japan, eastern China, and Java. Professor Iddings, who was graduated in the Columbia School of Mines in 1878–79, and in microscopic petrography by the University of Heidelberg in 1879–80, is well fitted for a research of this kind. His connection with and acquaintance in various foreign scientific societies will be of assistance in prosecuting this remote investigation, which will be reported fully as it progresses.

BOTANICAL COLLECTIONS.

Work under a small grant to Miss Alice Eastwood, for re-collecting the botanical species secured by the botanist Thomas Nuttall in 1836 in the region of Santa Barbara, Cal., has been successfully prosecuted, as mentioned in the last report. As a result, Miss Eastman has sent to the National Museum two sets of plants, one of 341 desirable specimens, which have been mounted for the National Herbarium. The second, and by a few specimens the smaller set, will be used for exchange purposes, many valuable additions to the Herbarium being frequently secured in this manner.

INVESTIGATIONS UNDER THE HODGKINS FUND.

As stated in the last report, I have given consideration to the use of the portion of the Hodgkins fund devoted to the increase and diffusion of more exact knowledge of the atmospheric air in relation to the welfare of man. While much valuable work has been done under this fund, it appeared to me that it would be more in consonance with the ideas of the founder, if at least a portion of it might be employed in some way to aid in the knowledge of the

[a] Smithsonian Miscellaneous Collections, Vol. LIII, pp. 53–230.

prevention of disease and its cure. In following out this sphere of work the Institution issued a circular, under date of February 3, 1908, offering a prize of $1,500 for the best treatise on "The relation of atmospheric air to tuberculosis" that should be presented at the international congress on tuberculosis, which was held in Washington from September 21 to October 12, 1908. This prize aroused widespread interest among the students on this subject and resulted in the receipt by the Institution of 81 papers submitted in competition. All of these have been referred to the committee on awards, whose report is expected in a short time.

Grants from the Hodgkins fund, although not numerous during the past year, have been the means of furthering important investigations which are still in progress.

RESEARCHES ON ATMOSPHERIC AIR.

A Hodgkins grant was approved in October, 1908, for the erection of a small stone shelter on the summit of Mount Whitney, California, for the use of investigators during the prosecution of researches on atmospheric air, or on subjects closely related thereto.

The pioneer trip to the summit of Mount Whitney in the summer of 1881 by the late Secretary Langley, at that time director of the Allegheny Observatory, will be recalled in this connection as well as his earnestly expressed conviction that in no country is there a finer site for meteorological and atmospheric observations than the United States possesses in Mount Whitney and its neighboring peaks.

As emphasized in the report of the Langley expedition, a permanent shelter on the peak is an absolute necessity for the prosecution of continued observations there, and the erection of such a shelter has now been made possible by the extension of railway facilities toward the base of the mountain and the improvement of the trails to the summit.

Mr. C. G. Abbot, who succeeded Secretary Langley as director of the Astrophysical Observatory of the Smithsonian Institution, and to whose immediate suggestion and earnest personal efforts the preparation for and the establishment of this important post on Mount Whitney are largely due, began his observations there in the summer of 1909, and obtained important data in the determination of the solar constant.

The cooperation of Prof. W. W. Campbell, the director of Lick Observatory, University of California, at Mount Hamilton, has been most helpful during the erection of the shelter, and the interest of many of the citizens of Lone Pine, near the border line of the government reservation, has been heartily and patriotically expressed. It is easily seen that the local feeling in favor of the station will make its occupation more readily and comfortably available by members

of the research parties who will from time to time desire to work there.

The class of researches to be prosecuted at this exceptionably favorable station are not only of great scientific interest, but are expected also to prove of value in determining questions having a direct, practical influence on the preservation and progress of human life on our globe.

INTERNATIONAL STANDARD PYRHELIOMETERS.

A limited grant from the Hodgkins fund was approved in February, 1909, for the construction of several silver disk pyrheliometers. These instruments are to be placed in charge of scientific investigators in widely separated localities for the purpose of establishing an international scale for the comparison of observations on solar radiation. The varying results published by observers have made the need of international cooperation in this connection apparent, and the matter has received considerable attention at conferences of the Solar Union.

These simple and comparatively inexpensive instruments are to be constructed after a design by Mr. Abbot. Similar pyrheliometers have been employed in the researches of the Astrophysical Observatory for several years and have proved entirely satisfactory.

PUBLICATIONS UNDER THE HODGKINS FUND.

Bibliography of aeronautical literature.—An exhaustive bibliography of aeronautical literature, compiled by Mr. Paul Brockett, assistant librarian of the Smithsonian Institution, has been completed to July 1, 1909, and is now in course of publication. This work contains references to about 13,500 published articles and is designed to render available the voluminous literature in all languages, on aviation.

Mechanics of the earth's atmosphere.—In 1891 the Institution published a volume of translations of important foreign memoirs on the "Mechanics of the earth's atmosphere," which was prepared by Prof. Cleveland Abbe. There was put to press during the past year a second collection of papers on this subject.

SMITHSONIAN TABLE AT NAPLES ZOOLOGICAL STATION.

The occupants of the Smithsonian table at Naples during the past year were Dr. C. A. Kofoid, of the University of California and the San Diego Marine Biological Station, and Dr. F. M. Guyer, of the University of Cincinnati. Dr. Kofoid is studying the question of sexual reproduction among Dinoflagellata and carrying on experimental work on autotomy in Ceratium, with reference to temperature and vertical distribution in the sea. Their investigations covered a period of seven months.

The present lease of the table expires December 31, 1909, but its renewal for another term of three years has been decided on, so that applications for the seat may now be submitted at any time.

As in former years, the cooperation of the members of the advisory committee has been of great value in the examination of applications for the seat, and is always thoroughly appreciated.

PUBLICATIONS.

The publication work of the Smithsonian Institution has from its beginning been one of its most important functions. It has been the principal medium for the "diffusion of knowledge" throughout the world. The Smithsonian Contributions to Knowledge, the Smithsonian Miscellaneous Collections, and the Smithsonian Annual Reports are publications widely known, and the demand for copies of these works has constantly been much in excess of the possible supply. The editions of the "Contributions" and the "Collections" are necessarily restricted by the limited income of the Institution, and their distribution is almost entirely to public institutions rather than to individuals. The Annual Reports, however, are public documents, issued at the expense of a congressional appropriation. Although this permits of editions of several thousand copies, yet the entire number is each year exhausted soon after the date of publication.

Besides the publications of the Institution proper there are issued under its direction the Bulletins and Annual Reports of the United States National Museum and of the Bureau of American Ethnology, and the Annals of the Astrophysical Observatory. The details relating to these various series during the year will be found in the appendix to this report.

In the series of "Contributions" no new volume was published, although there was issued a new edition of Professor Langley's memoir on "The internal work of the wind," originally printed in 1893. To this new edition was added, as an appendix, a translation of the "Solution of a special case of the general problem," by Réné de Saussure, which appeared in 1893 in Revue de l'Aéronautique Théorique et Appliqué, Paris, in connection with a French reproduction of the above memoir by Professor Langley.

The quarterly issue of the Smithsonian Miscellaneous Collections has now reached its fifth volume. Twenty papers were published in this series during the year. One of these papers, "Some recent contributions to our knowledge of the sun," was a lecture delivered at Washington April 22, 1908, under the auspices of the Hamilton fund of the Smithsonian Institution. Another paper, by Dr. Cyrus Adler, tells of the relation of Richard Rush to the Smithsonian Institution. Mr. Rush was agent of the United States to secure the bequest of

James Smithson. He successfully completed the legal steps necessary to establish the claim of the United States in the English courts, and in August, 1838, arrived in New York with half a million dollars in gold sovereigns which were formally transferred to the Treasurer of the United States. Mr. Rush later rendered important service in the organization of the Institution and was one of its first Regents, serving on the Board from 1846 until his death in 1859.

The continued demand for the Smithsonian Physical Tables, prepared by the late Prof. Thomas Gray, necessitated the reprinting of a fourth edition from the stereotype plates. A thorough revision of these Tables is in preparation to bring the work within the range of the important advance made in the science of physics during the last decade.

The volume of "Smithsonian Mathematical Tables: Hyperbolic Functions," prepared by Dr. George F. Becker and Mr. C. E. Van Orstrand, which was in press at the close of the last fiscal year, has been completed as a "special publication."

Three papers descriptive of my researches in Cambrian Geology and Paleontology have been added to those mentioned in my last report. These are: No. 3, Cambrian Brachiopoda: Description of New Genera and Species; No. 4, Classification and Terminology of the Cambrian Brachiopoda; and No. 5, Cambrian Sections of the Cordilleran Area. The last-named paper is accompanied by a number of illustrations of various parts of the Rocky Mountains showing the Cambrian Cordilleran sections which had been examined to a total thickness of more than 12,000 feet.

Among the works in press at the close of the year was a paper on "Landmarks of Botanical History," by Dr. Edward L. Greene, and a work on the "Mechanics of the Earth's Atmosphere," comprising a selection of important French and German papers translated and edited by Prof. Cleveland Abbe.

There was practically completed, ready for press, at the close of the year a Bibliography of Aeronautics containing references to about 13,500 books and papers on that subject, dating from the earliest days of printing down to the publications of the present year.

The greater part of the Annual Report for 1908 was in type at the close of the year, but press work could not be completed. The volume contains 27 papers showing progress made in astronomy, physics, biology, geology, and other branches of knowledge.

To meet the demand for copies of papers by Secretary Langley on aerial navigation, there was reprinted a special edition, under one cover, of four articles that had appeared in the Smithsonian Reports from 1897 to 1904, as follows: "Story of experiments in mechanical flight" (1897); "The Langley aerodrome" (1900); "The greatest flying creature" (1901); and "Experiments with the Langley aero-

drome" (1904). The introduction to this reprint, written by Assistant Secretary Adler, reads as follows:

The international fame of Samuel Pierpont Langley rests primarily upon his epoch-making researches in solar physics, but during the last ten years of his life his name was best known to the world at large by his experiments in mechanical flight.

Mr. Langley was the first to produce a machine heavier than air which, supported and propelled by its own engine and possessing no extraneous lifting or sustaining power, actually made an independent flight for a considerable distance, this being accomplished for the first time on May 6, 1896. He afterwards constructed other models driven by both steam and gasoline engines, which made frequent successful flights, and was thus the first to demonstrate by actual experiment the possibility of mechanical flight.

In addition to building various models and machines, most of which are now on exhibition in the United States National Museum, Mr. Langley recorded his studies and experiments in two technical works—"Experiments in Aerodynamics," published originally by the Smithsonian Institution in 1891, and "The Internal Work of the Wind," the original edition of which was issued by the Institution in 1893. The copious and painstaking notes made by Mr. Langley in connection with his latest experiments in mechanical flight are now in course of preparation for publication and will be issued by the Institution on completion, thus forming the third volume of this more technical series.

Mr. Langley also wrote a few occasional popular papers relating to this same class of experiments, which were published in the Smithsonian reports and elsewhere, the editions of which are now quite exhausted. In order to meet the ever-increasing demand for information on a subject which is now claiming universal attention, and in which Mr. Langley was the pioneer, some of these less technical articles are here brought together and reprinted under a single cover.

The publications of the National Museum during the year included a large number of papers in the Proceedings, and several Bulletins, the general contents of which are enumerated in the appendix.

The Bureau of American Ethnology published its Twenty-sixth Annual Report and a number of Bulletins. One of the Bulletins, No. 42, by Dr. Aleš Hrdlička, gives the results of his study of tuberculosis among certain Indian tribes.

The Annual Reports of the American Historical Association and of the National Society of the Daughters of the American Revolution were received from those organizations and were communicated to Congress in accordance with their national charters.

The allotments to the Institution and its branches, under the head of public printing and binding during the past fiscal year, aggregating $72,700, were, as far as practicable, expended prior to June 30. The allotments for the year ending June 30, 1910, are as follows:

For the Smithsonian Institution for printing and binding annual reports of the Board of Regents, with general appendixes	$10,000
For the annual reports of the National Museum, with general appendixes, and for printing labels and blanks for the Bulletins and Proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum library	34,000

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	72,700

The practice of sending out abstracts of the publications of the Institution and its branches to newspapers throughout the country has been continued, and in this way many millions of readers, who would not have ready access to the scientific information in the papers themselves, have been reached.

ADVISORY COMMITTEE ON PRINTING AND PUBLICATION.

The committee on printing and publication has continued to examine manuscripts proposed for publication by the branches of the Institution and has considered various questions concerning public printing and binding. Twenty-seven meetings of the committee were held during the year and more than a hundred manuscripts were passed upon. Upon the resignation of Dr. Cyrus Adler, chairman of the committee, as assistant secretary of the Institution, the committee was reorganized as follows: Dr. Frederick W. True, head curator of biology, United States National Museum, chairman; Mr. C. G. Abbot, director of the Astrophysical Observatory; Mr. W. I. Adams, of the International Exchanges; Dr. Frank Baker, superintendent of the National Zoological Park; Mr. A. Howard Clark, editor of the Smithsonian Institution; Mr. F. W. Hodge, ethnologist, the Bureau of American Ethnology; Prof. O. T. Mason, head curator of anthropology, United States National Museum; Dr. George P. Merrill, head curator of geology, United States National Museum; and Dr. Leonhard Stejneger, curator of reptiles and batrachians, United States National Museum.

In order to prevent duplication of work in the examination of papers, the Museum advisory committee on publications was discontinued and its duties transferred to this committee.

THE LIBRARY.

The additions to the Smithsonian Library during the year aggregated 29,729 complete volumes and parts of volumes, besides over 34,000 parts of periodical publications. Of the accessions more than 20,000 were placed in the Smithsonian deposit in the Library of Congress, and the remainder were divided among the libraries of the Secretary's office, the Astrophysical Observatory, the National Zoo-

logical Park, the International Exchanges, and the National Museum library. The library of the Bureau of American Ethnology, which is administered separately from the general library, has also had numerous additions. The Institution has continued the policy of sending to the Library of Congress public documents received in exchange for its publications.

During the last two years special efforts have been made to complete the sets of the publications of scientific societies and learned institutions in the Smithsonian deposit, including serial publications in the main collection, resulting in the receipt of nearly 4,000 parts, an increase of more than 2,000 over the previous year.

The reference books in the Institution and the general library, together with the sectional libraries in the National Museum and the library of the Bureau of American Ethnology, have been very freely consulted.

The importance of the collection of scientific works in the library of the Institution is becoming more and more appreciated each year by the scientific investigator, as is evidenced by the increase in the number of publications withdrawn for consultation, especially the proceedings and transactions of the scientific societies and learned institutions.

The assistant librarian has been engaged in preparing a bibliography of aeronautical literature, which includes the indexing of about 13,500 papers in periodicals and proceedings of aeronautical societies, books and separate pamphlets on the subject, and comprises all available titles, domestic and foreign, published before July 1, 1909. At the close of the year the manuscript was ready for the printer.

PRESERVATION OF AMERICAN ANTIQUITIES.

Under the terms of the act of Congress approved June 8, 1906, uniform regulations for the preservation of archeological and other objects on the public domain were prepared by the Secretaries of the Interior, War, and Agriculture, with the cooperation of the Smithsonian Institution. Under rule 8 of these regulations applications for permits to carry on explorations or researches are referred to the Smithsonian Institution for recommendation, and during the year a number of such applications were acted on by the Institution.

CONGRESSES, CELEBRATIONS, AND EXPOSITIONS.

International Congress of Orientalists.—At the Fifteenth International Congress of Orientalists, held in Copenhagen, Denmark, August 14 to 20, 1908, the Smithsonian Institution and the National Museum were represented by Dr. Paul Haupt, professor of semitic philology in Johns Hopkins University, and associate of the National Museum in historic archeology. At the suggestion of the Institution,

Doctor Haupt, Dr. C. R. Lanman, of Harvard University, Prof. Morris Jastrow, jr., of the University of Pennsylvania, and Prof. A. V. W. Jackson, of Columbia University, were designated by the Department of State as delegates of the United States Government to this congress.

Congress of Americanists.—Dr. Franz Boas, of Columbia University, was representative of the Institution at the Sixteenth International Congress of Americanists, held at Vienna September 8 to 14, 1908, and the Department of State, at the suggestion of the Institution, designated, besides Doctor Boas, the following delegates on the part of the United States Government: Prof. Marshall H. Saville, of Columbia; Dr. George Grant McCurdy, of Yale; Dr. Charles Peabody, of Harvard; and Dr. Paul Haupt, of Johns Hopkins.

Fisheries Congress.—The International Fisheries Congress was held in Washington September 22 to 26, 1908, delegates being present from a large number of countries and from various societies and clubs interested in fisheries. The Institution was represented by Dr. T. N. Gill and Dr. F. W. True; the National Museum by Mr. W. de C. Ravenel and Dr. Leonhard Stejneger. Dr. Richard Rathbun, Assistant Secretary of the Institution, served as delegate at large from the Government. In connection with this congress the Smithsonian Institution had offered a prize of $200 for the best essay or treatise "On international regulation of the fisheries on the high seas: Their history, objects, and results." This prize was awarded to Mr. Charles H. Stevenson, of the United States Bureau of Fisheries.

Tuberculosis Congress.—In compliance with the direction of the President, the new building for the National Museum was selected for the meetings of the International Congress on Tuberculosis, $40,000 being placed at the disposal of the Secretary of the Smithsonian Institution for the necessary arrangements in this connection.

The plans for the adaptation of the building to this purpose were put in the hands of the superintendent of construction, Mr. Bernard R. Green, and the work necessary was conducted by him to a successful conclusion. About 100,000 square feet of the building on the first and second floors, exclusive of the south wings, were used for the purposes of the congress. In order to make the space as attractive as possible, muslin was used to cover the rough places and many flags of the United States and of foreign nations were gracefully festooned about the halls. The Institution is indebted to the War, Navy, and Treasury departments, and also to the Bureau of American Republics, for the use of the flags. The temporary arrangements for the illumination of the building required 600 lamps of 80 candlepower each, consuming about 40,000 feet of wiring.

The congress opened on September 21, 1908, and adjourned on October 12. By November 3 all traces of the convention had been

removed and the building was again ready for the resumption of construction operations. About $25,000 was expended in fitting up the building for the congress ($15,000 being thus unused from the appropriation).

Thirty-one independent nations and forty-five States of the Union were represented. There were 438 contributors, of whom 312 were citizens of the United States. The total attendance at the congress was approximately 148,000.

Among the contributors to the exhibits the Smithsonian Institution presented results of an investigation among certain of the Indian tribes for the Department of the Interior, with a view to showing the actual amount of tuberculosis existing. This work was done by Dr. Aleš Hrdlička, of the National Museum, who visited the Menominee, Sioux, Quinault, Hupa, and Mohave tribes. The exhibit occupied a space amounting to 18 by 40 feet, and the congress expressed its appreciation of it by awarding the Institution a gold medal.

As already mentioned in the paragraphs on the Hodgkins fund, the Institution offered a prize of $1,500 for the best treatise on "The relation of atmospheric air to tuberculosis."

Anniversary of birth of Torricelli.—At the exercises commemorating the three hundredth anniversary of the birth of Evangelista Torricelli, held at Faenza, Italy, in November, 1908, Professor Senator Giovanni Copellini was requested to act as the representative of the Institution.

American Mining Congress.—Dr. George P. Merrill, head curator of geology, United States National Museum, represented the Institution and the Museum at the eleventh annual session of the American Mining Congress, held at Pittsburg, Pa., December 2 to 5, 1908.

Pan-American Scientific Congress.—The first Pan-American Scientific Congress was held in Santiago, Chile, December 25, 1908, to January 6, 1909. The Smithsonian Institution was represented by Mr. William H. Holmes, Chief of the Bureau of American Ethnology and curator of prehistoric archeology in the National Museum, who presented a paper on "The peopling of America." An account of the congress, by Mr. Holmes, is given as an appendix to the present report.

Aeronautical exposition.—The Institution sent seven large photographs of the Langley aerodrome to the International Aeronautical Exposition held at Frankfort on the Main, Germany, February 27, 1909.

National Academy of Sciences.—As has been the custom for many years, the Institution afforded facilities for the meetings of the National Academy of Sciences, April 21 to 23, 1909. One of the halls of the National Museum was used for the public meetings of the academy, the council meetings being held in rooms in the Smithsonian

building. The programme of the meetings included the usual number of papers covering a wide field.

Congress of photography.—The Smithsonian Institution accepted an invitation to participate in the International Congress on Photography at Dresden, Germany, May to October, 1909, and sent a number of enlarged photographs and transparencies.

International Archeological Congress.—Upon the recommendation of the Smithsonian Institution Mr. A. M. Lythgoe, of the Metropolitan Museum of Art, and Prof. Paul Baur, of Yale University, were designated by the Department of State as delegates on the part of the United States to the Second International Archeological Congress, which was held at Cairo, Egypt, Easter, 1909.

Darwin celebration.—It was my pleasure, by resolution of the Board of Regents, to represent the Institution at the one hundredth anniversary of the birth of Charles Darwin, held at Cambridge University, England, June 22 to 24, 1909, when the university conferred upon me the degree of Sc. D. In this connection a bronze bust of Darwin, a gift of many of Darwin's admirers in America, was presented to the university.

University of Geneva anniversary.—Prof. J. M. Baldwin, of Johns Hopkins University, was appointed to represent the Smithsonian Institution at the three hundredth anniversary of the founding of the Geneva University, which was held at Geneva July 7 to 10, 1909.

University of Leipzig anniversary.—The Institution accepted an invitation to participate in the five hundredth anniversary of the University of Leipzig held July 28 to 30, 1909, and Dr. William H. Welch, of Johns Hopkins University, Baltimore, Md., consented to act as its representative on that occasion.

Congress for the History of Religions.—Dr. Paul Haupt, of Johns Hopkins University, and Prof. Morris Jastrow, jr., of the University of Pennsylvania, were designated, at the suggestion of the Institution, as delegates on the part of the United States to the Third International Congress for the History of Religions, held at Oxford, England, September 15 to 18, 1909.

Alaska-Yukon-Pacific Exposition.—In the act of Congress approved May 27, 1908, an appropriation of $200,000 was made for an exhibition by the Government at the Alaska-Yukon-Pacific Exposition held at Seattle, begining June 1 and closing October 1, 1909. Mr. W. deC. Ravenel, administrative assistant in the United States National Museum, was designated by the Secretary as Representative of the Smithsonian Institution and the National Museum. An allotment of $24,000 was made for an exhibit by the Institution and the Museum to illustrate our national history, especially with reference to Alaska, Hawaii, the Philippine Islands, and the United States west of the Rocky Mountains. Mr. Ravenel's account of this exhibit is given in an appendix to the present report.

Mr. Ravenel was also appointed by the President as a member of the United States Government board of managers of the exposition.

LANGLEY MEDAL AND MEMORIAL TABLET.

As a tribute to the memory of the late Secretary Samuel Pierpont Langley and his contributions to the science of aerodromics, the Regents on December 15, 1908, adopted the following resolution:

Resolved, That the Board of Regents of the Smithsonian Institution establish a medal to be known as the Langley medal; to be awarded for specially meritorious investigations in connection with the science of aerodromics and its application to aviation.

Following the establishment of this medal a committee on award, composed of the following gentlemen of recognized attainments in the science of aerodromics, was appointed by the Secretary:

Mr. Octave Chanute, of Chicago, chairman.
Dr. Alexander Graham Bell, Washington, D. C.
Maj. George O. Squier, U. S. Army.
Mr. John A. Brashear, Allegheny, Pa.
Mr. James Means, formerly editor of the Aeronautical Annual, Boston, Mass.

The obverse of the medal is the same as in the Hodgkins medal and was designed by M. J. C. Chaplain, of Paris, a member of the French Academy. It represents a female figure, seated on the globe, carrying a torch in her left hand and in her right a scroll emblematic of knowledge, and the words "Per Orbem." The reverse is adapted from the seal of the Institution as designed by Augustus St. Gaudens, the special inscription being inserted in the center instead of the map of the world. The medal is about 3 inches in diameter.

The committee recommended that the first medal be bestowed on Wilbur and Orville Wright, and the medal was awardeu to these gentlemen under the following resolution, adopted by the Board of Regents on February 10, 1909:

Resolved, That the Langley medal be awarded to Wilbur and Orville Wright for advancing the science of aerodromics in its application to aviation by their successful investigations and demonstrations of the practicability of mechanical flight by man.

At the meeting of the Board of Regents on December 15, 1908, the following resolution was adopted:

Resolved, That the Secretary of the Smithsonian Institution be requested to report to the Board of Regents as soon as practicable upon the erection in the Institution building of a tablet to the memory of Secretary Langley, setting forth his services in connection with the subject of aerial navigation.

Designs for this tablet are now being prepared by a well-known architect of this city, whose advice I have requested.

MISCELLANEOUS.

GREENOUGH STATUE OF WASHINGTON.

The Greenough statue of Washington, which was transferred to the custody of the Institution by joint resolution of Congress of May 22, 1908, introduced by Representative Mann, was removed from the plaza east of the Capitol in November, 1908, and has been installed in the west hall of the Smithsonian building.

MEMORIAL CONTINENTAL HALL.

Under date of April 30, 1909, the president-general of the National Society of the Daughters of the American Revolution communicated with the President, offering to place at the disposal of the Smithsonian Institution the use of the auditorium in Memorial Continental Hall. The President transmitted this offer to the Secretary of the Institution, and its thanks were expressed in a statement that the needs of the Institution at present are of a special nature and require particularly facilities for laboratory and research work, for which Continental Hall is not well adapted, but should there be need in the future for additional space for lecture purposes and the like, the Institution would be glad to avail itself of the courteous proposal of the Daughters of the American Revolution.

NATIONAL MUSEUM.

The operations of the National Museum are discussed in detail by the assistant secretary in the appendix to this report and also in a separate volume, and need not therefore be fully treated here.

It was expected that the new building would be ready for occupancy before June 30, but delayed contracts and other circumstances prevented its completion. The entire stonework of the outer walls was, however, finished, as were also the roofs and skylights of the building. Much progress was made in the interior and it is expected that some of the halls and workrooms will be ready for use early in the autumn. A large part of the first and second floors and of the basement were utilized in the autumn of 1908 for the meetings and exhibition halls of the Sixth International Tuberculosis Congress, an appropriation having been made by the Government for the erection of necessary partitions and other fittings.

It was found to be in the interest of economy to install in the new building a central heating and electrical plant of sufficient capacity to serve the needs of the older buildings as well, the pipes and wires to be carried through a small connecting tunnel.

Over 250,000 specimens were added to the Museum collections during the year, about 200,000 of them pertaining to biology and the remainder to geology and anthropology. One of the most important

additions to the division of ethnology was a contribution from Dr. W. L. Abbott, consisting of about 500 objects from southwestern Borneo. I may also mention a number of Chinese velvets and embroideries of the Chien-lung period (1736–1795), presented by the Baroness von Sternberg as a memorial to her husband, the late Baron Speck von Sternberg, German ambassador to the United States. To the technological collections were added more than 200 objects transferred from the United States Patent Office. These included a number of rifles, muskets, revolvers, and pistols, making the firearms exhibit in the National Museum one of the finest in the country. Many other objects of interest are enumerated by the assistant secretary in his detailed report. The department of biology received a noteworthy gift of about 1,200 European mammals and 61 reptiles from Mr. Oldfield Thomas, of the British Museum, and Mr. Gerrit S. Miller, of this Museum. This has so greatly increased the importance of the National Museum collection of the mammals of Europe that it now ranks as one of the largest and most valuable in the world. I may also mention a contribution of about a thousand mammals and birds of Borneo, received from Dr. W. L. Abbott.

In connection with the work of excavation and repair of the Casa Grande ruins in Arizona, under the direction of the Smithsonian Institution, as authorized by act of Congress approved March 4, 1907, there were collected and placed in the National Museum about 650 stone axes and hammers, rubbing and grinding stones, earthenware bowls and vases, pieces of basketry and textile fabrics, shell ornaments, and wooden implements. From similar excavations in the Mesa Verde National Park, Colorado, there were received about 500 objects of like character. The department of geology received a large series of Cambrian fossils from the Rocky Mountains, collected during my field studies in that region. There were also added to the collections many interesting objects pertaining to mineralogy and paleobotany. Eighty-two regular sets of geological specimens to the number of 7,739 were distributed during the year for educational purposes, besides 1,300 specimens of geology, marine invertebrates, and fishes arranged in special sets.

In my last report mention was made of a loan collection of laces, embroideries, rare porcelains, enamels, jewelry, and other artistic objects, temporarily installed in the hall occupied by the gallery of art. This collection was brought together by Mrs. James W. Pinchot with the assistance of a committee of ladies of Washington. The extent of the collection is limited on account of present lack of space. The lace exhibit is specially noteworthy in variety and value. It is expected that this temporary collection will lead to a permanent exhibit of art objects that may help to elevate the standard of American art workmanship.

Two field parties in which the Institution and Museum are greatly interested left this country during the year for important collecting regions, from both of which especially valuable results may be expected. The first, which will explore Java and some of the adjacent islands, is being conducted by Mr. Owen Bryant, of Cohasset, Mass., entirely at his own expense. He is accompanied by Mr. William Palmer, of the Museum staff, and will present to the Museum a large share of the specimens obtained. The party sailed at the beginning of the calendar year 1909. The second expedition is that under the direction of Col. Theodore Roosevelt into British East Africa and more inlands districts. This expedition is more fully mentioned on another page.

In the near future it will be possible to give the national collections adequate space and more systematic arrangement. In the new building it is proposed to exhibit collections representing ethnology, archeology, natural history, and geology, while the older buildings will be more specially given up to the arts and industries. The Museum thus amply provided with space will enter upon a new era of prosperity and usefulness.

NATIONAL GALLERY OF ART.

Some notable accessions have been made to the National Gallery of Art as enumerated in the appendix. I may specially mention additions to the Charles L. Freer collection, consisting of a number of oil paintings, pastels, 247 pieces of oriental pottery, and 25 miscellaneous examples of oriental art. Mr. William T. Evans has also increased his generous gift of works of contemporary American artists so that it now numbers 84 oil paintings, representing 58 artists. This collection, which had been exhibited for some months at the Corcoran Gallery of Art, was transferred to the Museum building during the first week of July, 1909.

Congress having failed to authorize the adaptation of the large hall of the Smithsonian building for the exhibition of the rapidly increasing collection of works of art, it has become necessary to make temporary use of one of the halls in the new Museum building and its adaptation to that purpose will soon begin.

BUREAU OF AMERICAN ETHNOLOGY.

The Bureau of American Ethnology during the year has been engaged mainly in making summaries of the information resulting from many years of study, both in the field and office, of the languages, social organization and government, systems of belief, religious customs, and arts and industries of the Indians, as well as their physical and mental characteristics.

The bureau has collected data relating to 60 families or linguistic stocks and upward of 300 tribes. It does not expect to study all of the tribes in detail, but rather to investigate a sufficient number as types which may stand for all. The results of the work heretofore accomplished are embodied in 26 published reports, 36 bulletins, 8 volumes of contributions, and in many manuscripts preserved in the archives of the bureau. It has seemed wise at this stage of the researches to prepare a summary of our knowledge of the tribes, and this has taken the form of a Handbook of the Indians, of which one large volume is published and the second nearly through the press. In order to keep this summary within the compass of an easily consulted handbook many important subjects are treated merely in outline. Other handbooks dealing with the more important branches of the work are in course of preparation. The first is the Handbook of Languages, which is now in press and will form two volumes. The arts and industries are also being treated in separate volumes, and handbooks relating respectively to religions, folklore, social customs, government, sign language, pictography, æsthetic arts, physical and mental characters, pathology and medicine, archeology, geographical names, etc., are in prospect.

The people of the United States have two great obligations which the bureau is trying to fulfill: (1) That of acquiring a thorough knowledge of the Indian tribes in the interests of humanity; (2) that of preserving to the world an adequate record of the American race which is so rapidly disappearing. The work is of national, even of world-wide, importance, and unless steadfastly carried forward by the Government can never be completed.

Recently much popular interest has been manifested in the antiquities of the country, more especially in the great pueblo ruins and cliff dwellings of the arid region, and the Fifty-ninth Congress enacted a law for the preservation of these antiquities. A first step in making this law effective is their exploration. A second is the excavation and repair of the more important ruins to insure their preservation and to make them available to the public and for study.

Dr. J. Walter Fewkes, of the Bureau of American Ethnology, has continued the work of excavation and repair of the ancient ruins in the Mesa Verde National Park, in cooperation with the Department of the Interior. During the year the repair of Spruce Tree House was completed, and at the end of June he had made excellent progress in uncovering and repairing the crumbling walls of Cliff Palace, the greatest of the ancient ruins of its kind in this country.

There is need also for ethnological work in the Hawaiian Islands and Samoa, for the following reasons: It is regarded as most important that the Government should have definite and detailed information regarding the native inhabitants of these islands, which

are under its control and for whose welfare it is responsible. It is not less a duty of the nation to preserve some record of this peculiar race for the purposes of history and science, as neglect will become a source of deep regret. An experienced ethnologist should make investigations regarding the history, social institutions, religion, and general culture of the people, and a physical anthropologist should study their physical and mental characteristics.

A work by Dr. N. B. Emerson—Unwritten Literature of Hawaii: the Sacred Songs of the Hula—is now in press, and there is also being prepared by Dr. Cyrus Thomas, of the bureau's staff, and Prof. H. M. Ballou, of Boston, Mass., a catalogue of books and papers relating to the Hawaiian Islands.

Another field for research that should be developed is among the tribes of the Middle West. There is now a strong sentiment among historical societies and educational institutions of this section in favor of prosecuting more vigorously the studies of the tribal remnants of the Mississippi Valley, for it is realized that when the old people of the present generation have passed away the opportunity for collecting historical and ethnological data will be lost forever.

Mr. J. P. Dunn has been engaged as a collaborator of the bureau on a study of the linguistics of the Algonquian tribes of this region, and Prof. H. E. Bolton, of the University of Texas, has continued his studies on the tribes of Texas.

Other collaborators of the bureau have been making special investigations relating to various tribes in different parts of the country.

INTERNATIONAL EXCHANGES.

For the purpose of more fully carrying into effect the provisions of the exchange convention concluded at Brussels on March 15, 1886, and proclaimed by the President January 15, 1889, a resolution was passed by Congress during the year setting aside a certain number of copies of the daily Congressional Record for exchange with the legislative chambers of foreign countries. Under the authority contained in this resolution arrangements for the exchange of the parliamentary record have been entered into with 21 governments, and the matter has been taken up with a number of other countries. It should be stated in this connection that the convention here referred to was the second exchange agreement concluded at Brussels between the United States and other countries on March 15, 1886. The first convention was for the exchange of government documents and scientific and literary publications, while the articles of the second agreement made it obligatory on the contracting States to transmit, immediately upon publication, a copy of the official journal to the legislatures of each. The full text of the resolution, together with

further details concerning this exchange, will be found in the appended report on the exchanges.

The increase in the number of packages handled by the bureau during the past year was the largest in the history of the exchanges—25,777 more packages having passed through the service than in 1908, the total number being 228,875. The weight of these packages was 476,169 pounds, a gain of 40,884 pounds over the preceding year.

The congressional appropriation for carrying on the system of exchanges during 1909 was $32,200 (the same amount as was granted for the preceding year), and the sum collected on account of repayments was $3,777.33, making the total available resources $35,977.33.

The results of the efforts of the bureau to procure larger returns of publications from abroad for the Library of Congress and the several departments and bureaus of the Government have been more than satisfactory—in fact, they have far exceeded my expectations, in some cases hundreds of volumes having been received.

The Japanese department of foreign affairs, which has in the past been good enough to distribute exchanges sent in its care for correspondents in Japan, has recently signified its willingness to forward to the Smithsonian Institution consignments bearing addresses in the United States.

A bureau of exchanges has been established by the Kingdom of Servia and placed under the direction of the department of foreign affairs at Belgrade, and the Argentine exchange bureau has been separated from the National Library and connected with the supervising commission of public libraries at Buenos Aires.

The total number of full sets of United States official publications now sent regularly to depositories abroad is 55, and the number of partial sets 33, Servia having been added during the year to the former and Alsace-Lorraine to the latter.

The number of correspondents has increased from year to year until the aggregate is now 62,630, or 2,507 more than at the conclusion of the fiscal year 1908.

NATIONAL ZOOLOGICAL PARK.

The National Zoological Park during the year added 576 new animals to its collections, which offsets a loss of 562 by exchange, death, and return of animals, and brings the number of individuals on hand June 30, 1909, up to 1,416. There were 564,639 visitors, a daily average of about 1,547, the largest number in any one month being in April, when 127,635 were counted, a daily average of 4,254.

The entire support of the park was derived from an appropriation of $95,000 for general purposes, including the purchase, transportation, care, and maintenance of animals; the care and improvement

of grounds; the construction and repair of all buildings, inclosures, roads, walks, and bridges. Of this amount the increased price of necessary provisions and labor brought the cost of maintenance alone to about $85,000. It was therefore possible to do little toward permanent construction or improvement of the more or less temporary shelters, roads, walks, and inclosures which lack of adequate funds at the time of the inception of the park made it necessary to build. It has not been possible as yet to develop the park to the standard that such institutions usually attain at the capitals of great nations.

The improvements made during the year were for the most part those necessary for the safety of visitors. A series of yards for bears and ten new yards for foxes and wolves were constructed, however, and many of the roads treated with tar preparations to prevent dust and abrasion. The superintendent of the park states that there are needed: A new aquarium, the present building being originally a hay shed, now in a most dilapidated condition; a general aviary and out-of-door shelter for hardy birds; an inclosure for sea lions and seals; an antelope house; a more centrally located office building; a restaurant and retiring rooms for visitors; and further improvements to roads and walks.

Of the 576 accessions to the collections during the year, 124 were gifts to the park, 12 were received in exchange, 307 were purchased, 9 were deposited, 110 were born and hatched in the National Zoological Park, and 14 were captured in the Yellowstone National Park. It is expected that the collections of the Zoological Park will benefit either directly or indirectly through the Smithsonian African expedition under Mr. Theodore Roosevelt, which left this country in March and is at present engaged in gathering specimens of fauna in Africa.

The appropriations during the eighteen years since it was established have permitted of the erection of only three permanent buildings, all of the others having necessarily been constructed cheaply and as temporary makeshifts to meet the successively urgent requirements of the growing collections. The result is that at the present time most of the animals are housed in poor wooden buildings and exposed cages, which are not only inadequate and unsightly but also entail a larger annual expense for repairs and maintenance than the dictates of economy would seem to justify. Elaborate and ornate buildings are not called for, but the necessity for substantial structures adapted to the requirements of the different groups of animals can not be too strongly urged.

It is also to be borne in mind that the Zoological Park is a part of the great park system extending through Rock Creek Valley. Its main roads are continuous with those leading up the creek and are traversed by the same vehicles, including heavy automobiles, which

makes it necessary to maintain these roads on a better basis than would be required if they were intended solely as entrances to the Zoological Park. The heavy expense which this involves falls upon the appropriation for the park, a fact which, it is felt, may not have been fully realized by the Congress in considering the park estimates.

Attention has heretofore been called to the importance of acquiring the narrow tracts of land lying between the park boundaries and the recently established highways on the southeast and west. The highways were located as close to the park as the topography would permit, so as to reduce these tracts to a minimum width, with the expectation that they would be acquired by the Government. Property in this vicinity is gradually increasing in value, and in the interest of economy the tracts should be secured now so that the park boundaries may be permanently established and guarded against injurious encroachment by adjacent grading.

ASTROPHYSICAL OBSERVATORY.

The work of the Astrophysical Observatory during the year consisted:

(1) Of bolometric observations carried on at Washington on the brightness of different parts of the sun's image; also some experimental work on the transparency of the air for long-wave rays, such as the earth radiates. A computation of the results of these experiments is now far enough advanced to show their satisfactory quality. Precise knowledge of the selective absorption of our atmosphere for earth rays is still lacking, and contradictory views are still being expressed about this important subject; hence it is hoped that these experiments will be useful in the study of the dependence of the earth's temperature on radiation.

(2) Spectrobolometric measurements of the solar constant of radiation have been continued at the Mount Wilson observatory in California. As in former years, evidences of a fluctuation of solar radiation were found in the results of the measurements thus far obtained. A new and improved standard pyrheliometer was found to be more satisfactory than the one used in 1906, and great confidence is felt in the results obtained with it. Efforts have also been made to carry the bolometric measurements much farther in the ultra-violet through the use of a large quartz prism, a large ultra-violet glass prism, and two magnalium mirrors. Mr. Abbot, the director of the Astrophysical Observatory, visited the summit of Mount Whitney (14,502 feet), where the institution is preparing to erect a shelter house for the use of observers. This is the mountain upon which Mr. Langley carried on his well-known observations in 1881, and it is believed that the location will prove to be of great value in the further study of the solar constant of radiation.

As stated in the two preceding annual reports, it is highly desirable to continue the solar observations throughout the year, and this can be accomplished by observing during the winter and spring months in southern Mexico, where a cloudless sky and high altitude of the sun may be had, although during those months bad observing conditions occur in the United States. Hitherto lack of funds has prevented a Mexican expedition.

The work of the observatory is receiving highly favorable notice both in this country and abroad, its results being employed by our own Weather Bureau and by foreign investigators as a basis for their measurements on the radiation of the sun.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The purpose of the International Catalogue of Scientific Literature is to collect and publish in 17 annual volumes a classified index of the current scientific publications of the world. This is accomplished by the cooperation of 32 of the principal countries of the world, each having a regional bureau which prepares the data necessary and indexes all scientific literature published within its domain. The material thus prepared is forwarded to a central bureau in London for publication in the annual volumes.

The various subscribers throughout the world bear the entire cost of printing and publishing by the central bureau, each country taking part in the enterprise bearing the cost of indexing and classifying its own publications. The 17 annual volumes combined contain between 10,000 and 12,000 printed pages.

The regional bureau for the United States furnishes yearly about 30,000 classified citations to American scientific literature, which is between 11 and 12 per cent of the total work.

Millions of dollars are being spent each year in scientific investigation and many of the foremost men of the day are devoting their entire time to such work. The results of their labors find publicity through some scientific journal of which there are over 5,000 being regularly indexed by the various regional bureaus, and over 500 in the United States alone. In addition to these periodicals are hundreds of books and pamphlets, all of which the International Catalogue aims to index in its yearly work.

The International Catalogue furnishes in condensed, accurate, and permanent form a minutely classified index to all of these publications. It is necessary for each paper to be carefully studied by a person competent to thoroughly understand the subject treated, as the method of classification actually furnishes a digest of the contents in addition to the usual bibliographisal data. The catalogue is to science what the legal digest is to law.

During the past year 34,409 classified index cards of American scientific literature were prepared and forwarded to London, as compared with 28,528 during the year preceding. The publication of the sixth annual issue was completed during the year and 9 of the 17 volumes of the seventh annual issue were received from the Central Bureau and distributed to the subscribers in this country.

NECROLOGY.

OTIS TUFTON MASON.

It is with deep regret that I have to announce the death, on November 5, 1908, of one of our strong men, Prof. Otis T. Mason, who had been associated with the Institution since 1873, first as a collaborator in ethnology, next as curator of that branch, and finally as head curator of the department of anthropology. I may say, indeed, that this association and influence dates much farther back, when, at 12 years of age, in 1851, he began his education in Washington when the activities of the Institution affected every intelligent citizen.

Professor Mason was born in 1838, so that his life has been almost contemporaneous with the Smithsonian Institution, and he bears an honorable share in its history. He says in his autobiography:

> My first studies were in the culture of the eastern Mediterranean peoples, which I followed persistently until the early seventies, when a chance acquaintance with Professor Henry and Professor Baird, of the Smithsonian Institution, opened the Western Hemisphere to my mind and changed the current of my life.

His agreeable qualities as a man, his earnestness in his work, and his contagious enthusiasm render this loss a most severe one to the Institution.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

APPENDIX I.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1909:

BUILDINGS.

Although it had been fully expected, as explained in the last report, that the new building would be completed before the close of the year, delayed contracts and other circumstances interfered so greatly with the progress of the work that no part of the structure was in condition for occupancy at the end of June. The entire stonework of the outer walls of the building, including the porch, columns, and front of the south pavilion in which the main entrance is located, was, however, finished, as were the roofs and skylights of the building generally. The placing of the slate on the dome of the rotunda and on the adjacent roof of the south pavilion was under way, but the laying of the extensive granite approaches, for which the stone has been delivered, had not been begun.

Much remains to be done in the interior of the rotunda, but as it is the main part of the building which is most urgently needed for the accommodation of the collections and laboratories, it is there that the work has been most energetically prosecuted. Except for some special items, such as metal doors, transoms, etc., the construction of which will require several months, it is expected that at least some parts of the building will be ready for use and that the moving from the older buildings may be started before autumn.

It is interesting to mention that the building has already been made to serve a commendable purpose as the meeting place of the Sixth International Tuberculosis Congress, held in the early autumn of 1908. Being then in a very unfinished condition, it was necessary to make special arrangements, authorized by an act of Congress, for such partitions and other fittings as were required for the accommodation of the several sections and for the display of the extensive collections that were brought together. A large part of the first and second floors as well as of the basement was given over to the congress, and while the progress of construction on the building was thereby much retarded, the delay may be regarded as fully sanctioned by the exceptionally important nature of the event which occasioned it.

The reconstruction of the main roofs of the old Museum building was completed during the summer of 1908, when the slate covering of the rotunda was replaced with tin. The use of slate on these roofs in the beginning had been a mistake in view of their generally slight pitch and the relatively light character of the supporting iron framework. The old roofs had always leaked badly, but up to the present time the new ones have shown no weakness of any kind, and it is felt that they have been built in a proper and substantial manner. Other important repairs interfered with the work of filling in the large archways between the halls of the old building, intended, as explained in previous

reports, to provide against the spread of fire, though something was done in this direction. A much-needed alteration in the arrangements and conveniences of the photograph gallery was in progress at the end of the year.

Much work was done in the preparation and construction of furniture for the new building, more especially for the storage rooms and laboratories, in which it is important that fireproof material be employed to the greatest extent possible. There is already in use a large amount of wooden furniture of modern and appropriate design which it would be extravagant to dispense with, and it is therefore being sheathed with sheet steel to conform to the required conditions.

In regard to new storage furniture, an effort is being made to obtain all metal work, and in view of its recent reduction in cost, due to competition, it now appears feasible to provide for the protection of the immense reserve collections on a basis in keeping with the substantial character of the building. There were on hand at the close of the year 2,407 exhibition cases, 3,184 storage cases, and 1,645 pieces of office and laboratory furniture.

The boiler and electrical plant installed in the new building, embodying the latest improvements, is found to be of sufficient capacity for also heating and lighting the older buildings, and, in the interest of economy, it has been decided to make this one plant serve for all. Plans for carrying this arrangement into effect were nearly completed at the close of the year, and it is expected that the connections can be made before autumn. It will be necessary to construct a small tunnel for carrying the pipes and wires from the new building to the Smithsonian building, where they will enter the existing conduits. While the new building will be heated by hot water, steam will be carried to the older buildings, the latter being the medium for which their pipes and radiators are now adapted.

NATIONAL GALLERY OF ART.

By a third deed of gift, dated May 10, 1909, Mr. Charles L. Freer, of Detroit, Mich., added to his large donation of American and oriental art the following examples acquired since the transfer of the previous year, namely: Four oil paintings and 1 pastel, by Dwight W. Tryon; 3 oil paintings and 1 pastel, by Thomas W. Dewing; a portrait of ex-President Roosevelt, by J. Gari Melchers; 2 oil paintings, 1 water color, 4 drawings and sketches, 1 album of sketches, and 3 etchings and dry points, by James McNeill Whistler; 4 oriental paintings; 247 pieces of oriental pottery; and 25 miscellaneous examples of oriental art.

Mr. William T. Evans, of New York, also continued to make important additions to his collection of the works of contemporary American artists, which, at the close of the year, numbered 84 oil paintings received in Washington, representing 58 artists. As the Corcoran Gallery of Art required for its own use the space which has been occupied by the Evans pictures, the transfer of the latter was arranged for in June and carried into effect during the first week of July, 1909. The walls and screens of the picture gallery in the Museum building were entirely given over to this collection, and the new installation displays the paintings to much better advantage than the previous one. This change, however, necessitated the removal of the paintings which have hitherto been hanging in the gallery to temporary quarters in the Smithsonian building.

It has now become imperative to provide some place where the paintings belonging to the National Gallery of Art can be segregated, and since the fitting up of the second story of the Smithsonian building has so far failed to secure the approval of Congress, it has been decided to make temporary use of one of the skylighted halls in the new Museum building. Its adaptation to this purpose will be taken up early in the new fiscal year.

It should be mentioned that the full-length portrait of Guizot, the French statesman and writer, by G. P. A. Healy, belonging to the Government, has been recalled from the Corcoran Gallery of Art. An important addition to the historical-portrait series is a full-length painting of Rear-Admiral George W. Melville, U. S. Navy, by Sigismond de Ivanowski. This portrait was executed on the order of a number of friends of the distinguished naval officer and presented through the American Society of Mechanical Engineers at their annual meeting, held in Washington, in May, 1909.

ART TEXTILES.

The loan collection of art textiles and other objects begun in May, 1908, by Mrs. James W. Pinchot, with the assistance of a number of ladies of Washington, has received much attention, and its importance has been greatly increased by many valuable additions. The limited amount of space which could be allotted to this subject in the picture gallery tended to restrict the number of contributions, but as soon as the removal of the paintings to another hall has been effected the entire area of the present one will become available. The collection is now contained in 24 cases, of which 9 are devoted to laces, 7 to other art fabrics, 4 to porcelains, 2 to enamels, and 2 to fans. With these are also exhibited numerous examples of silverware, jewelry, and wood and ivory carving. There have been 22 contributors since the last report. The assemblage of lace constitutes the most noteworthy part of the collection, being exceeded in variety and value only by the collections of the Metropolitan Museum of Art of New York and the Boston Museum of the Fine Arts. This art movement, so auspiciously inaugurated and so earnestly supported, if it be sedulously followed up, is certain to prove an important factor in the future history of the National Museum. It was started with the definite purpose of stimulating the formation of a permanent exhibit, which should be valued not only on account of its attractiveness and historical interest, but more especially as furnishing motives and designs which may help to elevate the standard of art workmanship in this country. Its growth has been exceptional, and it is hoped that its intent will be fulfilled.

ADDITIONS TO THE COLLECTIONS.

The total number of accessions to the Museum during the year was 1,358, comprising 254,787 specimens, distributed among the three departments, as follows: Anthropology, 26,400; biology, 216,324; and geology, 12,063.

Department of Anthropology.—The most important contribution in ethnology consisted of about 500 objects illustrating the handiwork and domestic arts of the natives of southwestern Borneo, collected and presented by Dr. W. L. Abbott, to whom the Museum was already indebted for several large gifts of a similar character from the Malaysian region. Next should be mentioned a valuable collection obtained by Dr. Aleš Hrdlička in the course of his investigations relative to tuberculosis among the Indians of the southwestern United States, and many objects from the northern coast of Alaska, donated by Mr. E. de K. Leffingwell, who is conducting extensive explorations in that region. Ethnological material was also received from the Philippine Islands, Africa, and Central and South America.

Most noteworthy among the additions in prehistoric archeology were the collections resulting from the work of Dr. J. Walter Fewkes, of the Bureau of American Ethnology, in the excavations and repairs, conducted first at the Casa Grande ruins in Arizona, under a special appropriation by Congress to the Smithsonian Institution, and, later, at the Spruce Tree House in the Mesa

Verde National Park, Colo., under authority from the Department of the Interior. The number of objects forwarded to Washington from the former locality was 662 and from the latter 501. In these important undertakings, justified by the great historical and scientific significance of the ruins, everything that formed an integral part of the structures or could be safely left at the sites was allowed to remain, only such objects being taken away as would tend to attract looting or would be likely to fall into the hands of unwarranted collectors.

The division of historic archeology was enriched by a manuscript of the Mahabarata, the great epic of India, containing 90,000 couplets, written in Sanscrit characters on palm leaves, a gift from the learned Rajah Sir Sourindro Mohun Tagore. Several interesting additions were made to the very valuable loan collection of Jewish ceremonial objects by the generous friend of the Museum, Haidji Ephriam Benguiat, of New York.

The collections of physical anthropology, which are not restricted to the human race, but also extend to other groups of the higher vertebrates, received important additions from many widely separated regions. Mention should especially be made of the generous action by the Metropolitan Museum of Art, of New York City, in allowing the National Museum to share, without expense, in the results of its Egyptian excavations, which are in charge of Prof. Albert M. Lythgoe. The skeletal remains of the ancient Egyptians found in the tombs uncovered by the explorations, and hitherto not generally preserved, are now being saved and in greater part turned over to the National Museum, where their study should result in interesting contributions on the physcial characteristics of these peoples. A large number of remains were received during the year, and, on the invitation of the Metropolitan Museum, Doctor Hrdlička, assistant curator in charge of these collections, had the opportunity of visiting Egypt last winter for the purpose of instructing the excavators as to the best methods of preserving and packing the remains for shipment and of making studies on the spot.

The division of technology received numerous accessions, including many objects transferred from the Patent Office. The subjects principally represented were firearms (of which the Museum collection is now the finest in the country), electrical devices, calculating machines, printing presses, the early history of the aeroplane, and watch movements.

Two gifts of exceptional beauty and value from the Government of China were added to the collections in ceramics. One was a celadon vase of large size and graceful shape, the other one of the famous peachblow vases from the imperial treasure house at Mukden.

To each of the divisions of graphic arts and musical instruments a few additions were made. Plans were begun for broadening and enlarging the collections of medicine so as to meet the requirements of the recent extensive investigations into this subject, and they will be carried out as soon as additional space becomes available.

Among many gifts and loans to the division of history, mention should be made of a number of valuable presents to the Hon. Gustavus Vasa Fox by the Czar of Russia during his mission to that country in 1866, and bequeathed to the Museum by his widow; also interesting relics of the *Jeannette* arctic expedition of 1879–1881, and memorials of Gen. Judson Kilpatrick, U. S. Army, and Commander Harry H. Hosley, U. S. Navy.

Department of Biology.—The largest amount of zoological material from any single source was derived from the Bureau of Fisheries, and especially from the explorations of the steamer *Albatross* among the Philippine Islands, in which Dr. Paul Bartsch, assistant curator of mollusks, participated for about

a year, being detailed as a member of the scientific staff of that vessel. A part of the collections obtained on this expedition, including over 100,000 specimens of mollusks and other groups of marine invertebrates, was transferred directly to the Museum for working up. Doctor Bartsch was also enabled to make some important collections of birds and reptiles. The same bureau likewise turned over to the Museum other important collections of marine invertebrates and fishes, chiefly from explorations in various parts of the Pacific Ocean.

Among important gifts were about 1,200 European mammals presented by Mr. Oldfield Thomas, of the British Museum, and Mr. Gerrit S. Miller, jr.; about 700 mammals and 200 birds collected in Borneo by Dr. W. L. Abbott; about 600 specimens, mainly of invertebrate animals obtained in Labrador, by Mr. Owen Bryant; and a large collection of Peruvian reptiles, mollusks, crustaceans, and sponges from the Peruvian Government. The large collection of birds secured during the expedition of Mr. Robert Ridgway to Costa Rica was received in the summer of 1908. Besides those mentioned above the principal accessions of reptiles came from the Philippines and Panama, and of fishes from New South Wales and Florida.

The division of insects received over 32,000 specimens, including several accessions of special value. Mr. William Schaus added to his previous noteworthy donations about 16,000 specimens of Lepidoptera from Costa Rica and other tropical countries. Mr. H. L. Viereck, of the Bureau of Entomology, and Mr. J. C. Crawford, of the National Museum, presented their private collections of Hymenoptera, amounting to over 5,000 specimens in all. Lord Walsingham and Mr. F. D. Codman contributed many Central American species described in the Biologia Centrali Americana. The balance of the accessions consisted mainly of transfers from the Department of Agriculture, and represented many parts of the United States.

The additions to the collections of mollusks and other marine invertebrates were mainly derived from the explorations of the Bureau of Fisheries, as elsewhere described. A notable gift from the Zoological Museum of Copenhagen, Denmark, consisted of several hundred crabs from the Gulf of Siam, including 20 genera and 66 species new to the Museum.

The herbarium received extensive collections, coming mostly from Mexico, New Mexico, Oregon, and the Philippines.

Department of Geology.—Nine series of rock specimens, the results of field work in as many parts of the United States, were transferred by the Geological Survey. In invertebrate paleontology the more noteworthy additions were a large series of Cambrian fossils from the Rocky Mountain region, resulting from the explorations of Secretary Walcott during the summer of 1908; a large collection of Paleozoic fossils from the Appalachian Valley and central Tennessee, made by the curator of the division; and a collection of Tertiary fossils from the Coalinga district, California, received from the Geological Survey. A large amount of material from the Fort Union beds of Sweet Grass County, Mont., representing many new and little known mammalian species, constituted the principal accession in vertebrate paleontology.

CARE AND PRESERVATION OF COLLECTIONS.

The collections have been maintained in good condition notwithstanding the overcrowding in all the divisions. Much of the routine work was planned with the view of placing the collections in such shape as to permit of their removal to the new building in systematic order, but the delay in the completion of the building has made this part of the task especially difficult. With the assur-

ance that the new structure would be finished during the winter or spring of 1909, no appropriation was requested or obtained for continuing the occupancy of the rented buildings, in which, for many years, large quantities of museum specimens and other property have been housed. As these buildings had to be surrendered at the end of the year it became necessary to transfer nearly all of this material in bulk to the new building, where it occupies a large part of one of the exhibition floors. Under more favorable circumstances it would have been unpacked and assorted beforehand.

As good progress was made in the sorting, classifying, labeling, and cataloguing of the accessions of the year as was possible under the adverse conditions and with the relatively small staff of experts attached to the Museum. The examination of the collections resulting in many important scientific contributions, in which a number of specialists connected with other establishments have participated.

The exhibition collections have been added to and changed only in minor ways, principally in connection with the loan collection of art textiles, technology, history, and historic archeology.

MISCELLANEOUS.

Of duplicate material, chiefly natural history, separated from the collections in the course of recent studies, over 9,000 specimens arranged in classified sets for educational purposes were distributed to many high-grade schools and colleges throughout the country. About 10,000 duplicates were used in making exchanges with museums and other scientific establishments, from which an equivalent in new material has been or will be received. To specialists in different fields connected with other institutions, both at home and abroad, about 19,000 specimens were sent for examination, all of which, except some of the duplicates, will be returned to the Museum. A large part of the work on these loan collections is being carried on directly in the interest of the National Museum.

The number of visitors to the public halls was a little less than a quarter of a million, which is about the annual average. This is in striking contrast with the records of large museums in other places, where the hours of opening are extended to evenings and Sundays for the benefit of the working people. While the additional cost involved in the extra hours of heating and the employment of a few more watchmen would be inconsiderable, the means at the disposal of the museum have never been quite sufficient to accomplish this worthy purpose. It is hoped that this matter may be satisfactorily adjusted in connection with the new building.

The publications issued by the Museum consisted of the annual report for the year ended June 30, 1908; volumes 34 and 35 and part of volume 36 of the Proceedings; 3 bulletins and parts of 2 other bulletins. They comprised 91 separate papers and memoirs, all of which except the administrative report were descriptive of Museum collections. In addition, a number of papers of the same character were printed in the Quarterly Issue of the Miscellaneous Collections of the Smithsonian Institution and elsewhere.

The additions to the library, which is restricted to the subjects covered by the activities of the Museum, consisted of 2,680 books, 3,671 pamphlets, and 227 parts of volumes, which increased the total contents of the library to 36,244 volumes and 56,010 unbound papers. The annual appropriation of $2,000 for the purchase of books, periodicals, and pamphlets required for the classification of collections, is wholly inadequate to meet the needs of this work, and should be at least doubled. For a large part of its increase the library is dependent

upon gifts and exchanges, but even these means combined with the purchase fund are not nearly sufficient to satisfy the important demands in this direction.

In conjunction with the Institution, the Museum is participating extensively in the government exhibit at the Alaska-Yukon-Pacific Exposition at Seattle, which opened on June 1 and will close on October 16. The general subject which, in accordance with the law, the Institution and Museum were directed to illustrate is that part of the national history of the United States which relates to Alaska, the Philippine Islands, and that section of the country lying west of the Rocky Mountains. Samoa and Guam have also been included. The collections assembled for this purpose, obtained partly from original sources and in part selected from the Museum exhibits, consist of models, pictures, and actual objects, representing the peoples, conditions, etc., from prehistoric to modern times. The exhibit is interesting and instructive and has been attractively arranged.

The Museum, in conjunction with the Bureau of American Ethnology, also sent to the International Photographic Exhibition at Dresden, Germany, a series of enlarged photographic prints and transparencies covering a variety of subjects, but designed to illustrate the perfection to which the art of photography has attained in this country in the portrayal of scientific subjects.

Respectfully submitted.

RICHARD RATHBUN,
Assistant Secretary in charge of U. S. National Museum.

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

45745°—SM 1909——4

APPENDIX II.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: The operations of the Bureau of American Ethnology for the fiscal year ended June 30, 1909, conducted in accordance with the act of Congress making provision for continuing researches relating to the American Indians, under direction of the Smithsonian Institution, were carried forward in conformity with the plan of operations approved by the Secretary June 18, 1908.

As in previous years, the systematic ethnologic work of the bureau was intrusted mainly to the regular scientific staff, which comprises eight members. As this force is not large enough to give adequate attention to more than a limited portion of the great field of research afforded by the hundreds of Indian tribes, the deficiency was supplied in a measure by enlisting the aid of other specialists in various branches of ethnologic work. By this means the bureau was able to extend its researches in several directions at a comparatively modest outlay.

The work of the bureau for the year comprised: (A) The continuation of various unfinished researches among the Indian tribes and (B) the summarizing for publication of available data from all sources.

(A) The unfinished researches were in continuation of systematic investigations already in hand and were essential to a reasonable rounding out of the work among the tribes. These researches were distributed as follows:

Regular force: Matilda Coxe Stevenson, the Pueblo tribes; James Mooney, the Great Plains tribes; J. N. B. Hewitt, the Iroquoian tribes; J. R. Swanton, the Southern tribes; F. W. Hodge, literary researches for the Handbook of the Indians; J. W. Fewkes, archeology of Southwestern tribes; W. H. Holmes, technology of the tribes; Cyrus Thomas, bibliography of Hawaii.

Collaborators: Franz Boas and eight assistants, the languages of the tribes; Aleš Hrdlička, the physical anthropology of the tribes; Frances Densmore, ceremony and songs of the Ojibwa tribes; J. P. Dunn, linguistics of the Algonquian tribes of the Middle West; N. B. Emerson, the Hawaiians; H. M. Ballou, the Hawaiians; H. E. Bolton, the tribes of Texas; J. P. Reagan, Northwest Coast tribes; Alice C. Fletcher, the Omaha tribe; Francis La Flesche, the Omaha tribe; W. F. Gerard, etymology of Indian names.

(B) The summarizing of the materials now available relating to the tribes was initiated by the preparation of the Handbook of the Indians, which assumes to cover the whole ground in brief articles arranged in alphabetical order. Its preparation has led to a clearer understanding of the work done and to be done, and the researches now in hand contemplate the preparation of a series of handbooks, each to be devoted to a full presentation of a single branch of the subject, as follows:

(*a*) Handbook of the Tribes: History, distribution, settlements, population, etc., of each stock, tribe, and minor group. Preliminary assemblage of the data is embraced in the present Handbook of American Indians, of which Part I is published and Part II almost ready.

(*b*) Handbook of Languages: Volume I now in press, Volume II in preparation. As several hundred languages are to be considered, a number of years will be required to complete the work.

(*c*) Handbook of Race History: Physical and mental characters, physiology, pathology, medicine, etc. Researches in hand, but requiring extensive additional investigation.

(*d*) Handbook of Social Systems: Organization and customs of society, the family, clan, tribe, confederacy, government, etc. A large body of material is already in hand, but much additional research is necessary.

(*e*) Handbook of Religions: Religious customs, rites and ceremonies, folklore, etc. The large body of data in hand requires much elaboration, with additional research.

(*f*) Handbook of Technology: Arts, industries, implements, utensils, manufactures, building, hunting, fishing, etc.

(*g*) Handbook of the Esthetic Arts: Painting, sculpture, ornaments, music, drama, etc.

(*h*) Handbook of Sign Language.

(*i*) Handbook of Pictography.

(*j*) Handbook of Treaties and Land Cessions.

(*k*) Handbook of Games and Amusements.

(*l*) Handbook of Burial Customs.

(*m*) Handbook of Economics: Food resources, culinary arts, medicinal resources, etc.

(*n*) Handbook of Archæology. The extensive researches of past years need to be supplemented by much additional exploration.

(*o*) Handbook of Geographical Names.

(*p*) Handbook of Hawaii. Researches initiated by the preparation of a bibliography of 6,200 titles now nearly ready and a work on mythology now in press.

(*q*) Bibliographies.

(*r*) Dictionaries.

(*s*) Grammars.

(*t*) Portfolios of portraits, etc.

The body of data in hand relating to the Indians probably surpasses that heretofore obtained relating to any primitive people, but still falls short of the rounding out that should characterize the work of the American nation, dealing as it does with a race and a culture which are rapidly disappearing.

During the year researches were carried on in Arizona, New Mexico, Colorado, Texas, Oklahoma, Louisiana, South Carolina, Indiana, and Oregon, and were incidentally extended to the Argentine Republic, Chile, Bolivia, Peru, California, Washington, and British Columbia.

The chief devoted his time while in the office to the administrative work of the bureau, giving the necessary attention to his duties as curator of the Section of Prehistoric Archæology and to the National Gallery of Art in the National Museum. During the year considerable progress was made in the preparation of a work already well advanced, on the stone implements of North America.

Having been designated by the Department of State to represent the Smithsonian Institution at the First Pan-American Scientific Congress, held at Santiago, Chile (at which he represented also the George Washington University), on October 29 the chief took passage on the Hamburg-American steamer *Amerika* for England, sailing thence by way of Vigo, Spain, and Lisbon, Portugal, to Buenos Aires. After spending ten days in the Argentine capital with members of the delegation, making official visits and pursuing studies in various public institutions, he traversed the pampean country by rail to Mendoza, and thence up the Mendoza River to Las Cuevas at the base of the cumbre or crest of the Andes. Taking coach at this point he crossed to the Chilean

side and soon reached Santiago. The three weeks spent in Santiago were taken up largely with affairs of the delegation, including official duties and attendance on meetings of the Congress. The section of the natural sciences, including anthropology, met daily, and on December 28 the chief acted as chairman of the section. His contribution to the programme of the congress was a paper on "The peopling of America," an abstract of which follows:

Discussion of the problem of the origin of the American aborigines involves consideration of several important questions, as follows:

(1) Evolution of the human species from lower forms.

(2) Geographical location of the original home of the race.

(3) Dispersal to the different land areas of the globe.

(4) Differentiation of the subraces physically and culturally.

(5) Chronology of the racial history.

In the present state of our knowledge we can not assume to dispose finally of these several questions. It is most important, however, that the whole subject should be passed under review at frequent intervals, and the data assembled, classified, and critically examined. The writer's views, formulated after careful consideration of the various phases of the subject presented, considering more especially the North American evidence, are expressed in the following summary of probabilities:

(1) That the human family is monogenetic; that is to say, the present subraces have been derived by differentiation from a common stock.

(2) That the precursor—that is to say, man before he reached the human status—occupied a limited area.

(3) That this area was tropical or subtropical and was situated in the Old World rather than in the New.

(4) That multiplication of numbers led to wide distribution, and that isolation on distinct land areas finally led to the differentiation of the subraces.

(5) That the separation into distinct groups began at an early period, but not until after the typical human characters had been developed.

(6) That the human characters were acquired in Tertiary time, and that dissemination extended to distant continents, mainly in Quaternary time.

(7) That the pioneers of the present American race belonged to the well-differentiated Asiatic subrace and that they reached America by way of Bering Strait.

(8) That the early migrations included few individuals and occurred at widely separated periods; that the movements were slow and by means of the ice bridge in winter or by skin boats in summer.

(9) That the culture of the immigrants in all cases was very primitive, not rising above the hunter-fisher stage.

(10) That successive migrations involved numerous distinct groups or tribes, so that the American race is a composite of diversified Asiatic elements more or less completely amalgamated.

(11) That the result was a new people and a new culture, essentially American.

(12) That the Eskimo—forming a widely distributed ethnic group occupying the northern shores of both continents—acquired their physical characteristics and peculiar culture under the influence of Arctic conditions, and that they are the descendants of marginal tribes early forced to the northward from southern Eurasian sources of population.

(13) That occasional accessions of population may have resulted from the accidental arrival of voyagers from other lands, though not in numbers large enough to affect the race perceptibly.

(14) That in the present period prior to the Columbian discovery occasional voyagers from southern Asiatic culture centers or from Japan or China may have reached American shores and left an impress on the culture of middle America.

(15) That the peopling of America with the present race was accomplished in late Glacial or post-Glacial time rather than in early Glacial or Tertiary time.

(16) That much of the recorded geological evidence of great human antiquity in America is unreliable and requires critical revision.

(17) That the aboriginal peoples will soon disappear as the result of interminglings with other races and failure to accommodate themselves to new conditions; that America will be fully occupied by a cosmopolitan people embody-

ing the best elements of every civilization—a race of superior capacity and force, destined in its full fruition to surpass all others in the grandeur of its achievements; and that the activities of the present and of future Pan-American scientific congresses will contribute a worthy share in the accomplishment of this grand result.

At the closing session of the congress the chief was made a member of a committee of five to arrange for the next meeting of the congress, to be held in Washington, D. C., in October, 1912.

While in Santiago much attention was given to the national museum, which contains a great deal of material illustrating the ethnology and archeology of Chile, and a number of private collections, rich chiefly in Peruvian antiquities, were visited.

The homeward trip from Santiago included excursions to Bolivia, where the small national museum was visited and where studies were made of the ruined city of Tiahuanaco; to Peru, where a brief period was devoted to a study of the rich collections of the national museum; and to Panama for a short stay. Washington was reached on February 11, and reports were then prepared for the institutions which the chief represented as delegate and for publication in scientific journals.

The services of the chief were enlisted during the early months of the year in the preparation of the Institution's exhibit to illustrate the history of the Pacific Coast States and the Pacific islands at the Alaska-Yukon-Pacific Exposition at Seattle. Before leaving for South America in October he designed a number of lay-figure family groups, which were elaborated by the sculptor during the winter months; and on his return from the South he attended to the completion of these groups and to the construction of a model of the Santa Barbara mission establishment, California, for the exposition. On May 4 he proceeded to Seattle to assist in setting up the exhibits, stopping en route to select a site on the southern rim of the Grand Canyon of the Colorado suitable for the erection of the monument to the late Maj. J. W. Powell recently provided for by the Congress; at Los Angeles, to examine the collections in the Southwestern Museum; at Santa Barbara, to study the plan of the mission; and at San Francisco, to visit the museum of the University of California. While in Seattle visits were made to Tacoma, Wash., and to Victoria, British Columbia, for the purpose of examining collections of ethnological and archeological material preserved in these places. The chief returned to Washington on June 11.

During the year the chief made studies of a more or less elaborate nature in the following museums:

Blackmore Museum, Salisbury, England.
University of La Plata Museum, Argentine Republic.
Faculty of Philosophy and Letters Museum, Buenos Aires, Argentine Republic.
National Museum, Buenos Aires.
National Museum, Santiago, Chile.
National Museum, La Paz, Bolivia.
National Museum, Lima, Peru.
California University Museum, San Francisco.
Southwestern Museum, Los Angeles.
Ferry Museum (Tozier collection), Tacoma, Wash.
University of Washington Museum, Seattle, Wash.
Provincial Museum, Victoria, British Columbia.
Field Museum of Natural History, Chicago.
Academy of Sciences Museum, Philadelphia.

Early in the year the bureau was urged by the officers of the Mississippi Valley Historical Association to contribute data relating to the history of the Indian tribes of the region for the meeting of the association convened in St. Louis June 15, 1909. The chief contributed a paper entitled "Remarks on the aboriginal history of the Mississippi Valley;" and Mr. James Mooney and Dr. John R. Swanton were designated to attend the meeting and present papers dealing with kindred subjects.

Mrs. M. C. Stevenson, ethnologist, remained in the field, in New Mexico, during the entire year. Having established headquarters at Española, she devoted her time largely to investigations among the local Pueblo tribes, interrupting the work for short periods to record valuable data communicated by visiting members of the Zuñi tribe. Her researches included detailed studies of the history, social organization and customs, religion and religious practices, and arts and industries of the Santa Clara and San Ildefonso tribes; and progress was made in the comparative study of these varied subjects among the numerous pueblos.

Aside from the more systematic ethnological work, Mrs. Stevenson gave much attention to her unfinished papers on "The preparation of cotton, yucca, and wool for the loom by the New Mexican tribes" and on the "Medicinal and food plants used by the Zuñi Indians."

Mr. F. W. Hodge, ethnologist, was engaged chiefly in continuing the editorial work on Part 2 of the Handbook of American Indians, carrying along the proof reading toward the close of the alphabet and writing and inserting many articles on lesser subjects that it had been found essential to include. In this work he had the assistance especially of Mr. J. N. B. Hewitt, who prepared articles pertaining chiefly to the Iroquois tribes; of Mr. William R. Gerard, of New York, who revised and rewrote numerous articles involving the etymology of Indian terms; and of Dr. Herbert E. Bolton, of the University of Texas, who continued to supply, to the end of the alphabet, articles relating to the tribes of Texas. The work of completing the second part of the Handbook of American Indians did not proceed as rapidly as was hoped at the beginning of the year, owing to the fact that the burden of the administrative work of the bureau devolved upon Mr. Hodge when the chief was called to South America and later to the Seattle Exposition, as previously mentioned. In the handbook work Mr. Hodge had the clerical assistance of Mrs. Frances Nichols. It is now expected that Part 2 will be ready for distribution in the near future. Mr. Hodge represented the bureau on the Smithsonian advisory committee on printing and publication, and served also as a member of the subcommittee on bibliographical citations. In addition he prepared answers to many inquiries from correspondents, oftentimes requiring considerable research.

Dr. Cyrus Thomas, ethnologist, devoted his time during the year to work on the catalogue of books and papers relating to the Hawaiian Islands. This catalogue, in the preparation of which Prof. H. M. Ballou, of Boston, Mass., is joint author, has grown to an extent not anticipated at the outset. During the last and next preceding fiscal years Professor Ballou examined, for this purpose, the libraries of Boston and other cities of New England, and also of New York. He also visited Hawaii, where he made a careful examination of the public and private libraries of Honolulu, obtaining thereby considerable early mission and official material of a bibliographical nature not found elsewhere. During the same period Doctor Thomas visited Boston and Worcester twice, searching the libraries chiefly along special lines to which Professor Ballou had not given exhaustive attention; he also devoted considerable time to an examination of the libraries of Washington. In addition to these researches considerable bibliographical material has been obtained by corre-

spondence. As a result of this work the number of titles in the catalogue (which is now about finished) reaches some 6,200—more than eight times the number in the largest catalogue in the same field hitherto published. Hon. George R. Carter, former governor of the Territory of Hawaii, has given much encouragement to this work; in fact, with Professor Ballou, he formed the leading spirit in its inception, though the beginning of the work for the bureau was undertaken quite independently. Doctor Thomas has appended a subject or cross-reference catalogue of about 3,200 titles, which is so nearly complete that it is hoped the entire work will be submitted for publication before the end of August, 1909. In addition to this work Doctor Thomas assisted to some extent in the preparation of Part 2 of the Handbook of American Indians, and attended to such official correspondence as was referred to him.

Mr. James Mooney, ethnologist, during the entire year was occupied chiefly in an investigation of the subject of the Indian population north of Mexico at the period of first disturbance and occupancy of the country by the whites. A preliminary study was condensed for introduction into Part 2 of the Handbook of the Indians. The final work is expected to appear as a bulletin of the bureau. The investigation is being carried out in detail for each well-defined geographic section, and for each tribe or tribal group separately, from the earliest period to the present, with careful sifting of authorities and consideration of Indian habits of living. No such detailed and extended study of the subject has ever before been attempted, and the result must prove of interest and importance. The usual share of attention was given also throughout the year to the preparation and proof reading of various articles for the Handbook of the Indians and to routine correspondence. On request of the Mississippi Valley Historical Association, Mr. Mooney, together with Doctor Swanton, attended the meeting of that body at St. Louis, June 17–19, as representatives of the bureau, and presented papers on the ethnology of the central region.

During the year Dr. John R. Swanton, ethnologist, was engaged as follows: The months of October, November, and December, 1908, were spent in Oklahoma, Texas, and Louisiana. In Oklahoma the Natchez linguistic material collected by Gallatin, Pike, Brinton, and Gatschet was gone over with one of the four surviving speakers of the Natchez language, and about fifty pages of text were recorded. In Texas the Alibamu Indians were visited in an endeavor, partially successful, to determine the relationship of the Pascagoula tribe, formerly resident near them. In Louisiana the linguistic material collected by Gatschet and Duralde was gone over with some of the surviving Attacapa, Chitimacha, and Tunica. On the way to Washington Doctor Swanton visited Columbia, S. C., to examine the early archives of that State. The most important result of the expedition, however, was the discovery at Marksville, La., of a woman who remembers a large amount of the Ofo language formerly spoken on Yazoo River. As large a vocabulary of this language as possible was recorded.

In the office Doctor Swanton completed the proof reading of his work "Tlingit myths and texts," which was ready for the press at the close of the year. He completed also a bulletin on "The Indian tribes of the lower Mississippi Valley and northern coast of the Gulf of Mexico," and read proofs of the same. Additional work was accomplished as follows: The editing of the late J. O. Dorsey's material on the Biloxi language (in press), and the proof reading of the same; the copying of texts collected during the field expedition above referred to, and incorporating the linguistic material then obtained with the material previously collected in the Natchez, Attacapa, Chitimacha, and Tunica languages, and the copying on cards of the Ofo vocabulary; the reading of

galley proofs of sketches of the grammar of the Haida and the Tlingit for the Handbook of Indian Languages; assistance rendered Doctor Thomas in preparing for publication his bulletin on the languages of Mexico and Central America, and work incidental to the preparation for publication of Byington's Choctaw Dictionary (in press).

Mr. J. N. B. Hewitt, ethnologist, was occupied in the office during the entire year. For a large portion of the time he was engaged in amending and transcribing the Onondaga text which, with a long supplement, is to form Part II of his Iroquoian Cosmology, and in supplying an interlinear rendering and a free translation of the text. From his researches in connection with the preparation of articles for the Handbook of the American Indians he arrived at facts which greatly modify hitherto accepted views regarding the location and interrelations of the tribes around lakes Huron and Michigan. In this connection he pursued extended studies of the early history of the Potawatomi, Mascoutens, Kickapoo, Sauk, Foxes, Miami, and the "Nation de la Fourche," or "Tribe of the Fork," in an effort to identify these tribes with those known to the early Hurons by names which occur in the writings of Champlain, Sagard, and the Jesuit Fathers. The expulsion of the Potawatomi, Sauk, Foxes, and the Tribe of the Fork from their earliest known habitat in Michigan by the Neutrals and their Ottawa allies—not by the Iroquois, as commonly asserted—was determined, and the most probable course of their retreat fixed. Similar research was conducted among early records to determine as far as possible the identity of the tribes whose names are recorded on the Dutch "Carte Figurative" of 1614, which represents them as living along the middle and upper Susquehanna River and its western affluents. As these names were erroneously identified as Spanish in origin, and as such adopted without question, much confusion and many inaccuracies have arisen in recent historical works.

Mr. Hewitt continued the collection and elaboration of linguistic data for the sketch of Iroquois grammar as exemplified in the Onondaga and the Mohawk, with parallel illustrative examples from the Seneca, Cayuga, and Tuscarora. He also partially rewrote the articles "Seneca" and "Sauk" for the Handbook of American Indians, and endeavored, so far as was feasible, to incorporate in the remaining galley proofs of this work the results of his later researches. Mr. Hewitt was also called on to prepare data of an ethnologic nature for official correspondence.

At the beginning of the year Dr. J. Walter Fewkes, ethnologist, was in the field, having just completed the excavation and repair of the cliff ruin known as the "Spruce-tree House," in Mesa Verde National Park, Colorado. Before the close of July he returned to Washington and commenced the preparation of a report on this work, and undertook to complete the reports of unfinished researches of previous years. During his stay in Washington his services were enlisted in the building of a number of large models of the ruins for the Alaska-Yukon-Pacific Exposition at Seattle and in supervising the painting of panoramic views of the Cliff Palace in Mesa Verde National Park for the same purpose.

In June Doctor Fewkes again took up his work among the Mesa Verde ruins, and by the close of the year had made excellent progress in uncovering and reenforcing the crumbling walls of Cliff Palace, the greatest of the ancient ruins of its kind in the arid country.

The funds for the actual work of excavation and repair of these ruins were furnished by the Department of the Interior, which has control of the park. Being the essential feature of the park, it is most fortunate that these important and interesting ruins are now receiving adequate care and protection,

since in recent years the progress of destructive agencies, especially the activities of relic hunters, has been very rapid.

SPECIAL RESEARCHES.

As in former years, a number of collaborators were engaged in conducting researches of a special nature in various fields. Dr. Franz Boas, honorary philologist of the bureau, continued his labors on the Handbook of Languages, assisted by a number of students. Prominent among these is Dr. Leo J. Frachtenberg, who at the close of the year was engaged in studying the language of the Siletz tribe on its reservation in Oregon. Volume I of the Handbook of Languages is now in press, and the work of Doctor Boas for the year included the proof reading of this volume as well as the preparation of the text of Volume II.

Miss Frances Densmore continued her researches relating to the music of the Chippewa, and a paper dealing with this subject was submitted for publication as Bulletin 45. A number of valuable phonographic records were obtained.

Mr. J. P. Dunn, who was assigned the linguistic work among the western Algonquian tribes left unfinished by the late Doctor Gatschet, continued the study of the Miami language among tribal remnants in Indiana and Oklahoma, and submitted a number of preliminary papers.

COLLECTIONS.

The collections acquired by the bureau and transferred to the National Museum during the year comprise fifteen accessions, the more important being as follows:

Collection of West Indian antiquities, purchased from C. W. Branch, St. Vincent, British West Indies.

Indian relics from Moosehead Lake, Maine, presented by Mr. J. D. McGuire.

Cache of flaked stone objects from Moosehead Lake, Maine, purchased from T. Wilson.

Collection of bones, pottery fragments, etc., obtained by Mr. J. D. McGuire and Dr. Aleš Hrdlička at Piscataway, Md.

Archeological objects collected by Dr. J. W. Fewkes, ethnologist, during the excavation and repair of Spruce-tree House in the Mesa Verde National Park, Colorado.

Pottery fragments from Coden, Ala.

Stone implements from Tiahuanaco, Bolivia, and an earthenware vessel from Nazco, Peru, collected by Mr. W. H. Holmes.

Fragments of earthenware of the variety known as "salt vessels," from the vicinity of Shawneetown, Ill., presented by Mr. R. Moore, of Equality, Ill.

Ethnologica of the Chitimacha Indians, collected by Dr. John R. Swanton.

PUBLICATIONS.

The editorial work remained in charge of Mr. J. G. Gurley, who for a short period had the assistance of Mr. Stanley Searles.

Work on the publications of the bureau during the fiscal year may be briefly summarized as follows: The proof reading of the Twenty-sixth Annual Report and of Bulletin 34 was completed, and these publications were issued. The Twenty-seventh Annual Report and Bulletins 39, 41, 42, 43, 46, and 47 were prepared for and submitted to the Government Printing Office. Of these at the close of the year Bulletin 42 was issued, while Bulletins 39 and 41, also Bulletin 38 (the proof reading of which occupied much time during the year), were substantially ready for the bindery. The Twenty-seventh Annual and Bulletin 43 were in galley form, and considerable progress had been made in the

composition of Bulletins 46 and 47. The preparation of nearly all the manuscript of Bulletin 40, Part I, was finished, and most of the volume was in type.

At the close of the year manuscripts duly approved for publication as bureau bulletins were on hand, as follows:

Bulletin 37 (partially edited). Antiquities of central and southeastern Missouri, by Gerard Fowke.

Bulletin 44 (partially edited). Linguistic families of Mexico and Central America, by Cyrus Thomas, assisted by John R. Swanton.

Bulletin 45. Chippewa music, by Frances Densmore.

The distribution of publications continued as in former years. The Twenty-sixth Annual Report was issued in July, and Bulletin 34 in December. During the year 1,676 copies each of the Twenty-sixth Annual Report and Bulletin 34 were sent to regular recipients, and 3,000 volumes and pamphlets were transmitted in response to special requests, presented largely by Members of Congress. The number of requests for the bureau's publications greatly exceeded those received during any previous year.

ILLUSTRATIONS.

The preparation of illustrations continued in charge of Mr. De Lancey Gill, with Mr. Henry Walther as assistant. Illustrative material for six bulletins and one annual report was completed during the year; of this material 498 illustrations were photographic prints and 77 were drawings. Proofs of the illustrations of three bulletins were examined and approved. Portrait negatives of 22 visiting Indian delegations to the number of 196 were made. The total output of the photographic laboratory was as follows: New negatives, 473; films exposed in the field and developed in the office, 454; photographic prints, 3,498.

LIBRARY.

The library continued in charge of Miss Ella Leary, librarian. During the year 1,459 volumes and about 700 pamphlets were received and catalogued, and about 2,000 serials, chiefly the publications of learned societies, were received and recorded. As the law now permits the binding of miscellaneous publications belonging to the library at the expense of the allotment for general printing and binding, it was found possible to bind a much larger number of volumes than in previous years, and thus to save many valuable works that were threatened with destruction. During the year 2,194 volumes were sent to the bindery, and of these all but about 500 had been received before the close of the fiscal year. In addition to the use of its own library, which is becoming more and more valuable through exchange and by limited purchase, it was found necessary to draw on the Library of Congress for the loan of 513 volumes. The library of the bureau now contains 15,511 volumes, about 11,000 pamphlets, and several thousand unbound periodicals.

LINGUISTIC MANUSCRIPTS.

Mr. J. B. Clayton served as custodian of manuscripts. The bureau now possesses 1,678 manuscripts, mostly linguistic, 19 having been added during the year, mainly by purchase. All of these are of great value, and the number includes four by Miss Frances Densmore on Chippewa music, four by Mr. J. P. Dunn on Miami and Peoria linguistics, one each by Miss Alice C. Fletcher on the Omaha Indians, Mr. D. I. Bushnell on the Choctaw Indians of Louisiana, and Mr. Paul Radin on the Winnebago Indians. The card catalogue of manuscripts is complete to date.

Respectfully submitted.

W. H. Holmes, *Chief.*

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

APPENDIX III.

REPORT ON THE INTERNATIONAL EXCHANGES.

SIR: I have the honor to submit a report on the operations of the International Exchange Service during the fiscal year ending June 30, 1909.

The most noteworthy event in connection with the service during the year was the passage of the following resolution:

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That for the purpose of more fully carrying into effect the provisions of the convention concluded at Brussels on March fifteenth, eighteen hundred and eighty-six, and proclaimed by the President on January fifteenth, eighteen hundred and eighty-nine, the Public Printer is hereby authorized and directed to supply to the Library of Congress such number as may be required, not exceeding one hundred copies, of the daily issue of the Congressional Record 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, such documents, when received, to be deposited in the Library of Congress. (Approved March 4, 1909.)

Though the Smithsonian Institution has endeavored on previous occasions to have the Congress set aside a number of copies of the daily Congressional Record for exchange with foreign governments, it has only now been possible to have the matter favorably acted upon—twenty years having elapsed since the ratification by this Government of the Brussels convention for the immediate exchange of the official journal.

Upon the passage of the above resolution, the Congressional Record was at once sent to the following countries, the parliaments of which already transmit their official journal to the Library of Congress or have agreed to do so:

Australia.	Greece.	Portugal.
Austria.	Guatemala.	Roumania.
Belgium.	Honduras.	Russia.
Brazil.	Hungary.	Servia.
Canada.	Italy.	Spain.
Cuba.	New South Wales.	Switzerland.
France.	Prussia.	Uruguay.

The subject has been brought to the attention of other countries, and it is anticipated that during the coming year this proposed exchange, which is of so much importance to the members of the various national legislatures, will be entered into with a number of additional governments. It should be stated, in this connection, that the exchange here alluded to is separate and distinct from the exchange of official documents which has existed between the United States and other countries for a number of years. It is interparliamentary, and provides for the immediate transmission, direct by mail, of the official journal as soon as published.

That the Smithsonian system of exchanges is appreciated by governmental and scientific establishments and men of learning throughout the world is indicated by the large number of packages intrusted to its care for distribution.

During the past year 228,875 packages were handled, being an increase over the number for the preceding year of 25,777—the largest annual increase in the history of the service. The total weight of these packages was 476,169 pounds, a gain of 40,884 pounds.

The handling and recording of these parcels has taxed to the utmost the limited force engaged in conducting the service, and it has only been possible to keep abreast of the work by the diligent application of each employee.

The appropriation by Congress for the support of the service during 1909 was $32,200 (the same amount as was granted for the preceding year), and the sum collected on account of repayments was $3,777.33, making the total available resources for carrying on the system of international exchanges $35,977.33.

In the last report it was stated that the bureau had entered upon an active and definite campaign to secure reciprocal returns from abroad for the exchanges sent by this Government and its departments and bureaus. Though this work has added greatly to the correspondence of the office, it has been pursued with unabated vigor during the past year, and the results have been more than satisfactory. In some cases the returns have exceeded all expectations, hundreds of volumes having been received.

While the Japanese department of foreign affairs at Tokyo has, for a number of years, been good enough to distribute exchanges sent in its care for correspondents in Japan, the department has only recently signified its willingness to act in the full capacity of a bureau of exchanges—forwarding to the Smithsonian Institution consignments for distribution in the United States, as well as transmitting to their addresses in Japan exchanges sent in its care.

Reference was made in the last report to the fact that the Kingdom of Servia, which was one of the signatories to the Brussels convention of 1886, had not established a bureau of exchanges and that the good offices of the Department of State had been solicited in bringing the matter to the attention of the Servian officials. I am gratified to state that these efforts have resulted in the establishment of a bureau under the department of foreign affairs at Belgrade. Packages received for Servia in the future will therefore be sent to that department for distribution instead of being forwarded through the Smithsonian agent in Germany, as formerly. In the communication from Servia regarding this subject, it is stated that copies of all of the official, scientific, and literary publications will henceforth be forwarded to the United States, and a request is made for similar documents of this Government. Servia has accordingly been added to the list of those countries receiving full sets of official publications, the first shipment, consisting of 20 cases containing a collection of documents published since 1901, having been made on June 22, 1909.

In response to a request forwarded to the Library of Congress through the Department of State, Alsace-Lorraine was added to the list of foreign countries receiving partial sets of official documents of the United States. The first shipment, composed of 6 cases, was made under date of April 29, 1909.

Just before the close of the year a communication was received from the director of the Biblioteca Nacional at Buenos Aires, stating that by decree of his Government the Argentine bureau of exchanges had been withdrawn from the national library and connected with the comisión protectora de bibliotecas populares, Buenos Aires, which is under the direction of the department of public instruction. Consignments intended for that country will therefore be forwarded to the commission in the future. The Institution desires to record here its grateful acknowledgements for the services rendered in the past by the national library in the distribution of exchanges in the Argentine Republic.

In spite of the extra efforts put forth by this bureau in making shipments to all countries at least once a month—in some instances, two, three, and even

four times a month—complaints regarding delay in the delivery of packages to addresses in other countries have been received by the Institution. These delays, as a rule, occur in the various foreign exchange bureaus after consignments have passed beyond the control of the Institution. An improvement in the service in this respect can therefore be brought about only by the societies and individuals in other countries themselves taking the matter up directly with their own governments. Whenever such complaints have been received this course has been suggested.

So far as reported to this office, the service has not suffered the loss of any of its consignments during the past year. When it is considered that nearly 2,000 boxes were shipped to every quarter of the globe, this statement is worthy of note.

INTERCHANGE OF PUBLICATIONS BETWEEN THE UNITED STATES AND OTHER COUNTRIES.

The statement which follows shows in detail the number of packages received for transmission through the International Exchange Service during the year ending June 30, 1909:

Country.	Packages.		Country.	Packages.	
	For.	From.		For.	From.
Algeria	146	68	Dominica	43	....
Angola	3	....	Dutch Guiana	33	....
Antigua	46	....	Ecuador	247	31
Arabia	29	....	Egypt	369	282
Argentina	3,378	464	Falkland Islands	5	....
Austria-Hungary	8,005	2,909	Fiji Islands	38	....
Azores	32	....	France	13,074	5,969
Bahamas	33	....	French Cochin China	41	7
Barbadoes	110	....	French Guiana	3	....
Beira	12	....	German East Africa	22	....
Belgium	4,535	2,753	Germany	24,821	8,763
Bermudas	79	....	Gibraltar	4	2
Billiton	2	....	Gold Coast	7	....
Bismarck Archipelago	1	....	Grenada	7	....
Bolivia	180	....	Great Britain and Ireland	22,608	8,427
Borneo	6	....	Greece	1,548	3
Brazil	2,713	486	Greenland	8	....
British America	7,306	446	Guadeloupe	2	....
British Burma	47	2	Guatemala	384	....
British Central Africa	1	....	Haiti	1,242	....
British East Africa	4	....	Hawaiian Islands	46	....
British Guiana	84	....	Honduras	318	....
British Honduras	64	....	Hongkong	188	1
Bulgaria	215	131	Iceland	60	37
Canary Islands	18	....	India	2,710	176
Cape Colony	1,663	22	Italy	7,458	1,352
Cape Verde Islands	1	....	Jamaica	261	68
Ceylon	263	....	Japan	3,244	1,646
Chile	2,461	2,450	Java	220	128
China	1,088	65	Kongo Free State	2	....
Colombia	1,348	1	Korea	66	....
Costa Rica	1,672	4	Lagos	2	....
Cuba	1,544	265	Liberia	527	1
Curaçao	11	....	Lourenço Marquez	122	....
Cyprus	6	....	Luxemburg	84	41
Denmark	2,022	1,015	Macao	1	....

Country.	Packages.		Country.	Packages.	
	For.	From.		For.	From.
Madagascar	30		St. Kitts	14	
Madeira	8		St. Lucia	12	
Malaya	6		St. Martin	12	
Malta	128	1	St. Pierre and Miquelon	14	
Martinique	14		St. Thomas	17	
Mauritius	74		St. Vincent	4	
Mexico	1,763	257	Salvador	186	83
Montenegro	105		Samoa	17	
Montserrat	2		Santo Domingo	25	
Morocco	15		Sarawak	3	
Natal	248	16	Senegal	6	
Netherlands	3,226	1,517	Servia	735	1
Nevis	3		Siam	1,193	76
Newfoundland	152	39	Sierra Leone	24	
New Hebrides	13		Society Islands	20	
New South Wales	2,955	462	South Australia	1,605	439
New Zealand	1,880	243	Spain	2,599	185
Nicaragua	230	1	Straits Settlements	224	4
Norfolk Islands	13		Sudan	34	1
Norway	2,670	522	Sumatra	6	
Orange River Colony	129	1	Sweden	8,366	50
Panama	190		Switzerland	4,348	1,540
Paraguay	170	2	Tasmania	1,321	11
Persia	45		Transvaal	1,411	10
Peru	1,562	761	Trinidad	127	
Philippine Islands	199		Tunis	39	8
Porto Rico	27		Turkey	1,556	
Portugal	1,800	2	Turks Islands	20	
Portuguese West Africa	3		United States	52,524	180,292
Queensland	1,589	261	Uruguay	1,965	867
Reunion	27		Venezuela	1,289	2
Rhodesia	36		Victoria	3,329	208
Roumania	536	12	Western Australia	1,463	561
Russia	5,339	2,435	Zanzibar	17	
St. Croix	4				
St. Helena	8		Total	228,875	228,875

During the year there were sent abroad 1,963 boxes (an increase over 1908 of 54 boxes), of which 236 contained complete sets of United States Government documents for authorized depositories and 1,727 were filled with departmental and other publications for depositories of partial sets and for distribution to miscellaneous correspondents.

EXCHANGE OF GOVERNMENT DOCUMENTS.

The number of packages sent abroad through the International Exchange Service by United States Government establishments during the year was 122,340, an increase over the number forwarded during the preceding twelve months of 19,646; while 20,216 packages were received in exchange, an increase of 3,363. This disparity between the number of packages received and those sent may be accounted for largely by the fact that many returns for the publications forwarded abroad are not made through the exchange service, but are sent to their destinations direct by mail. This difference is further due to the

practice of sending consignments to the Library of Congress intact, in many cases a whole box of publications being entered on the records of this office as one package.

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENT 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 55 full sets of United States official publications and 33 partial sets—Servia having been added during the year to the list of countries receiving full sets and Alsace-Lorraine to the list of those receiving partial sets, the details concerning which will be found above. The recipients of full and partial sets are as follows:

DEPOSITORIES OF FULL SETS.

Argentina: Ministerio de Relaciones Exteriores, Buenos Aires.
Argentina: Biblioteca de la Universidad Nacional de La Plata.
Australia: Library of the Commonwealth Parliament, Melbourne.
Austria: K. K. Statistische Central-Commission, Vienna.
Baden: Universitäts-Bibliothek, Freiburg.
Bavaria: Königliche Hof- und Staats-Bibliothek, Munich.
Belgium: Bibliothèque Royale, Brussels.
Brazil: Bibliotheca Nacional, Rio de Janeiro.
Canada: Parliamentary Library, Ottawa.
Cape Colony: Government Stationery Department, Cape Town.
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 de Publicaciones, San José.
Cuba: Department of State, Habana.
Denmark: Kongelige Bibliotheket, Copenhagen.
England: British Museum, London.
England: London School of Economics and Political Science, London.
France: Bibliothèque Nationale, Paris.
France: Préfecture de la Seine, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Greece: Bibliothèque Nationale, Athens.
Haiti: Secrétairerie d'État des Relations Extérieures, Port au Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Home Department, Government of India, Calcutta.
Ireland: National Library of Ireland, Dublin.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Department of Foreign Affairs, Tokyo.
Manitoba: Provincial Library, Winnipeg.
Mexico: Instituto Bibliográfico, Biblioteca Nacional, Mexico.
Netherlands: Library of the States General, The Hague.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: General Assembly Library, Wellington.
Norway: Storthingets Bibliothek, Christiania.
Ontario: Legislative Library, Toronto.
Peru: Biblioteca Nacional, Lima.
Portugal: Bibliotheca Nacional, Lisbon.

Prussia: Königliche Bibliothek, Berlin.
Quebec: Legislative Library, Quebec.
Queensland: Parliamentary Library, Brisbane.
Russia: Imperial Public Library, St. Petersburg.
Saxony: Königliche Oeffentliche Bibliothek, Dresden.
Servia: Ministère des Affaires Etrangères, Belgrade.
South Australia: Parliamentary Library, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instrucción Pública y Bellas Artes, Madrid.
Sweden: Kungliga Biblioteket, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Parliamentary Library, Hobart.
Transvaal: Government Library, Pretoria.
Turkey: Department of Public Instruction, Constantinople.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Caràcas.
Victoria: Public Library, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Württemberg: Königliche Landesbibliothek, Stuttgart.

DEPOSITORIES OF PARTIAL SETS.

Alberta: Legislative Library, Edmonton.
Alsace-Lorraine: K. Ministerium für Elsass-Lothringen, Strassburg.
Bolivia: Ministerio de Colonización y Agricultura, La Paz.
British Columbia: Legislative Library, Victoria.
Bremen: Kommission für Reichs- und Auswärtige Angelegenheiten.
Bulgaria: Minister of Foreign Affairs, Sofia.
Ceylon: United States Consul, Colombo.
Ecuador: Biblioteca Nacional, Quito.
Egypt: Bibliothèque Khédiviale, Cairo.
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.
Malta: Lieutenant-Governor, Valetta.
Montenegro: Ministère Princier des Affaires Étrangères, Cetinje.
Natal: Colonial Governor, Pietermaritzburg.
Newfoundland: Colonial Secretary, St. John.
New Brunswick: Legislative Library, St. John.
Nicaragua: Superintendente de Archivos Nacionales, Managua.
Northwest Territories: Government Library, Regina.
Nova Scotia: Legislative Library, Halifax.
Orange River Colony: Government Library, Bloemfontein.
Panama: Secretaria de Relaciones Exteriores, Panama.
Prince Edward Island: Legislative Library, Charlottetown.
Paraguay: Oficina General de Informaciones y Canjes y Commisaria General de Inmigracion, Asuncion.
Roumania: Academia Romana, Bucarest.
Salvador: Ministerio de Relaciones Exteriores, San Salvador.

Straits Settlements: Colonial Secretary, Singapore.
Siam: Department of Foreign Affairs, Bangkok.
Vienna: Bürgermeister der Haupt- und Residenz-Stadt.

CORRESPONDENTS.

The record of exchange correspondents at the close of the year contained 62,630 addresses, being an increase of 2,507 over the preceding year. A table showing the number of correspondents in each country at the close of 1907 will be found in the report for that year.

LIST OF BUREAUS OR AGENCIES THROUGH WHICH EXCHANGES ARE TRANSMITTED.

Following is a list of bureaus or agencies abroad through which the distribution of exchanges is effected. Those in the larger and many in the smaller countries forward to the Smithsonian Institution in return contributions for distribution in the United States:

Algeria, via France.
Angola, via Portugal.
Argentina: Presidente de la Comisión Protectora de Bibliotecas Populares, Ministerio de Instrucción Pública, Buenos Aires.
Austria: K. K. Statistische Central-Commission, Vienna.
Azores, via Portugal.
Barbados: Imperial Department of Agriculture, Bridgetown.
Belgium: Service Belge des Échanges Internationaux, Brussels.
Bermuda. (Sent by mail.)
Bolivia: Oficina Nacional de Inmigración, Estadística y Propaganda Geográfica, La Paz.
Brazil: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
British Colonies: Crown Agents for the Colonies, London.[a]
British Guiana: Royal Agricultural and Commercial Society, Georgetown.
British Honduras: Colonial Secretary, Belize.
Bulgaria: Institutions et Bibliothèque Scientifiques de S. A. R. le Prince de Bulgarie, Sofia.
Canada. (Sent by mail.)
Canary Islands, via Spain.
Cape Colony: Government Stationery Department, Cape Town.
Chile: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
China: Zi-ka-wei Observatory, Shanghai.
Colombia: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogota.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Cuba. (Sent by mail.)
Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
Ecuador: Ministerio de Relaciones Exteriores, Quito.
Egypt: Director-General, Survey Department, Giza (Mudiria).
France: Service Français des Échanges Internationaux, Paris.
Friendly Islands. (Sent by mail.)
Germany: Karl W. Hiersemann, Königsstrasse 29, Leipzig.

[a] This method is employed for communicating with several of the British colonies with which no medium is available for forwarding exchanges direct.

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 Guatemala, Guatemala.
Guinea, via Portugal.
Haiti: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
Honduras: Biblioteca Nacional, Tegucigalpa.
Hungary: Dr. Julius Pikler, Municipal Office of Statistics, City Hall, 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: Department of Foreign Affairs, Tokyo.
Java, via Netherlands.
Korea. (Shipments temporarily suspended.)
Liberia: Department of State, Monrovia.
Lourenço Marquez: Government Library, Lourenço Marquez.
Luxemburg, via Germany.
Madagascar, via France.
Madeira, via Portugal.
Mexico. (Sent by mail.)
Montenegro: Ministère Princier des Affaires Etrangères, Cetinje.
Mozambique, via Portugal.
Natal: Agent-General for Natal, London.
Netherlands: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.
Newfoundland. (Sent by mail.)
New Guinea, via Netherlands.
New Hebrides. (Sent by mail.)
New South Wales: Board for International Exchanges, Public Library, Sydney.
New Zealand: Dominion Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.
Paraguay: 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, Bibliotheca Nacional, Lisbon.
Queensland: Board of Exchanges, Brisbane.
Roumania, via Germany.
Russia: Commission Russe des Echanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
Saint Christopher. (Sent by mail.)
Salvador: Ministerio de Relaciones Exteriores, San Salvador.
Santo Domingo. (Sent by mail.)
Servia: Department of Foreign Affairs, Belgrade.
Siam: Department of Foreign Affairs, Bangkok.
South Australia: Public Library of South Australia, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instrucción Pública y Bellas Artes, Madrid.
Sumatra, via Netherlands.

Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service des Echanges Internationaux, Bibliothèque Fédérale Centrale, Bern.
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Tasmania: Royal Society of Tasmania, Hobart.
Transvaal: Government Library, Pretoria.
Trinidad: Victoria Institute, Port of Spain.
Tunis, via France.
Turkey: American Board of Commissioners for Foreign Missions, Boston.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional, Montevideo.
Venezuela: Biblioteca Nacional, Caracas.
Victoria: Public Library of Victoria, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Zanzibar. (Sent by mail.)

Dr. Cyrus Adler resigned his position as assistant secretary in charge of library and exchanges on September 30, 1908.

Respectfully submitted.

F. V. Berry,
Chief Clerk, International Exchange Service.

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

Appendix IV.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

Sir: I have the honor to submit the following report on the condition and operations of the National Zoological Park for the fiscal year ending June 30, 1909.

RESOURCES.

The entire support of the park was provided for by an item in the sundry civil act approved May 27, 1908, appropriating $95,000 for general purposes, including the purchase, transportation, care and maintenance of animals; the care and improvement of grounds; the construction and repair of all buildings, inclosures, roads, walks, and bridges. A sum of equal amount has been appropriated annually for several years past. The considerable increase in the prices of the necessary provisions and labor has made it increasingly difficult to do anything toward developing the park to the standard that such institutions usually attain at the capitals of great nations. The expenses of maintenance alone amounted to about $85,000, so it will be seen that there was but little margin left for additional works.

It should be remembered that at the inception of the park the funds provided for buildings and improvements were entirely inadequate for its proper equipment and that consequently the management was forced to construct cheap, temporary shelters, roads, walks, and inclosures. These have now arrived at about their limit of usefulness and do not admit of further economical repair. It is not for the interest of the Government to continue to erect structures of this class, and it would certainly be advantageous to have sufficient appropriations to replace them with satisfactory permanent buildings.

BUILDINGS AND INCLOSURES.

The principal improvements made during the year were the completion of a series of bear yards and the construction of a series of 10 new yards for wolves and foxes.

Bear yards.—Six yards of the series had been built up to the beginning of the year. During 1908–9 the terminal yard, 42 feet wide and 26 feet deep, at the east end of the series, was built, and the north end of the series was completed by the construction of three yards from 32 to 36 feet deep and 32, 24, and 40 feet wide, respectively. All of the yards have floors of rock and concrete except the large one at the north end, where most of the area has been left in the original hard clay over which is spread a thick layer of sand. A concrete walk 12 feet wide was constructed in front of all the new yards, and a trellis of steel bars was built over the walk and in front of the cages, over which vines will be trained, to afford shelter until trees are large enough to give sufficient shade. The cost of the work on the bear yards during the year was about $6,000. The steep bank adjoining the yards was graded and a macadam walk with stone steps was built to furnish a convenient approach.

The completion of the series of yards made it possible to transfer all of the bears from the temporary wooden cages that they have been occupying to their permanent quarters. The cages were then removed, and the area which they had occupied was graded and planted.

Wolf and fox yards.—Since the occupation of the park the wolves and foxes have been kept in temporary yards near the lion house. This has been unsatisfactory in several respects, the yards being of an irregular and unsightly character, rather obtrusive, and not as secure as desirable. A better site for them was selected at the foot of the steep acclivity, where the stream from the beaver valley empties into Rock Creek. There were constructed here a series of ten yards having a total frontage of 230 feet, with a depth varying from 16 to 36 feet. The fence was constructed of heavy wire netting with square mesh, on steel posts, and has a height of 6 feet 6 inches. A retiring den for each yard was excavated in the hill at the rear of the cages and arranged with a door outside the inclosure for the keeper's use. These cages, as well as the bear yards, were completed and occupied in the late autumn of 1908.

An entirely pleasant feature of this site is its secluded, woodland character, enhanced by the little stream flowing down over rocks to the creek. Considerable planting was done here, using the material indigenous to the neighborhood in order to retain as far as possible the original character of the forest.

The cost of this series of yards was about $2,600.

ROADS AND WALKS.

Lack of funds prevented the continued prosecution of the repair of roads and walks in the park, only such work being done as was absolutely necessary for the public safety. The Adams Mill road and part of the road along the banks of the creek were treated with a coal-tar product known as "terracollo," to obtain freedom from dust and prevent the washing of the roadbed during heavy rains. This was fairly successful. Some of the walks were treated with another coal-tar preparation known as "tarvia." This, too, proved an excellent preventive of dust and abrasion.

The shaded walk and stairway from the Adams Mill entrance to the lower levels of the park was completed and a small rest house and shelter built at the upper end. It is believed that this walk can be made one of the most attractive features of the park. In spite of the careful watch, some difficulty is experienced in preventing the uprooting and carrying away by visitors of the ferns and other specimens that have been planted in profusion along its sides. The amount expended on the walk during the present year was about $700, while the rustic shelter, 20 by 25 feet, cost approximately $400.

ACCESSIONS AND LOSSES.

Gifts included 5 chamois from Bernese Oberland, received through the Department of the Interior from the Swiss Government as a gift to the United States Government; 3 young Alaskan brown bears from Mr. George Mixter, 2d, of Boston, Mass.; 3 Barbados woolless sheep, from the United States Department of Agriculture; a large grizzly bear and female black bear with 2 cubs were received from Lieut. Gen. S. B. M. Young, superintendent Yellowstone National Park; also 2 mule deer and 2 prong-horn antelopes from Maj. H. C Benson, who succeeded General Young at the Yellowstone Park. Ten beavers were also obtained in the Yellowstone Park through the cooperation of General Young.

A lioness, a pair of Sarus cranes, 2 European flamingoes, and a fishing cat were received in exchange for surplus animals.

Purchases included a pair of Rocky Mountain sheep, an Arabian camel, a reindeer from Alaska, a cassowary, 2 South American condors, 2 jabirus, etc.

Births numbered 110, and included a Brazilian tapir, 3 American bison, a yak, 4 tigers, 2 black bears, a llama, 6 Barbary sheep, 17 deer of 6 species, kangaroos, armadillos, etc., also various birds.

The deaths included the Philippine water buffalo, which died from peritonitis resulting from the bursting of an abscess of the rumen; a young orang, which died from leukemia; and a leopard, which, also, died from peritonitis. A Rocky Mountain goat, which was deposited in the park, died thirty-seven days after its receipt, from tuberculosis, which evidently had been contracted while it was kept in confinement near the place of capture in British Columbia. An European flamingo, a crowned pigeon, and several other birds died from aspergillosis, and five storks from cercomonad roup.

One hundred and thirty-eight autopsies were made by the pathologists of the Bureau of Animal Industry and two by the Laboratory of Hygiene, which gave the following results:

Cause of death, 1908–9.

Pneumonia	20	Hydrophilosis	1
Tuberculosis	16	Subcutaneous acariasis	1
Pulmonary congestion	8	Uncinariasis	2
Aspergillosis	6	Proteus baçillosis	3
Enteritis (and gastro-enteritis)	20	Echinococcosis	1
Nephritis	6	Porocephalus infestation	2
Necrosis of liver	2	Rabies	3
Hepatitis	1	Myofibroma	1
Parenchymatous degeneration of liver	1	Goiter	1
Fatty degeneration of liver	1	Osteomalacia	2
Peritonitis	5	Impaction of bowel	3
Pericarditis	2	Impaction of crop	1
Fatty degeneration of heart and liver	1	Urinary concretions in cloaca	1
Valvular obstruction of heart	1	Broken egg in cloaca	1
Septicemia	1	Starvation	5
Leukemia	1	Starvation resulting from cystic tumor in throat	1
Cercomonad roup	4	Stillborn	4
Infectious entero-hepatitis	1	Accident	7
Coccidial typhlitis	1	No cause found	2

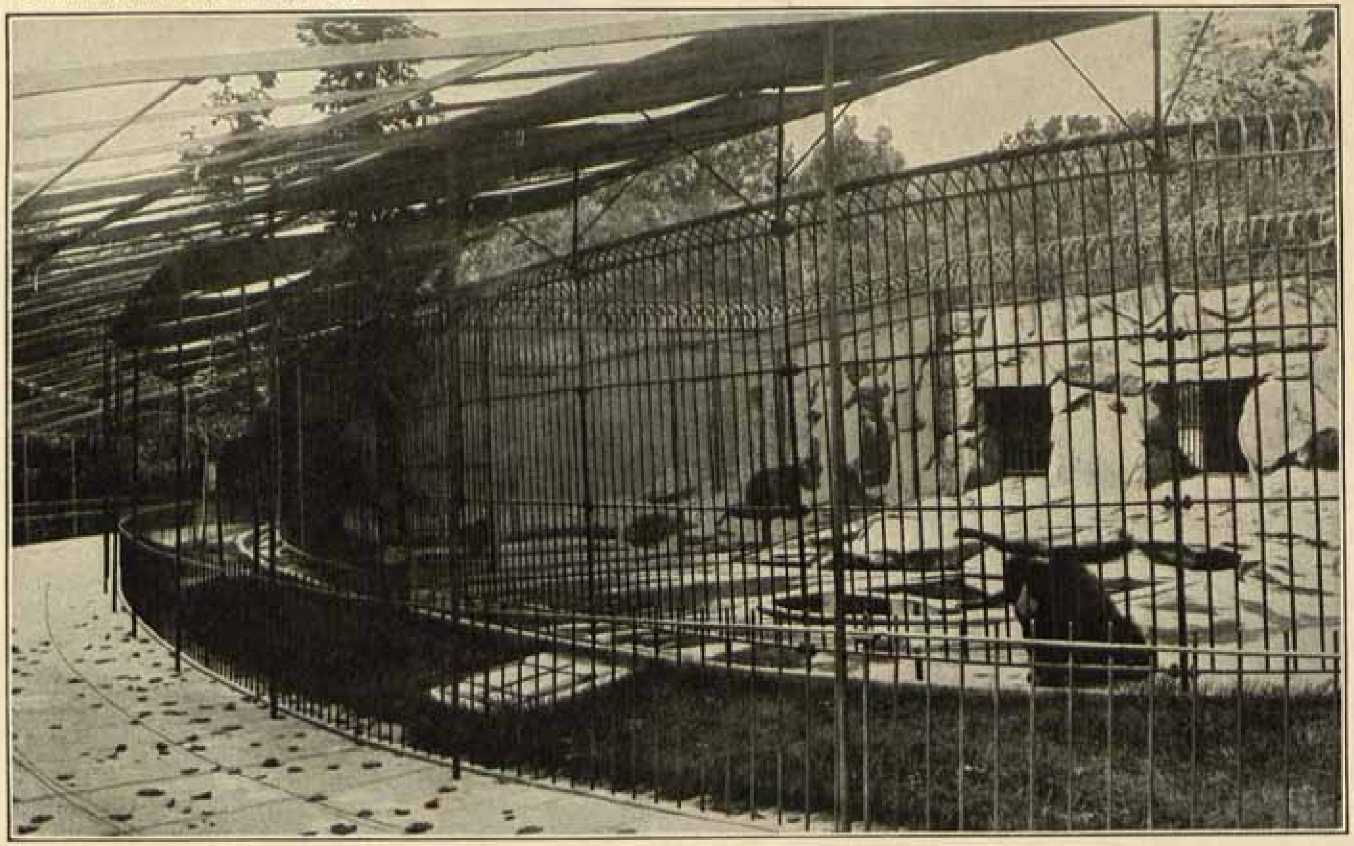
VISITORS.

The number of visitors to the park during the year was 564,639, a daily average of about 1,547. The largest number in any month was 127,635, in April, 1909, a daily average of 4,254.

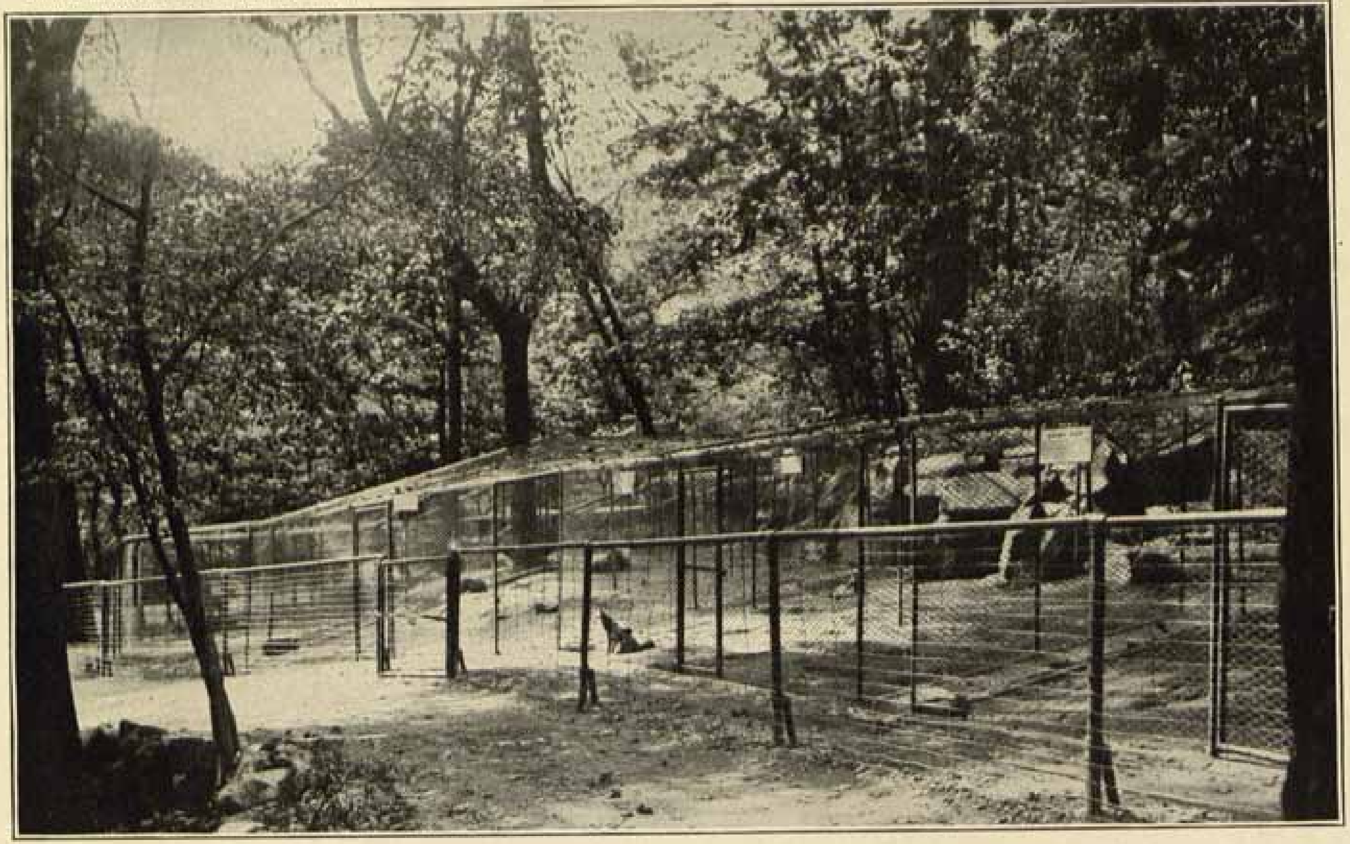
During the year there visited the park 148 schools, Sunday schools, classes, etc., with 4,611 pupils, a monthly average of 384 pupils. While most of them were from the city and the immediate vicinity, 25 of the schools were from neighboring States, and classes came from Lowell, Warren, Boston, Fall River, and Dover, Mass.; Portland, Augusta, and Auburn, Me.; and Wallingford, Vt.

NEEDS OF THE PARK.

Aquarium.—The present building was originally a hay shed of ordinary Virginia pine lumber. It is now in a most dilapidated condition, the foundation



BEAR YARDS IN NATIONAL ZOOLOGICAL PARK.



WOLF AND FOX YARDS IN NATIONAL ZOOLOGICAL PARK.

having sunk so much as to crack the glass of the fish tanks, thus causing them to leak. It will be necessary to close this building temporarily unless some means are found for totally reconstructing it. An exhibit of fish and other marine animals is one of the most attractive that can be given in a zoological collection, and it is very desirable that it should be maintained.

General aviary.—The need for a structure of this character is evident to any intelligent visitor to the park. Only a part of the collection can now be exhibited to the public because of lack of room. A number of outdoor shelters and cages should also be provided for the exhibition of hardy birds.

Inclosure for sea lions and seals.—A proper pool for these animals, with suitable shelter, should be built as soon as possible. A good site for such an exhibit would be just above the wolf and fox dens in the beaver valley.

Antelope house.—The inadequacy of this building has been mentioned in previous reports. If any considerable additions of ruminant animals are received at the park, it will be necessary to enlarge it.

Office building.—It is greatly to the disadvantage of the park to have the superintendent's office at so great a distance from the general working force. A suitable structure should be built near the center of activity.

Restaurant and public comfort.—The park is becoming more and more a place of frequent resort for the public, as is shown by the number of visitors. The present arrangements are totally inadequate. A good restaurant building is urgently needed. Shelters and addition public comfort quarters for visitors are also wanted. At present, whenever a quick rainstorm occurs, many visitors are unable to get proper shelter.

Roads and walks.—It is highly desirable that the construction of roads and walks, which was commenced under the appropriation of $15,000, made in 1907, should now be continued. The general appropriation for the park is insufficient for this purpose.

STATEMENT OF THE COLLECTION.

Accessions during the year:

Presented	124
Received in exchange	12
Purchased	307
Deposited	9
Born and hatched in the National Zoological Park	110
Captured in Yellowstone National Park	14
Total	576

Presented.

Diamond rattlesnake, C. R. Kappone, Cairo, Ga	1
Rhesus monkey, F. N. Meyer, Department of Agriculture	2
Alligator, Mrs. G. F. Graham, jr	1
Common canary, William J. Myatt, Sharon Hill, Philadelphia, Pa	27
Chapman's curassow, C. H. Jones, Campeche, Mexico	1
Purplish guan, C. H. Jones, Campeche, Mexico	1
Barbados sheep, experiment station, United States Department of Agriculture	3
Alaska peninsula, brown bear, George Mixter, 2d, Boston, Mass	3
Common canary, R. L. Beard, 1013 H street NW., Washington, D. C	1
Unidentified bird, Wm. J. Myatt, Sharon Hill, Philadelphia, Pa	1
Chicken snake, E. T. Carrico, Stithton, Ky	1

Hog-nosed snake, E. T. Carrico, Stithton, Ky	1
Capuchin monkey, Miss M. Alexander, Moorefield, W. Va	1
Coyote, the President, Washington, D. C	1
Banded rattlesnake, Dr. Prentiss Wilson, 2024 O street NW., Washington, D. C	1
Blacksnake, Mrs. Hall, 2428 Wisconsin avenue, Washington, D. C	1
Spotted lynx, Mr. Hunt, superintendent registry division, city post-office	1
Black bear, the President, Washington, D. C	1
Cooper's hawk, Russel Meredith, 1219 Girard street, Washington, D. C	1
Hog-nosed snake, Capt. J. Walter Mitchell, the Evening Star, Washington, D. C	1
Gray fox, Miss M. P. Offterdinger, 330 A street NE., Washington, D. C	1
Lizard, D. J. Nicholson, Orlando, Fla	1
Diana monkey, Nikolai Sokoloff, 14 Park lane, Jamaica Plain, Boston, Mass	1
Sharp-shinned hawk, W. A. Sherman, Vienna, Va	1
English rabbit, Mrs. John R. McLean, Friendship, D. C	11
Common ferret, Mrs. John R. McLean, Friendship, D. C	1
Alligator, Miss Sarah Leon, 1133 Fourteenth street, Washington, D. C	1
Yellow-fronted amazon, E. A. Klages, Crafton, Pa	1
Rabbit, J. B. Henderson, jr., 1306 Euclid place, Washington, D. C	1
Brown capuchin monkey, Hon. S. B. Elkins, United States Senate	1
Pine snake, George V. Green, 304 Tenth street NW., Washington, D. C	2
Barn owl, Charles Ewald, Alexandria, Va	1
Mallard duck, Mrs. L. E. Johnson, 1007 L street NW., Washington, D. C	1
Red-tailed hawk, Jesse Hand, jr., Belleplain, N. J	1
Belgian hare, J. H. Fellows, 5504 Wisconsin avenue, Washington, D. C	1
American raven, J. K. P. Gates, Keokee, Va	1
Barn owl, Adrian Poole, Ashburn, Va	1
Barred owl, 1111 K street NW., Washington, D. C	1
Screech owl, W. S. Hinman, 2700 Thirteenth street NW., Washington, D. C	1
Bullfinch, attaché of the Austrian embassy, Washington, D. C	1
Common opossum, the President, Washington, D. C	3
Common opossum, W. L. McAtee, Department of Agriculture	1
Mule deer, Maj. H. C. Benson, superintendent Yellowstone National Park, Wyoming	2
Prong-horn antelope, Maj. H. C. Benson, superintendent Yellowstone National Park, Wyoming	2
Raccoon, Charles H. Smith, Piedmont, Va	1
Raccoon, F. J. Clark, Irvine, Pa	1
Common opossum, Pink Cherry Market Company, Atlanta, Ga	9
Alligator, Mr. Widderfield, 1217 Connecticut avenue NW., Washington, D. C	3
Yellow-fronted amazon, Richard Wood, 43 Quincy place, Washington, D. C	1
Common skunk, F. Johnson, Washington, D. C	1
Great horned owl, F. Johnson, Washington, D. C	2
Alligator, attaché of the Austrian embassy, Washington, D. C	1
Alligator, Harry Williams, 418 E street NE., Washington, D. C	1
Bald eagle, C. F. Brock, 53 I street NE., Washington, D. C	2
Chamois, Swiss Government	5
Common canary, George Hawkins, 2316 First street NW., Washington, D. C	1

Black snake, F. C. Harley, Washington, D. C.	1
Black muscovy duck, J. H. Holmead, 3531 Thirteenth street NW., Washington, D. C.	1
Alligator, John H. Knight, 1410 Chapin street NW., Washington, D. C.	1
Common canary, A. L. Brandon, 2130 G street, Washington, D. C.	1
Common goat, Louis Brandt, 400 New Jersey avenue NW., Washington, D. C.	1
Cougar, A. P. Proctor, New York City	1
	124

SUMMARY.

Animals on hand July 1, 1908	1,402
Accessions during the year	576
Total	1,978
Deduct loss (by exchange, death, and returning of animals)	562
On hand June 30, 1909	1,416

	Species.	Individuals.
Mammals	143	578
Birds	173	711
Reptiles	38	127
Total	354	1,416

Respectfully submitted.

Frank Baker, *Superintendent.*

Dr. Charles D. Walcott,

Secretary of the Smithsonian Institution.

APPENDIX V.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

SIR: During the past year the temporary wooden shelters used for observing on Mount Wilson, California, in 1905, 1906, and 1908 have been torn down and replaced by a structure of cement blocks. This was erected at a cost of $2,200 on a plot of ground 100 feet square in horizontal projection, leased for a term of ninety-five years by the Smithsonian Institution from the Mount Wilson Solar Observatory. The new observing shelter is L shaped in plan, 36 feet long, 27 feet wide, and with the two branches of the L 14 and 10 feet wide, respectively. Four tall piers are provided for the future erection of a tower over the south end of the structure. The proposed tower is intended for use as a vertical telescope in solar observations and also as a suitable station for making measurements of the brightness of the sky and clouds. Within the new building is a chamber of constant temperature in which is the spectro-bolometric outfit, and also a dark room for photographic work and a small office room. The site leased is on the edge of a preciptous ridge overlooking canyons about 1,000 feet deep on the east, south, and west. It is thoroughly isolated from disturbances caused by electric service, gas engines, or traffic, and seems to be peculiarly well adapted for the work in hand.

The personnel of the observatory has continued principally unchanged. Mr. L. B. Aldrich completed his temporary service as bolometric assistant on September 20, 1908. Dr. L. R. Ingersoll was engaged temporarily as bolometric assistant on Mount Wilson beginning June 21, 1909.

WORK OF THE YEAR.

1. *Work at Washington.*

Mr. Fowle has continued bolometric observations of the brightness of different parts of the sun's image whenever conditions favored. No measurements of the solar constant of radiation were attempted at Washington, as that branch of the work can seldom be done there successfully, on account of smoke and clouds.

A most interesting piece of experimental work on the transparency of air for the long-wave rays, such as the earth radiates, had been begun by Mr. Fowle early in 1908. Results have been obtained by him for the transmission of all rays between wave-lengths 1μ and 10μ, through a column of air 400 feet long, containing various known amounts of water vapor. Computation of the results from these experiments is so far advanced as to show their satisfactory quality. Many additional experiments with still longer columns of air and other amounts of water vapor, and extending as far down in the spectrum as wave-length 17μ, are in preparation.

The late Secretary Langley stated,[a] as a result of his Mount Whitney observations: "I consider that the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall

[a] Report of the Mount Whitney Expedition, p. 123.

to −200° C. if that atmosphere did not possess the quality of selective absorption." A little later his experimental results on the temperature of the moon led him to change this view, for he said:[a] "As between my observations and my inferences, I hold to the former; and since later and long-continued observations * * * show that the temperature of the sunward surface of the moon (which is certainly nearly airless) is almost certainly not greatly below zero (centigrade), I have been led to believe myself mistaken in one of my inferences drawn from former experiments." Precise knowledge of the selective absorption of our atmosphere for earth rays is still lacking, although two decades have elapsed since this was written, and contradictory views are still being expressed about this very important subject by able writers. It is hoped that Mr. Fowle's experiments will add much definite information, useful in the study of the dependence of the earth's temperature on radiation.

Computations of the results of Washington and Mount Wilson observations have gone on steadily, but it has not been possible to keep the reductions abreast with the numerous observations now being obtained. It has been considered desirable to make daily observations of the "solar constant of radiation" during the observing season at Mount Wilson, and the reduction of each day's observations requires several days of measurements and computations at Washington.

2. Work at Mount Wilson.

Spectro-bolometric measurements of the "solar constant of radiation" were continued by Mr. Abbot (with the assistance till September 20 of Mr. Aldrich) on every favorable day until about November 20, 1908. The expedition was renewed late in the following spring by Mr. Abbot, and observations begun on June 1, 1909. As in former years, evidences of a fluctuation of solar radiation were found in the results of the measurements of 1908 thus far obtained. Various improvements in the modes of observing have been made, especially in the bolometric measurements of the ultra-violent region of the spectrum, and also in pyrheliometry. A new and improved standard pyrheliometer was tried repeatedly on Mount Wilson. Its action is more satisfactory than the one used in 1906, and great confidence is felt in the results obtained with it. Apparently the results published on the provisional arbitrary scale of pyrheliometry employed in Volume II of the Annals are several per cent higher than they would be if expressed on the scale of the standard calory. On the other hand, the results of the year indicate that a larger allowance of increase should have been made for solar rays in the ultra-violet and extreme infra-red regions of the spectrum not observed in 1905 and 1906 by the bolometer, and this increase will probably nearly or quite compensate the change of scale in pyrheliometry, leaving the mean "solar constant" value very near to 2 calories per square centimeter per minute, as stated in Volume II of the Annals. Great efforts have been made this past year to carry the bolometric measurements much further in the ultra-violet. For this purpose a large quartz prism, a large ultra-violet glass prism, and two magnalium mirrors have been procured and are now in use on Mount Wilson, and daily observations are now carried as far as wave-length 0.335μ.

3. Mount Whitney Expeditions.

In August, 1908, with Director Campbell, of the Lick Observatory, Mr. Abbot spent about twenty-four hours on the summit of Mount Whitney (14,502 feet). This mountain, which was the objective point of the famous expedition of Mr. Langley in 1881, was recommended by him to be reserved by the Government

[a] The Temperature of the Moon, p. 193.

and used as the site for an observatory. The reservation was in fact made, but no observatory has been established there. Mr. Abbot carried with him to Mount Whitney a pyrheliometer and wet and dry thermometers, and made observations on the summit both in the afternoon and morning hours. Both he and Mr. Campbell were favorably impressed with the advantages of the place for observing, and with the relative convenience of ascending the mountain, considering its great altitude. Fine building stone, sand, and water were found at the summit. Messrs. Campbell and Abbot, therefore, recommended to the Secretary of the Smithsonian Institution that a grant from the Hodgkins fund should be made for the purpose of erecting on the summit of Mount Whitney a stone and steel house to shelter observers who might apply to the Institution for the use of the house to promote investigations in any branch of science. This recommendation was approved, and the house is now in course of construction (July, 1909).

It has been held by some astronomers that measurements of the "solar constant of radiation" by high and low sun observations from a single station at a low altitude, or even at the altitude of Mount Wilson, are subject to a great error by reason of the impossibility of correctly allowing for loss in our atmosphere. In order to ascertain if this objection is well founded, an expedition to Mount Whitney by Mr. Abbot is planned for August, 1909. He will carry a complete spectro-bolometric outfit, for which Mr. Kramer has constructed the mechanical parts in the shop of the Astrophysical Observatory at Washington. This apparatus will point directly at the sun, so as to dispense with reflections at a coelostat. A quartz prism and two magnalium mirrors constitute the sole optical parts of the spectroscope, as it will generally be used, but a glass prism and silvered mirrors will also be employed in the examination of the water vapor bands and of the infra-red spectrum. With the quartz and magnalium outfit it is expected to measure the energy of the spectrum from about wave-length 0.30μ in the ultra-violet to wave-length 4μ in the infra-red. Simultaneously with these "solar constant" measurements on Mount Whitney complete observations of the same kind will be made on Mount Wilson by Doctor Ingersoll, and if the results of the two shall agree it is thought that there will be left no ground for reasonable doubt of the accuracy of the method.

SUMMARY.

The principal work of the year comprises frequent spectro-bolometric examinations of the relative brightness of different parts of the sun's disk for rays of several different wave lengths; measurements of the transmission of long-wave rays, such as the earth emits, through very long columns of moist air; the steady continuation of the reduction of Mount Wilson and Washington observations; six months of almost daily observation on Mount Wilson for the determination of the variability of the sun; a preliminary observing expedition to the summit of Mount Whitney; and the complete preparation of apparatus and arrangements for a series of observations of the "solar constant" by the spectro-bolometric method, to be made simultaneously at Mount Wilson and Mount Whitney in August, 1909.

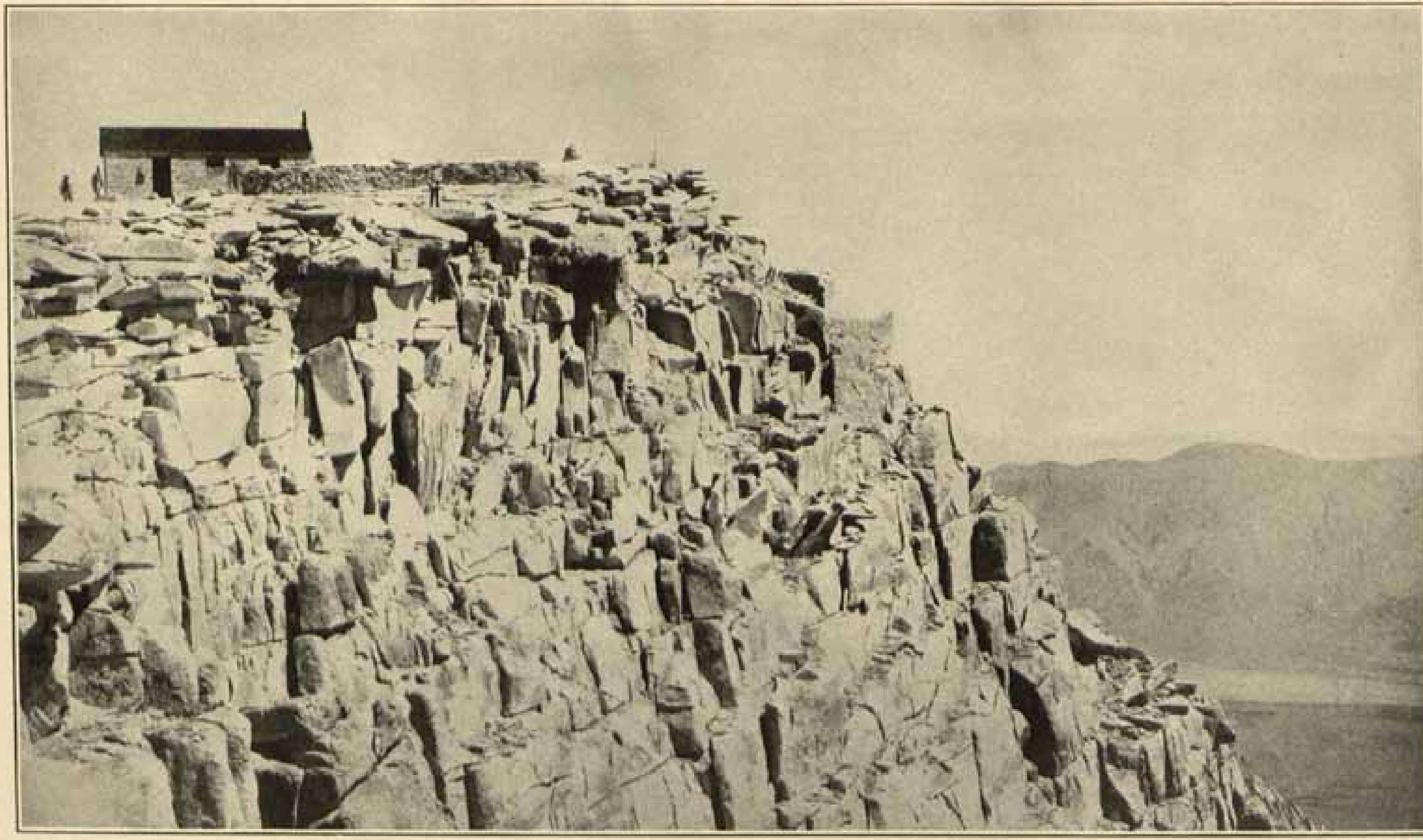
Respectfully submitted.

C. G. Abbot, *Director.*

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

SMITHSONIAN SHELTER FOR OBSERVERS ON MOUNT WHITNEY, CALIFORNIA. HEIGHT 14,502 FEET ABOVE SEA LEVEL.

SMITHSONIAN SHELTER FOR OBSERVERS ON MOUNT WHITNEY, CALIFORNIA.



SMITHSONIAN SHELTER FOR OBSERVERS ON MOUNT WHITNEY, CALIFORNIA.

MOUNT WHITNEY, CALIFORNIA. HEIGHT 14,502 FEET.

APPENDIX VI.

REPORT ON THE LIBRARY.

SIR: I have the honor to present the following report on the operations of the library of the Smithsonian Institution for the fiscal year ending June 30, 1909:

The retirement early last fall of Dr. Cyrus Adler, librarian of the Institution and later assistant secretary in charge of library and exchanges, in order to assume the presidency of the Dropsie College for Hebrew and Cognate Learning, of Philadelphia, Pa., was a serious loss to the library. His loyalty, his knowledge of library science at home and abroad, his love of books, and his intimate acquaintance with the workings of this library were invaluable not only to the Institution but to investigators at large.

The accessions recorded for the Smithsonian deposit, Library of Congress, numbered 1,623 volumes, 11,947 parts of volumes, 2,937 pamphlets, and 777 charts, making a total of 17,284 publications.

The accession numbers run from 488,289 to 495,195. These publications were sent to the Library of Congress as soon as received and entered, and in their transmission 166 boxes were required, which, it is estimated, contained the equivalent of 6,640 volumes, while the number of pieces sent, which includes parts of periodicals, pamphlets, and volumes, was 29,679. This does not include, however, about 3,883 parts of serial publications secured by exchange to complete sets transmitted separately.

The policy of sending to the Library of Congress public documents presented to the Smithsonian Institution, without stamping or entering, has been continued, and the number of publications given above does not include these, nor does it include other publications sent to the Library of Congress which are received through the International Exchanges.

The libraries of the Smithsonian office, of the Astrophysical Observatory, and the National Zoological Park have received 294 volumes and pamphlets and 1,690 parts of volumes and charts, making a total of 1,984, and a grand total, including the publications for the Smithsonian deposit, of 23,151.

The parts of serial publications entered on the card catalogue numbered 26,640, and 1,119 slips for completed volumes were made, together with 477 cards for new periodicals and annuals, which were added to the permanent record from the periodical recording desk.

Inaugural dissertations and academic publications were received from universities at the following places:

Basel.
Bern.
Bonn.
Breslau.
Dresden.
Erlangen.
Freiburg-im-Breisgau.
Giessen.
Halle-an-der-Saale.
Heidelberg.
Jena.
Kiel.
Königsberg.
Leipzig.
Lund.
Marburg.
New York.
Paris.
Philadelphia.
Rostock.
St. Petersburg.
Strassburg.
Warsaw.
Wurzberg.
Zürich.

Similar publications have been received from the technical high schools at—

Budapest.	Karlsruhe.	Prague.
Darmstadt.	Louvain.	Upsala.
Hannover.	Paris.	Wiesbaden.

In carrying out the plan to effect new exchanges and to secure missing parts to complete sets, 2,396 letters were written, resulting in about 477 periodicals being added to the lists and the receipt of about 3,883 parts lacking in the sets, which partially filled or entirely completed the various series of publications in the Smithsonian deposit. In writing for the missing parts of publications the library has had assistance from the International Exchanges of the Institution, but the results of these requests can not be definitely stated, as the replies from them were still coming in at the close of the year. In addition, the library has cooperated with the International Exchanges in sending out lists of government documents and serial publications of that class needed to complete the sets in the Library of Congress to the following: Argentine Republic, Austria-Hungary, Baden, Bavaria, Belgium, Bolivia, Bremen, Province of Buenos Aires, Colombia, Costa Rica, Cuba, Department of the Seine and city of Paris, France, Germany, Greece, Guatemala, Haiti, Free City of Hamburg, Grand Duchy of Hesse, Honduras, Italy, Jamaica, Japan, Malta, Mexico, Montenegro, Newfoundland, New Zealand, Nicaragua, Norway, Panama, Paraguay, Peru, Portugal, Prussia, Roumania, Russia, Sweden, Salvador, Saxony, city of Vienna, Uruguay, Wurttemberg.

A decided increase has been noted in the number of persons consulting the publications in the reading room, and in addition there were issued, for office use, 30 bound volumes of periodicals and 3,706 parts of scientific periodicals and popular magazines, making a total of 3,736. While the consultation has been chiefly by members of the staff, the various bureaus of the Government have availed themselves of the opportunity to use these publications and those in the sectional libraries of the Institution.

The mail receipts numbered 28,059 packages. The publications contained therein were stamped and distributed for entry from the mail desk. About 4,980 acknowledgments were made on the regular forms, which are in addition to those for publications received in response to the requests of the Institution for exchange.

The employees' library.—The books added numbered 19, and of these 18 were purchased, while 110 volumes of periodicals were bound. The number of books borrowed was 1,922, and the sending of a selected number of books from this library to the National Zoological Park and the Bureau of American Ethnology has been continued.

Art room.—The cataloguing of the collection of engravings in the art room received attention as time would allow, but there still remains a great deal to be done.

Bibliography of aeronautics.—The bibliography of aeronautical literature, which includes the indexing of papers in periodicals and proceedings of aeronautical societies, together with books and separate pamphlets on the subject, was completed, bringing the work up to July 1, 1909. At the close of the year the manuscript was ready for the printer.

American Historical Association.—The exchange of the annual reports of the American Historical Association from the allotment agreed upon for that purpose has resulted in a number of publications of historical societies throughout the world being added to the Smithsonian deposit at the Library of Congress.

UNITED STATES NATIONAL MUSEUM.

The library of the Museum has received many gifts of importance during the year. Dr. Charles A. White, Dr. William Healey Dall, and Dr. Charles W.

Richmond have added scientific publications which are of value in completing sets and filling in of the series of authors' separates. From the estate of Dr. Otis Tufton Mason, through the executor, Dr. E. B. Pollard, the Museum has received Doctor Mason's working library of anthropological publications, together with a collection of his manuscript notes. Dr. Wirt Tassin, for some time assistant curator of the Division of Mineralogy, contributed about 1,000 pamphlets relating to mineralogy and kindred subjects. There has also been secured by purchase from the estate of Dr. William H. Ashmead a complete collection of his writings, together with his manuscript notes.

Acknowledgments are also due to Dr. E. A. Schwarz, Mr. Wilfred H. Osgood, Dr. O. P. Hay, and Dr. W. P. Hay for collections of publications which they have presented. Additions have also been received to the William Schaus collection and a special bookplate engraved for it is now being placed in the books.

In the Museum library there are now 36,244 volumes, 56,010 unbound papers, and 110 manuscripts. The additions during the year consisted of 2,680 books, 3,671 pamphlets, and 227 parts of volumes. There were catalogued 1,280 books, 1,400 complete volumes of periodicals, and 4,213 pamphlets.

Special attention has been given to the preparation of volumes for binding, with the result that 1,783 books were sent to the government bindery.

The number of books, periodicals, and pamphlets borrowed from the general library amounted to 20,266, including 9,000 which were assigned to the sectional libraries. This does not include, however, the large number of books consulted in the library but not withdrawn.

The sectional libraries established in the Museum have remained the same, the complete list now standing as follows:

Administration.
Administrative assistant.
Anthropology.
Biology.
Birds.
Botany.
Comparative anatomy.
Editor.
Ethnology.
Fishes.
Geology.
History.
Insects.
Invertebrate palæontology.
Mammals.
Marine invertebrates.
Materia medica.
Mesozoic fossils.
Mineralogy.
Mollusks.
Oriental archæology.
Palæobotany.
Parasites.
Photography.
Physical anthropology.
Prehistoric archæology.
Reptiles.
Superintendent.
Taxidermy.
Technology.

SUMMARY OF ACCESSIONS.

The following table summarizes all the accessions during the year except for the Bureau of American Ethnology, which is separately administered:

Smithsonian deposit in the Library of Congress, including parts to complete sets	21,167
Office, Astrophysical Observatory, National Zoological Park, and international exchanges	1,984
United States National Museum library	6,578
Total	29,729

Respectfully submitted.

PAUL BROCKETT,
Assistant Librarian.

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

Appendix VII.

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, 1909.

The United States Regional Bureau is one of the 32 regional bureaus now cooperating, through a central bureau in London, in the production of the International Catalogue of Scientific Literature. The aim of the enterprise is to index and classify all current published scientific papers and by means of 17 annual volumes publish and distribute the data thus prepared to the various subscribers to the catalogue throughout the world. The methods employed in indexing and classifying each paper result in what is practically an analytical digest of the subject of each paper, this being accomplished by means of references to classification schedules which are arranged to include in systematic order each minute subdivision or subject of all the recognized natural and physical sciences. The regional bureaus are supported by the countries in which they are established, thus allowing all funds derived from subscriptions to be used to defray the actual cost of printing and publishing. The bureau in this country is supported by a direct congressional appropriation.

The allotment for the present fiscal year was $5,000, the same as for previous years; the number of the staff has remained the same, namely, five persons. During the year there were 34,409 classified index cards prepared by this bureau and forwarded to London as follows:

Literature of 1901	133
Literature of 1902	235
Literature of 1903	373
Literature of 1904	309
Literature of 1905	1,656
Literature of 1906	4,410
Literature of 1907	8,509
Literature of 1908	18,784
Total	34,409

The corresponding total for the fiscal year ending June 30, 1908, was 28,528, thus showing an increase of 5,881, or over 20 per cent. There has been an increase also in the number of citations furnished by other bureaus, for since the beginning of the enterprise in 1901 the number of pages in the combined 17 annual volumes has increased nearly one-third, as shown by the following table:

	Pages.
First issue	7,763
Second issue	8,826
Third issue	8,493
Fourth issue	8,681
Fifth issue	10,785
Sixth issue	10,049

The number of cards sent from this regional bureau has increased as follows:

For fiscal year 1902	6,990
For fiscal year 1903	14,480
For fiscal year 1904	21,213
For fiscal year 1905	24,182
For fiscal year 1906	25,601
For fiscal year 1907	28,629
For fiscal year 1908	28,528
For fiscal year 1909	34,409

Should this increase continue it would add largely to the cost of publication, and as there would be no corresponding addition to the receipts a decided deficit would result, for the subscription price to the catalogue, namely, $85 a year for 17 volumes, was fixed on a basis of the size and cost of the first annual issue. It appears not only desirable, but necessary, to condense the references as much as possible, though condensation, without loss of usefulness, necessitates much greater care on the part of the classifier in preparing a digest. It can not be hoped that much change in the present methods can be made without increasing the force of the bureau.

The following-named volumes of the catalogue were received and delivered to subscribers in this country, as follows:

Sixth Annual Issue—Physics, Chemistry, Palæontology, General Biology, Botany, Anthropology, Physiology, and Bacteriology, completing the issue.

Seventh Annual Issue—Mathematics, Mechanics, Physics, Astronomy, Mineralogy, Geology, Geography, Palæontology, and Zoology.

Through the resignation of Dr. Cyrus Adler, assistant secretary of the Smithsonian Institution, who was in charge of the United States branch of the International Catalogue, both this bureau and the organization as a whole met with a great loss, notwithstanding the fact that Doctor Adler still remains one of the members of the International Council, the body vested with the supreme control of the catalogue. Doctor Adler was closely identified with the work from the time the original ways and means were being discussed, and it is not too much to say that had it not been for his interest and efforts Mr. Langley, the late Secretary of the Institution, would not have aided the enterprise as he did with the private funds of the Institution. Had not this aid been forthcoming at the time the whole undertaking would have failed, for cooperation on the part of the United States was essential, and, this Government failing at first to lend its aid, there remained no other body than the Smithsonian Institution in a position to become responsible for the work in this country.

It is felt that this International Catalogue of Scientific Literature is but a beginning of what will be eventually a great cooperative international index and digest of all records of human achievement. There is no question of the need for such a publication and, with the satisfactory beginning already made, it is a question of cost alone which limits the field of the present enterprise to include only the literature of pure science to the exclusion of the extensive and valuable literature of the applied sciences and other technical literature.

There have been no losses of property during the year, excepting those caused by ordinary wear and deterioration.

In the sundry civil bill approved March 1, 1909, $6,000 was appropriated to carry on the work for the fiscal year ending June 30, 1910. This sum is an increase of $1,000 over the appropriation for previous years.

Respectfully submitted.

Leonard C. Gunnell,
Chief Assistant, Bureau of International Catalogue of Scientific Literature.

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

Appendix VIII.

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 fiscal year ending June 30, 1909:

There have been distributed a total of 757 volumes and separates in the series of Smithsonian Contributions to Knowledge, 15,080 in the series of Smithsonian Miscellaneous Collections, 22,991 in the series of Smithsonian Annual Reports, and 4,022 in the series of Special Publications. In addition thereto there were sent out by the Institution 1,313 publications not included in the Smithsonian series, making a grand total of 44,163, a decrease of 15,732 from the previous year. The total number of letters relating to publications received amounted to 6,825, an increase of 280 over the previous year.

I. SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

In the series of Smithsonian Contributions to Knowledge there appeared during the year no original papers, but there was published in August, to meet the increasing demand for the work, a reprint of Mr. Langley's memoir on The Internal Work of the Wind, originally published in 1893 in quarto form as No. 884, Smithsonian Contributions to Knowledge. To the present edition was added as an appendix a translation of the "Solution of a special case of the general problem," by Réné de Saussure, which appeared in 1893 with "Le Travail Intérieur du Vent" in Revue de l'Aéronautique Théorique et Appliqué, Paris, pages 58–68.

II. SMITHSONIAN MISCELLANEOUS COLLECTIONS.

In the series of Smithsonian Miscellaneous Collections, Volume LII, there were published 20 papers in the quarterly issue, volume 5, parts 2 and 3; and in the regular series, Volume XXXV, a fourth revised edition of the Smithsonian Physical Tables by Thomas Gray; and in Volume LIII of the regular series, 3 papers by Charles D. Walcott.

In the quarterly issue the following papers were published:

1813. Smithsonian Miscellaneous Collections. Quarterly issue. Volume 5, part 2 (containing Nos. 1814–1823). Octavo. Pages 121–276, with Plates IX–XVIII.

1814. The Nettelroth Collection of Invertebrate Fossils. By R. S. Bassler. Published September 23, 1908. Octavo. Pages 121–152, with Plates IX–XI.

1815. A New Opuntia from Arizona. By J. N. Rose. Published October 6, 1908. Octavo. Page 153, with Plate XII.

1816. The Story of the Devil-Fish. By Theodore Gill. Published October 15, 1908. Octavo. Pages 155–180.

1817. Indians of Peru. By Charles C. Eberhardt, American consul at Iquitos, Peru. Published October 24, 1908. Octavo. Pages 181–194, with Plates XIII, XIV.

1818. On Opuntia Santa-Rita, a Species of Cactus of Ornamental Value. By J. N. Rose, associate curator, division of plants, United States National Museum. Published December 29, 1908. Octavo. Pages 195, 196, with Plate XV.

1819. Two New Species of Abronia. By Anton Heimerl, University of Vienna, Austria. Published December 23, 1908. Octavo. Pages 197, 198.

1820. Preliminary Notice of a Collection of Recent Crinoids from the Philippine Islands. By Austin Hobart Clark, collaborator, department of marine invertebrates, United States National Museum. Published December 23, 1908. Octavo. Pages 199–234.

1821. The Relation of Richard Rush to the Smithsonian Institution. By Cyrus Adler. Published January 16, 1909. Octavo. Pages 235–251, with Plate XVI.

1822. Descriptions of Some New Species and a New Genus of American Mosquitoes. By Harrison G. Dyar and Frederick Knab, of the United States Department of Agriculture. Published January 12, 1909. Pages 253–266.

1823. Notes to Quarterly Issue. Volume 5, part 2. Octavo. Pages 267–273, with Plates XVII, XVIII.

1860. Smithsonian Miscellaneous Collections. Quarterly issue. Volume 5, part 3 (containing Nos. 1861–1868). Octavo. Pages 277–401, with Plates XIX–XXXVII.

1861. The Archer-Fish and Its Feats. By Theodore Gill. Published March 25, 1909. Octavo. Pages 277–286.

1862. The Peoples of Formosa. By Julean H. Arnold, American consul to Formosa. Published March 25, 1909. Octavo. Pages 287–293, with Plates XIX–XXII.

1863. Our Present Knowledge of Canal Rays: A Detailed Bibliography. By Gordon Scott Fulcher. Published March 25, 1909. Octavo. Pages 295–324.

1864. Observations on Living White Whales (Delphinapterus Leucas); with a Note on the Dentition of Delphinapterus and Stenodelphis. By Frederick W. True, head curator of biology, United States National Museum. Published April 28, 1909. Octavo. Pages 325–330, with Plate XXIII.

1865. Some Recent Contributions to Our Knowledge of the Sun. Hamilton Lecture. By George E. Hale, director of solar observatory of Carnegie Institution of Washington, at Mount Wilson, California. Published May 8, 1909. Octavo. Pages 331–360, with Plates XXIV–XXXVI.

1866. Some New South American Land Shells. By William H. Dall, curator, division of mollusks, United States National Museum. Published May 11, 1909. Octavo. Pages 361–364, with Plate XXXVII.

1867. The American Ferns of the Group of Dryopteris Opposita contained in the United States National Museum. By Carl Christensen, Copenhagen. In Press. Octavo. Pages 365–396.

1868. Notes to Quarterly Issue. Volume 5, part 3. Octavo. Pages 397–399.

In the regular series of Smithsonian Miscellaneous Collections the following have been published:

1038. Smithsonian Physical Tables. Fourth revised edition. By Thomas Gray. Octavo. Pages xxxv, 301. Part of Volume XXXV.

In this edition, published on account of the increased demand for the tables, Professor Gray made a few corrections, particularly in the tables of equivalents of metric and British imperial weights and measures, which were here brought up to date.

1810. Cambrian Geology and Paleontology. No. 3, Cambrian Brachiopoda: Descriptions of New Genera and Species. By Charles D. Walcott. Published October 1, 1908. Octavo. Pages 53–137, with plates 7–10. Part of Volume LIII.

1811. Cambrian Geology and Paleontology. No. 4, Classification and Terminology of the Cambrian Brachiopoda. By Charles D. Walcott. Published October 13, 1908. Octavo. Pages 139–165, with plates 11, 12. Part of Volume LIII.

1812. Cambrian Geology and Paleontology. No. 5, Cambrian Sections of the Cordilleran Area. By Charles D. Walcott. Published December 10, 1908. Octavo. Pages 167–230, with plates 13–22. Part of Volume LIII.

Publications numbered 1810, 1811, and 1812 were in continuation of the studies of Cambrian Geology and Paleontology, by Charles D. Walcott, the series of which began with Nos. 1804 and 1805, Nomenclature of Some Cambrian Cordilleran Formations and Cambrian Trilobites.

There were in press in the regular series of Smithsonian Miscellaneous Collections at the close of the fiscal year, publication No. 1869, The Mechanics of the Earth's Atmosphere (a collection of translations), second collection, by Cleveland Abbe, and No. 1870, Landmarks of Botanical History, Part I, by Dr. Edward L. Greene. There were in manuscript form, approved for publication, a Bibliography of the Occurrence and Distribution of Tin, by Frank L. and Eva Hess, and a Bibliography of Aeronautics, by Paul Brockett, assistant librarian of the Institution.

III. SMITHSONIAN ANNUAL REPORTS.

The Annual Report for 1907 was largely in type at the beginning of the fiscal year, but owing principally to a delay in the securing of paper the report was not finally published until late in the fall:

1824. 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, 1907. Octavo. Pages lvii, 726, with 79 plates.

The following papers, included in the Annual Report of the Board of Regents for 1907, and enumerated in the report on publications for 1908, were issued separately in pamphlet form:

1825. Proceedings of Board of Regents for the year ending June 30, 1907. Report of Executive Committee, Acts and Resolutions of Congress. Octavo. Pages xi–lvii.

1826. The Steam Turbine on Land and Sea. By Hon. Charles A. Parsons, C. B., M. A., D. Sc., F. R. S., M. R. I. Octavo. Pages 99–112, with 8 plates.

1827. The Development of Mechanical Composition in Printing. By Prof. A. Turpain, University of Poitiers. Octavo. Pages 113–129, with 3 plates.

1828. Some Facts and Problems Bearing on Electric Trunk Line Operation. By Frank J. Sprague. Octavo. Pages 131–161, with 7 plates.

1829. Recent Contributions to Electric Wave Telegraphy. By Prof. J. A. Fleming, M. A. D. Sc., F. R. S., M. R. I., Pender professor of electrical engineering in the University of London. Octavo. Pages 163–193.

1830. On the Properties and Natures of Various Electric Radiations. By W. H. Bragg, M. A., F. R. S., elder professor of mathematics and physics in the University of Adelaide. Octavo. Pages 195–214.

1831. Progress in Electro-Metallurgy. By John B. C. Kershaw. Octavo. Pages 215–230, with 10 plates.

1832. Advances in Color Photography. By Thomas W. Smillie, F. R. P. S. Octavo. Pages 231–237, with 1 plate.

1833. The Structure of Lippmann Heliochromes. By S. R. Cajal. Octavo. Pages 239–259.

1834. Bronze in South America before the Arrival of the Europeans. By Adrien de Mortillet, honorary president of the Société Préhistorique de France. Octavo. Pages 261–266.

1835. Some Opportunities for Astronomical Work with Inexpensive Apparatus. By Prof. George E. Hale, director of the Mount Wilson Solar Observatory

of the Carnegie Institution of Washington. Octavo. Pages 267–285, with 6 plates.

1836. The Progress of Science as Illustrated by the Development of Meteorology. By Cleveland Abbe. Octavo. Pages 287–309.

1837. Geology of the Inner Earth.—Igneous Ores. By Prof. J. W. Gregory, D. Sc., F. R. S. Octavo. Pages 311–330.

1838. The Salton Sea. By F. H. Newell, Director United States Reclamation Service. Octavo. Pages 331–345, with 9 plates.

1839. Inland Waterways. By George G. Chisholm. Octavo. Pages 347–370.

1840. The Present Position of Paleozoic Botany. By D. H. Scott, F. R. S., lately honorary keeper of the Jodrell Laboratory, Royal Botanic Gardens, Kew. Octavo. Pages 371–405, with 2 plates.

1841. The Zoological Gardens and Establishments of Great Britain, Belgium, and the Netherlands. By Gustave Loisel, director of the Laboratory of General Embryology at the School of Hautes Études, professor of zoology in the secondary courses of the Sorbonne, Paris. Octavo. Pages 407–448, with 8 plates.

1842. Systematic Zoology: Its Progress and Purpose. By Theodore Gill. Octavo. Pages 449–471, with 14 plates.

1843. The Genealogical History of the Marine Mammals. By Prof. O. Abel. Octavo. Pages 473–496.

1844. The Mediterranean Peoples. By Theobald Fischer, University of Marburg. Octavo. Pages 497–521.

1845. Prehistoric Japan. By Dr. E. Baelz, 1876–1902, professor Imperial Japanese University of Tokyo. Octavo. Pages 523–547, with 2 plates.

1846. The Origin of Egyptian Civilization. By Edouard Naville, D. C. L., LL. D., etc. Octavo. Pages 549–564.

1847. The Fire Piston. By Henry Balfour, M. A., curator of Pitt-Rivers Museum, Oxford. Octavo. Pages 565–593, with 5 plates.

1848. The Origin of the Canaanite Alphabet. By Franz Praetorius. Octavo. Pages 595–604.

1849. Three Aramaic Papyri from Elephantine, Egypt. By Prof. Eduard Sachau. Octavo. Pages 605–611, with 2 plates.

1850. The Problem of Color Vision. By John M. Dane. Octavo. Pages 613–625.

1851. Immunity in Tuberculosis. By Simon Flexner, M. D., Rockefeller Institute for Medical Research, New York City. Octavo. Pages 627–645.

1852. The Air of the New York Subway Prior to 1906. By George A. Soper. Octavo. Pages 647–667.

1853. Marcelin Berthelot. By Camille Matignon, professor of mineral chemistry at the Collège de France; former assistant professor to Berthelot at the Collège de France. Octavo. Pages 669–684, with 1 plate.

1854. Linnæan Memorial Address. By Edward L. Greene. Octavo. Pages 685–700, with 1 plate.

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, 1908, both forming part of the Annual Report of the Board of Regents to Congress, were printed in pamphlet form and published at the December meeting of the Board of Regents, as follows:

1855. Report of the Executive Committee and Proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1908. Octavo. Pages 3–18.

1856. Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1908. Octavo. Pages iii, 86.

The greater part of the Smithsonian Report for 1908 was in type at the close of the fiscal year. The General Appendix contains the following papers:

The Present Status of Military Aeronautics. By Maj. George O. Squier, U. S. Army.

Aviation in France in 1908. By Pierre-Roger Jourdain.

Wireless Telephony. By R. A. Fessenden.

Phototelegraphy. By Henri Armagnat.

The Gramophone and the Mechanical Recording and Reproduction of Musical Sounds. By Lovell N. Reddie.

On the Light Thrown by Recent Investigation on Electricity on the Relation between Matter and Ether. By J. J. Thomson.

Development of General and Physical Chemistry During the Last Forty Years. By W. Nernst.

Development of Technological Chemistry During the Last Forty Years. By O. N. Witt.

Twenty Years' Progress in Explosives. By Oscar Guttmann.

Recent Research in the Structure of the Universe. By J. C. Kapteyn.

Solor Vortices and Magnetism in Sun Spots. By C. G. Abbot.

Climatic Variations, Their Extent and Causes. By J. W. Gregory.

Uranium and Geology. By John Joly.

An Outline Review of the Geology of Peru. By George I. Adams.

Our Present Knowledge of the Earth. By E. Wiechert.

The Antarctic Question. By J. Machat.

Some Geographical Aspects of the Nile. By Capt. H. G. Lyons.

Heredity and the Origin of Species. By Daniel Trembly MacDougal.

Cactaceae of Northeastern and Central Mexico, together with a Synopsis of the Principal Mexican Genera. By William Edwin Safford.

Angler Fishes, their Kinds and Ways. By Theodore Gill.

The Birds of India. By Douglas Dewar.

The Evolution of the Elephant. By Richard S. Lull.

Excavations at Boghaz-Keui in the Summer of 1907. By Hugo Winckler and O. Puchstein.

Malaria in Greece. By Ronald Ross.

Carl von Linné as a Geologist. By A. G. Nathorst.

Life and Work of Lord Kelvin. By Sylvanus P. Thompson.

The Work of Henri Becquerel. By André Broca.

Owing to the unusual demand for the paper, there was published in March a reprint of number 1688, Parental Care among Fresh-water Fishes, by Theodore Gill, which appeared originally in the Annual Report of the Board of Regents for 1905.

IV. SPECIAL PUBLICATIONS.

Five special publications were issued during the year, as follows:

1808. Catalogue of the Botanical Library of John Donnell Smith, presented in 1905 to the Smithsonian Institution. Compiled by Alice Cary Atwood. Imperial octavo. Pages 94.

The catalogue was printed in an edition of 200 copies on Old Stratford paper, imperial octavo size, from the original stereotype plates used in its first publication by the National Museum as Part I of Volume XII of Contributions from the National Herbarium.

1809. Researches and Experiments in Aerial Navigation. By S. P. Langley. Reprinted from the Smithsonian Reports for 1897, pages 169–181, with 1 plate; 1900, pages 197–216, with 6 plates; 1901, pages 649–659, with 7 plates; 1904, pages 113–125, with 1 plate. Octavo.

The occasion for this reprint of Mr. Langley's papers, which was issued in August, is stated in the introduction. The articles were as follows:

I. Story of Experiments in Mechanical Flight. By Samuel Pierpont Langley. From the Smithsonian Report for 1897, pages 169–181 (with Pl. I). Published originally in the Aeronautical Annual, 1897.

II. The Langley Aerodrome. From the Smithsonian Report for 1900, pages 197–216 (with Pls. I–VI). Slightly abridged from an article published originally in McClure's Magazine, June, 1897.

III. The Greatest Flying Creature. By S. P. Langley (introducing a paper by F. A. Lucas). From the Smithsonian Report for 1901, pages 649–659 (with Pls. I–VII).

IV. Experiments with the Langley Aerodrome. By S. P. Langley. From the Smithsonian Report for 1904, pages 113–125 (with Pl. I).

1858. Contributions to the Life Histories of Fishes. By Theodore Gill. Volume I. 1904–1907. Reprints from Smithsonian Miscellaneous Collections, Smithsonian Annual Report, and Proceedings United States National Museum. Octavo. 323 pages (pagination as in originals), with 28 plates (numbered as in originals).

The contents of this volume is as follows:

I. A Remarkable Genus of Fishes—the Umbras. April 11, 1904. Smiths. Misc. Coll., Vol. 45, No. 1453.

II. The Sculpin and its Habits. January 31, 1905. Smiths. Misc. Coll., Vol. 47, No. 1552.

III. The Life History of the Angler. May 6, 1905. Smiths. Misc. Coll., Vol. 47, No. 1569.

IV. The Tarpon and Lady-fish and their Relations. May 13, 1905. Smiths. Misc. Coll., Vol. 48, No. 1576.

V. The Life History of the Sea-horse. July 6, 1905. Proc. U. S. Nat. Mus., Vol. 28, No. 1408.

VI. The Family of Cyprinids and the Carp as its Type. September 8, 1905. Smiths. Misc. Coll., Vol 48, No. 1591.

VII. Flying Fishes and their Habits. October 5, 1905. Rep. Smiths. Inst., 1904, No. 1629.

VIII. Parental Care among Fresh-water Fishes. January 21, 1907. Rep. Smiths. Inst., 1905, No. 1688.

IX. Some Noteworthy Extra-European Cyprinids. February 4, 1907. Smiths. Misc. Coll., Vol. 48, No. 1662.

X. Life Histories of Toadfishes (Batrachoidids) compared with those of Weevers (Trachinids) and Stargazers (Uranoscopids). May 4, 1907. Smiths. Misc. Coll., Vol. 48, No. 1697.

1859. Classified List of Smithsonian Publications Available for Distribution March, 1909. Octavo. Pages 39.

1871. Smithsonian Mathematical Tables. Hyberbolic Functions. Prepared by George F. Becker and C. E. Van Orstrand. Octavo. Pages li, 321.

The advertisement explains the purpose and scope of this publication:

"Among the early publications of the Smithsonian Institution was a very important volume of meteorological tables by Dr. Arnold Guyot. They were so widely used by geographers and physicists, as well as by meteorologists, that when the fourth edition was exhausted it was decided to recast the entire work and publish three separate volumes—Meteorological Tables, Geographical Tables, and Physical Tables—each of which have now passed through several editions.

"In the application of the data of these volumes to the study of natural phenomena certain mathematical tables beside those included in ordinary tables

of logarithms are urgently needed in order to save recurrent computation on the part of observers and investigators. It was therefore decided to publish the present volume of Mathematical Tables on 'Hyperbolic functions.'

"Hyperbolic functions are extremely useful in every branch of pure physics and in the application of physics, whether to observational and experimental sciences or to technology. Thus whenever an entity (such as light, velocity, electricity, or radioactivity) is subject to gradual extinction or absorption the decay is represented by some form of Hyperbolic functions. Mercator's projection is likewise computed by Hyperbolic functions. Whenever mechanical strains are regarded as great enough to be measured they are most simply expressed in terms of Hyperbolic functions. Hence geological deformations invariably lead to such expression, and it is for that reason that Messrs. Becker and Van Orstrand, who are in charge of the physical work of the United States Geological Survey, have been led to prepare this volume."

V. PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM.

The publications of the National Museum are: (*a*) The annual report, forming a separate volume of the Report to Congress by the Board of Regents of the Smithsonian Institution; (*b*) The Proceedings of the United States National Museum; (*c*) The Bulletin of the United States National Museum; and (*d*) the Contributions from the United States National Herbarium. The editorship of these publications is in charge of Dr. Marcus Benjamin.

The publications issued during the year are enumerated in the Report on the National Museum. These included Volume XXXIV of the Proceedings, containing Museum papers numbered 1610 to 1630; Volume XXXV, papers numbered 1631 to 1658; and Volume XXXVI, papers numbered 1659 to 1694. Three bulletins were issued:

62. Catalogue of the Type Specimens of Mammals in the United States National Museum, including the Biological Survey Collection. By Marcus Ward Lyon and Wilfred H. Osgood.

63. A Monographic Revision of the Coleoptera belonging to the Tenebrionidæ Tribe Eleodiini inhabiting the United States, Lower California, and Adjacent Islands. By Frank E. Blaisdell, sr.

64. A Critical Summary of Troost's Unpublished Manuscript on the Crinoids of Tennessee. By Elvira Wood.

In the series of Contributions from the United States National Herbarium there appeared:

Volume XII, part 4. The Mexican and Central American Species of Sapium, by Henry Pittier; Volume XII, part 5, New or Noteworthy Plants from Colombia and Central America, by Henry Pittier; Volume XII, part 6, Catalogue of the Grasses of Cuba, by A. S. Hitchcock; Volume XII, part 7, Studies of Mexican and Central American Plants, No. 6, by J. N. Rose; Volume XII, part 8, The Allionaceæ of the United States, with notes on Mexican Species, by Paul C. Standley; Volume XII, part 9, Miscellaneous Papers, by J. N. Rose, N. L. Britton, and William Maxon; and Volume XIII, part 1, Studies of Tropical American Ferns, No. 2, by William Maxon.

VI. PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

The publications of the bureau are discussed in detail in another appendix of the Secretary's report. The editorial work is in charge of Mr. J. G. Gurley. The Twenty-sixth Annual Report was issued during the summer, together with the usual number of separates of the accompanying papers, and also Bulletins 34, Physiological and Medical Observations Among the Indians of Southwestern

United States and Northern Mexico, by Aleš Hrdlička, and 42, Tuberculosis Among Certain Indian Tribes, by Aleš Hrdlička. At the close of the fiscal year there were largely in type or at the bindery the Twenty-seventh Annual Report, and Bulletins 38, 39, 40, part 1, 41, 43, 46, and 47.

VII. PUBLICATIONS OF THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY.

As an addenda to the Annals of the Smithsonian Astrophysical Observatory, Volume II, a short note on the Reflecting Power of Clouds was issued, as follows:

1738*a*. Note on the Reflecting Power of Clouds. By C. G. Abbot and F. E. Fowle, jr. (Addenda to Annals of the Astrophysical Observatory, Smithsonian Institution, Vol. II.) Octavo. Pages 3.

VIII. REPORT OF THE AMERICAN HISTORICAL ASSOCIATION.

Volumes I and II of the Annual Report of the American Historical Association for the year 1906, by law approved and communicated to Congress by the Secretary of the Smithsonian Institution, were published in August, 1908.

Volume I contained the following: Report of Proceedings of Providence Meeting, by Charles H. Haskins; Report of Proceedings of Pacific Coast Branch, by Max Farrand; The Renaissance of the Twelfth Century, by D. C. Munro; A Mediæval Humanist, by H. O. Taylor; Report of Conference on Teaching of History in Schools, by J. A. James; Report of Conference on History in College, by Max Farrand; Third Report of Conference on State and Local Historical Societies, by F. H. Severance; Comparison of Virginia Company with Other English Trading Companies, by Susan M. Kingsbury; The Colonial Policy of Great Britain, by G. L. Beer; William Penn, by Edward Channing; Some Aspects of the English Bill for the Admission of Kansas, by F. H. Hodder; The Attitude of Thaddeus Stevens Toward the Conduct of the Civil War, by J. A. Woodburn; History of Indian Consolidation West of the Mississippi, by Annie H. Abel.

Volume II contained the Seventh Report of the Public Archives Commission, with discussions of the following subjects: Summary of present state of legislation of States and Territories relative to the custody and supervision of the public records, by Robert T. Swan; public archives of Arkansas, by John Hugh Reynolds; public archives of Connecticut, by N. P. Mead; state and county archives of Delaware, by Edgar Dawson; state archives of Florida, by David Y. Thomas; archives of Augusta, Ga., and of Richmond County, by Julia A. Flisch; state archives of Ohio and of Ross County, by R. C. Stevenson; local archives of Tennessee, by St. George L. Sioussat; bibliography of public archives of the thirteen original States to 1789, by Adelaide R. Hasse.

The manuscript of Volumes I and II of the Annual Report for 1907 was sent to the Public Printer September 10, 1908, but the work had not been published at the close of the fiscal year. The manuscript of Volume I for 1908 was transmitted on June 17, 1909.

IX. REPORT OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The Eleventh Report of the Daughters of the American Revolution was received from the society in accordance with section 3 of the act of incorporation, which reads that "said society shall report annually to the Secretary of the Smithsonian Institution concerning its proceedings, and said Secretary shall communicate to Congress such portions thereof as he may deem of national interest and importance." After revision the report was communicated to Congress on June 1, 1909.

X. 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 Quarterly Issue of the Smithsonian Miscellaneous Collections.

Upon the resignation of Dr. Cyrus Adler, chairman of the committee, as assistant secretary of the Institution, the Secretary on October 21 reorganized the committee as follows: Dr. Frederick W. True, chairman; and Messrs. C. G. Abbot, W. I. Adams, Frank Baker, A. Howard Clark, F. W. Hodge, Otis T. Mason, George P. Merrill, and Leonhard Stejneger. At the same time the Museum advisory committee on printing and publication was discontinued and the responsibilities theretofore devolving upon it were transferred to the Smithsonian committee.

Twenty-seven meetings were held during the year and 110 papers and 6 printed forms were reported on.

XI. PRESS ABSTRACTS OF PUBLICATIONS.

Although the pressure of routine editorial work claimed most of the time of the editorial staff, abstracts of a number of the more popular publications, as well as articles on the work of the Institution and its branches, were furnished to a large number of newspapers, in continuance of the policy inaugurated in March, 1907.

Respectfully submitted.

A. HOWARD CLARK, *Editor.*

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

APPENDIX IX.

REPORT ON ALASKA-YUKON-PACIFIC EXPOSITION.

SIR: I have the honor to submit the following report of the participation of the Smithsonian Institution and National Museum in the Alaska-Yukon-Pacific Exposition at Seattle, Washington:

The act of Congress approved May 27, 1908, authorizing an exhibit by the departments and bureaus of the Government at the Alaska-Yukon-Pacific Exposition appropriated the sum of $200,000, to be expended under the direction of the United States Government board of managers, composed of three persons in the employ of the Government, one to be designated by the President as chairman, and one as secretary and disbursing officer. This board was charged with the selection, purchase, preparation, transportation, arrangement, safe-keeping, exhibition, and return of such articles and materials as the heads of the several departments and Secretary of the Smithsonian Institution, respectively, should decide to be embodied in the government exhibit thus authorized. There was also appropriated the sum of $125,000, to be expended under the direction of the Secretary of the Interior, to aid the people of the district of Alaska and the Territory of Hawaii in providing and maintaining appropriate and creditable exhibits of the products and resources of Alaska and Hawaii; and $25,000 was appropriated, to be expended under the Secretary of War, to aid the people of the Philippine Islands in providing and maintaining an appropriate exhibit of the products and resources of the Philippine Islands. In addition to this, the Secretary of the Treasury was directed to erect suitable buildings for the government exhibit, including an irrigation and biograph building; also a fisheries building, and buildings for the exhibits of the district of Alaska, the Territory of Hawaii, and the Philippine Islands, for which an appropriation of $250,000 was made. Mr. Jesse E. Wilson, Mr. W. de C. Ravenel, and Mr. W. M. Geddes were appointed members of the government board of managers; Mr. Wilson, chairman; Mr. Ravenel, vice-chairman; and Mr. Geddes, secretary and disbursing officer.

The act also provided that the Smithsonian Institution and National Museum should exhibit such articles of material of an historical nature as would impart a knowledge of our national history, especially that of Alaska, Hawaii, and the Philippine Islands, and that portion of the United States west of the Rocky Mountains. The Secretary of the Smithsonian Institution designated Mr. W. de C. Ravenel, administrative assistant, United States National Museum, as representative of the Institution and National Museum. Of the total appropriation, $24,000 was allotted to the Smithsonian Institution and National Museum and about 10,000 square feet of space in the main government building. The preparation of this exhibit was begun as soon as possible after the board was organized, in accordance with plans submitted by the representative, and was practically installed in the government building by June 1, when the exposition opened.

In the preparation of the exhibits by the Institution and the Museum the principal idea kept in view was to present an outline of our national achievements and progress, and of the facts connected with the development of the

western part of the United States, Alaska, Hawaii, and the Philippine Islands. The exhibits were classified as follows:

1. Portraits of eminent persons associated with the discovery and history of America.
2. Portraits of eminent persons connected with the history of the Pacific coast Alaska.
3. Portraits of eminent persons connected with the history of the Hawaiian Islands.
4. Portraits of eminent persons connected with the history of the Philippine Islands.
5. Historic scenes and landmarks.
6. History of the Capitol.
7. Historic vessels.
8. Early American steamboats.
9. History of land transportation.
10. History of the contributions of Henry and Morse to electricity and the telegraph.
11. Medallic history of the United States.
12. History of American cartography.
13. History of the territorial expansion of the United States.
14. History of the Pacific coast and Alaska:
    - The Spanish missions in California.
    - The Russian Orthodox Church in Alaska.
    - The Church of Latter-day Saints.
    - Modern pueblos of Arizona and New Mexico.
    - Ancient pueblos of Arizona and New Mexico.
    - The aborigines of California.
    - The aborigines of the North Pacific coast and Alaska.
    - Paintings and photographs of Alaska.
15. The Philippines:
    - Civilized and uncivilized peoples.
    - Series of photographs.
16. Hawaii:
    - Model of village.
    - Series of photographs.
    - Emerson ethnographic collection.
    - Church mission work in Hawaii.
17. Samoa:
    - The natives.
    - Paintings and photographs.
18. The Mariannes:
    - Series of photographs.
19. The history of photography.
20. The history of medicine in America.

The portion of the exhibit representing persons prominently connected with the discovery and history of America, Alaska, the Hawaiian Islands, and of the Philippine Islands consisted of 190 portraits, and there were also portraits and paintings representing historic scenes and landmarks.

Models of historic vessels were exhibited, including a Viking ship, the *Santa Maria*, the *Half Moon*, the *Mayflower*, and the *Constitution;* also models illustrating the development of the steam vessel, including John Fitch's steamboat, which plied on the Delaware in 1786; the *Clermont*, first used by Fulton in 1807 on the Hudson; the *Phoenix*, the *Savannah*, and others of great public interest.

In the exhibit of land transportation were shown the various early methods of transporting passengers and supplies, arranged in sequence and including models of the early locomotives, such as the John Bull and the Stourbridge Lion.

The collection of electrical and telegraphic apparatus was designed to demonstrate some of the more important features connected with Prof. Joseph Henry's researches in electrical science, and included five of his original instruments and reproductions of other pieces of apparatus.

The medallic history of the United States was portrayed by a series of bronze copies of 23 medals which were struck in honor of the Presidents of the United States from Thomas Jefferson to Theodore Roosevelt, and other medals commemorating special acts and events of historical importance in the development of the country.

American cartography and the story of the territorial expansion of the United States were illustrated by maps and by facsimiles of a number of treaties.

The history of the Pacific coast and Alaska was shown by means of paintings, by a model of the Santa Barbara mission building, relics from the different missions, and other interesting objects, an excellent model of St. Michael's Cathedral in Sitka, a large number of photographs of churches, clergy, and a collection of primers, liturgies, manuals, and other religious works connected with Russian missionary efforts in Alaska.

The history of the Mormon Church was illustrated by a collection of portraits of more than 40 persons conspicuous in its establishment and growth; albums containing pictures of Mormon temples and other buildings; and models of the temple and tabernacle in Salt Lake City; also a chart showing the migrations from Vermont to Illinois and other points.

An exhibit which attracted much attention consisted of models and paintings of ancient pueblos of Arizona and New Mexico. The style of buildings adopted by the ancient people of southern Arizona was graphically illustrated by a painting presenting a bird's-eye view of the prehistoric ruin of Casa Grande, situated in the desert about 50 miles southeast of Phoenix. The ruin comprises blocks of buildings, reservoirs, and ditches, fortified inclosures, and other constructions. The original settlement was composed of rectangular structures known as "compounds," illustrated by models A, B, and C. Some of these buildings were used for the performance of sacred rites and as habitations for medicine men and chiefs. The Smithsonian Institution has made extensive excavations and repairs of the Casa Grande ruin.

The characteristics of cliff-dwelling architecture were well portrayed in the model of Mummy Cave, a ruin in northeastern Arizona, and a painting of the Cliff Palace, the largest known of the cliff dwellings, situated in southeastern Colorado. Modern pueblo family life and dwellings were depicted by a group of Zuñi Indians of New Mexico, and by the well-known Hopi pueblo of Walpi, Ariz. A life-sized family group of Hupa Indians engaged in their customary occupations was selected to illustrate the aborigines of California.

The culture of the aborigines of the North Pacific coast and southeastern Alaska was represented by objects carved in wood, such as chests, totem poles, and numerous other specimens.

The industries of the western Eskimo of southeastern Alaska were represented by a model of a log house, lay figures of a man and woman, a collection of spears, harpoons, snowshoes, and boats; also specimens of basketry and other objects connected with their domestic pursuits.

A number of historical paintings lent by Mr. T. J. Richardson, and photographs by Lieut. George T. Emmons, U. S. Navy, portrayed the early history of Alaska.

The groups and other objects showing the life and habits of the Philippine Islanders formed a most attractive exhibit. Among these was a family group of the Negritos of Zambales, a small, black people inhabiting several isolated places in various islands of the Philippines. Their houses are nothing but rude shelters, and are scattered throughout the country. There was also exhibited a typical collection of specimens showing the arts and industries of this tribe.

The Igorot of Bontoc were represented by a family group of four figures. This people is of Malayan stock and pursue agriculture and other peaceful vocations. Until quite recently, in contrast to their pacific dispositions, they were addicted to the barbarous practice of head-hunting. Their arts were represented by a number of objects, including articles of personal adornment and carved wooden figures.

The arts and industries of the Moro and Bagobo tribes of Mindanao were shown by specimens of baskets, shellwork, ornaments, metal work, and costumes.

The Tagal, the most progressive of the native tribes, having been in contact with Spanish civilization for several centuries, were represented by articles of pottery, cups, bowls, cloth, costumes, arms, and a lay figure of a weaver at work.

The general history of the Philippine Islands at the close of the war with Spain was portrayed by a series of photographs of the natives, family life, occupations, dwellings, churches, and of historic scenes.

The exhibit illustrating the history of the Hawaiians comprised a model of a village of the early Hawaiians, who formerly lived in grass-thatched houses, grouped into villages, constituting the home of a clan, presided over by a chief and a priest. The exhibit also included a large series comprising several hundred ethnological objects collected by Mr. N. B. Emerson, and of photographs representing buildings, ancient and modern, and various data illustrative of church, settlement, and school work.

The Samoans, who are a robust and active people, living in comfortable palm-roofed houses, were represented by a family group. Oil painting of a Samoan man and woman and photographs of native houses formed a part of the exhibit, as well as a number of objects connected with their social life.

The Guam and Marianne Islands exhibit embraced photographs of some of the natives and their houses.

The evolution and history of photography was well illustrated by a collection prepared by Mr. Thomas W. Smillie, beginning with the earliest permanent photographs, and including examples of nearly all of the most important discoveries and inventions up to the present time. Many of the specimens were made by the inventors of the processes and others in the Museum laboratory. The collections of color photographs are especially fine, beginning with the tinting and then an elaborate coloring of the photograph by hand, and the patented processes for transferring the film to a colored base, which finally led to the almost perfect photographs in color, as made by Ives, Wood, Lippman, Miley, and the autochromes made in our own laboratory.

The history of medicine, prepared by Dr. J. M. Flint, consisted mainly of photographs and biographical sketches of noted doctors, beginning with the physician who accompanied Capt. John Smith to America and covering the twentieth century up to and including experiments conducted by Major Reed for the prevention of yellow fever in Cuba in 1891.

These exhibtis by the Institution and the Museum were prepared by the representative, with the assistance of Mr. W. H. Holmes, of the Bureau of American Ethnolgoy; Dr. Walter Hough, acting head curator of anthropology;

Dr. I. M. Casanowicz; Mr. T. T. Belote; Mr. T. W. Smillie; Mr. G. C. Maynard; and Dr. J. M. Flint, U. S. Navy. The groups were designed by Mr. Holmes and modeled by Mr. U. S. J. Dunbar. The models of Casa Grande were made by Mr. H. W. Hendley, under the direction of Dr. J. Walter Fewkes, and the model of the Hawaiian village by Mr. I. B. Millner.

The Museum is indebted to Mr. George Wharton James for the assembling of the exhibits from the California missions; to Rev. A. P. Kashevaroff for designing and collecting the exhibit of the Russian Orthodox Church in Alaska; to a committee of the Church of Latter-day Saints, of which Mr. O. F. Whitney was chairman, for an exhibit illustrating the history of that church; to the Board of Hawaiian Evangelical Association for a series of photographs showing mission work in Hawaii; and to Mr. H. W. Henshaw, Lieut. G. T. Emmons, U. S. Navy; Mr. T. J. Richardson; Dr. C. H. Townsend; and Mr. W. E. Safford for the loan of photographs and paintings.

Special acknowledgement is made of the cordial assistance rendered by the Department of State, the War Department, the Signal Corps, the Bureau of Fisheries, and the American Museum of Natural History.

The exhibit as a whole has attracted much attention, being of especial interest to students of history, and one of the most creditable sent out by the Institution. The exposition will close October 15, 1909.

Respectfully submitted.

W. de C. Ravenel,
Representative Smithsonian Institution
and National Museum.

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

APPENDIX X.

THE FIRST PAN-AMERICAN SCIENTIFIC CONGRESS, HELD IN SANTIAGO, CHILE, DECEMBER 25, 1908–JANUARY 6, 1909.

By W. H. HOLMES,

Delegate of United States Government representing the Smithsonian Institution.

The first Latin-American Scientific Congress, which was convened in Buenos Aires in 1898, was projected by the Argentine Scientific Society of that city and successfully carried out. It was attended by representatives of twelve Latin-American republics, and yielded results of such importance that a second congress was convened at Montevideo in 1901; and this was followed by a third at Rio de Janeiro in 1905. Arrangements were made for a fourth meeting at Santiago, Chile, in 1908, and the Chilean organization committee,[a] feeling that the activities of the congress, which had been limited to the discussion of the Latin-American problems and interests chiefly, should be extended to a fully Pan-American scope, decided that the Santiago meeting should be known as "The First Pan-American Scientific Congress."

The organization committee, through the medium of the Chilean Government, extended to the Government of the United States an invitation to participate. Secretary Root brought the matter to the attention of President Roosevelt,[b]

[a] The organization committee was constituted as follows: Honorary president, Marcial Martinez; President, Valentin Letelier; vice-presidents, Manuel E. Ballestros and Miguel Cruchaga; general secretary, Eduardo Poirier; assistant secretary, Augusto Vicuna S.; treasurer; Octavio Maira; Alejandro Alvarez, José Ramon Gutierrez, Alejandro del Rio, Miguel Varas, Luis Espejo Varas, Anselmo Hevia Riquelme, Vicente Izquierdo, Domingo V. Santa Maria.

[b] THE PRESIDENT: The Government of Chile has invited the Government of the United States to join in and to be represented by delegates at the Pan-American Scientific Congress, which is to assemble under its auspices at the capital city of Santiago during the ten days beginning December 25, 1908. The work of the congress will comprehend nine sections, devoted, respectively, to pure and applied mathematics, physical sciences, natural sciences, engineering, medicine and hygiene, anthropology, jurisprudence and sociology, pedagogics, and agriculture and animal industry.

Latin-American scientific congresses were held in 1898 at Buenos Aires, in 1901 at Montevideo, and in 1905 at Rio de Janeiro. Growing out of these previous conferences the congress of 1908 will be for the first time Pan-American. It will study and discuss many great subjects in which all the American republics have in common special interests; and its aim is to bring together the best scientific thought of this hemisphere for the scrutiny of many distinctively American problems and for an interchange of experience and of views which should be of great value to all the nations concerned.

It is therefore eminently appropriate that the United States should be adequately represented at this important First Pan-American Scientific Congress

and the President transmitted the invitation to Congress, accompanied by a commendatory message.[a] In due course the invitation was officially accepted and a liberal sum appropriated for the purposes of the congress. The committee of organization also extended invitations, through the Department of State at Washington, to a number of universities and other institutions and societies. As a result a large delegation was accredited to the congress. The membership of the delegation and the institutions represented are as follows:

Government delegates.

L. S. Rowe, University of Pennsylvania.
Paul S. Reinsch, University of Wisconsin.
Hiram Bingham, Yale University.
A. C. Coolidge, Harvard University.

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and should embrace this opportunity for cooperation in scientific research with the representatives of the other American republics. It is worthy of consideration that, in addition to the purely scientific interests to be subserved by such a congress and in addition to the advantages arising from an interchange of thought and the intercourse of the scientific men of the American countries and the good understanding and friendly relations which will be promoted, there are many specific relations arising from the very close intercourse between the United States and many Latin-American countries, incident to our expanding trade, our extending investments, and the construction of the Panama Canal, which make a common understanding and free exchange of opinion upon scientific subjects of great practical importance.

To make our representation possible I have the honor to recommend that the Congress be asked to appropriate the sum of $35,000, or so much thereof as may be necessary, to enable the United States to send a number of delegates corresponding to the number of sections into which the congress is to be divided, together with a secretary and disbursing officer, and to pay other necessary expenses.

Inasmuch as it is desired that all communications or scientific works to be presented to the congress be received before September 30, it is much to be hoped that provision for the participation of this government may be made at an early date and that the appropriation be made immediately available.

Respectfully submitted.

ELIHU ROOT.

DEPARTMENT OF STATE,
Washington, December 19, 1907.

[a] *To the Senate and House of Representatives:*

I transmit herewith for the consideration of the respective Houses of the Congress a report of the Secretary of State representing the appropriateness of early action in order that in response to the invitation of the Government of Chile the Government of the United States may be enabled fittingly to be represented at the First Pan-American Scientific Congress, to be held at Santiago, Chile, the first ten days of December, 1908.

The recommendations of this report have my hearty approval, and I hope that the Congress will see fit to make timely provision to enable the Government to respond appropriately to the invitation of the Government of Chile in the sending of delegates to a congress which can not fail to be of great interest and importance to the governments and peoples of all the American republics.

THEODORE ROOSEVELT.

THE WHITE HOUSE, *December 21, 1907.*

Col. William C. Gorgas, U. S. Army.
W. H. Holmes, Smithsonian Institution.
Bernard Moses, University of California.
George M. Rommel, Bureau of Animal Industry.
W. R. Shepherd, Columbia University.
W. B. Smith, Tulane University.

University and society delegates.

C. H. Hall, University of Minnesota.
Bernard Moses, University of California.
Albert A. Michelson, University of Chicago.
J. Lawrence Laughlin, University of Chicago.
W. R. Shepherd, Columbia University.
Thomas Barbour, Harvard University.
A. C. Coolidge, Harvard University.
J. B. Woodworth, Harvard University.
Adolph Hempel, University of Illinois.
W. H. Holmes, George Washington University.
Orville A. Derby, Cornell University.
H. D. Curtis, University of Michigan.
W. F. Rice, Northwestern University.
L. S. Rowe, University of Pennsylvania.
Webster E. Browning, Princeton University.
William B. Smith, Tulane University.
Paul S. Reinsch, University of Wisconsin.
Hiram Bingham, Yale University.
D. E. Salas, National Education Association.

In June, 1908, meetings of the government delegates were held at the State Department, Washington, under the tutelage of Secretary Root, who conveyed to them such instructions as were deemed necessary. Arrangements were made for the preparation and translation of papers dealing with appropriate subjects for presentation at the congress, and for the disposal of the sum allotted by the Department for the purposes of the congress. The organization of the delegation was completed by the selection of Dr. L. S. Rowe as chairman and Prof. Paul S. Reinsch as vice-chairman.

Under the guidance of Doctor Rowe a number of the delegates assembled in Buenos Aires early in December, where they were the recipients of the hospitality of the President of the Republic and the members of his cabinet, and of the ministers of the United States and Chile. Visits were made to numerous institutions of learning, hospitals, municipal buildings, parks, etc., and the visit to the University of La Plata was signalized by an exceptionally cordial interchange of courtesies. On December 10 the party crossed the Andes and established headquarters in the Hotel Oddo in Santiago. Here, before and during the sittings of the congress, the delegation held frequent meetings to plan and discuss their work in the congress. Meantime other delegations, representing seven North American and Central American and nine South American republics, were on hand; and the meeting for the selection of officers for the congress was held at the University of Chile on December 24.[a] It is a noteworthy fact that the

[a] The result was as follows: President, Enrique R. de Lisboa, Brazilian minister; vice-presidents, Lorenzo Anadon, Argentine minister; Federico Survella S. Quash, delegate from Uruguay, and Matias Manzanilla, delegate from Peru; secretaries, Emilio Fernandez, delegate from Bolivia; Melchior Lazo de la Vega, delegate from Panama; and Enrique Martinez Sobral, delegate from Mexico.

president and vice-president of the congress were the envoys of their respective countries to Chile, thus giving to the congress a somewhat political aspect. This aspect was also imparted in a measure by the naming of representatives of a number of the governments in Chile as chairmen of the national delegations in the congress.

At 10 p. m. on Christmas Day the opening session was held in the spacious Municipal Theater, and proved a most impressive ceremony. The President of the Republic, Señor Pedro Montt, was present, and addresses were made by various officials of the congress and by chairmen of the various national delegations. The address of Doctor Rowe, chairman of the American delegation, delivered in Spanish, was enthusiastically received.[a]

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[a] ADDRESS OF DR. L. S. ROWE AT THE OPENING SESSION.

YOUR EXCELLENCY, LADIES AND GENTLEMEN: This congress possesses an historical significance which it is difficult for us to appreciate at the present time. It marks an epoch in the intellectual development of the American Continent.

Complete isolation from one another has characterized the situation of the countries of this continent. This isolation has been one of the greatest obstacles to progress. The failure to develop a spirit of intellectual cooperation has resulted in a great loss of energy and has been one of the most important obstacles to the solution of many problems which would long ago have been solved had we been able to unite our energies and profit by each other's experience. The true scientific spirit has a far deeper significance than the mere desire to conduct investigations. It can not reach its highest expression if there exist petty rivalries or jealousies. For this reason the development of the scientific spirit contributes so much to the growth of a true international fraternal spirit. A vigorous spirit of cooperation, developed amongst the scientists of the American Continent, will enable us to destroy the last traces of the epoch in which the words "stranger" and "enemy" were synonymous.

The industrial development of the last century offers lessons of much importance to the scientific world. A study of the economic growth of modern countries clearly shows that the principle of competition is gradually giving way to the principle of cooperation.

The formation of trusts as well as the growth of trades' unions constitutes the concrete expression of these new tendencies. The eighteenth century and a considerable portion of the nineteenth were dominated by a spirit of individualism. During more than four generations, it was taken for granted that human progress is dependent on the struggle for existence and the conflict between individual and individual. During the nineteenth century the application of biological principles to human society strengthened this idea. It is the mission of the twentieth century to demonstrate that we must regard the principle of cooperation rather than that of competition as the fundamental principle of social progress.

In this congress it is our high privilege to inaugurate a new epoch giving concrete form to the idea of intellectual cooperation. In the International Bureau of American Republics we have a central organization admirably adapted to contribute toward the realization of this idea. We need such a center in order to place investigators in different portions of the American Continent in contact with one another, and in order that the results of such investigations may be made the common property of all the nations of America.

In the name of the delegation of the United States of America, I desire to express our sincere thanks for this opportunity to take part in the deliberations of this congress. No better opportunity could have been offered to become acquainted with our colleagues and fellow-investigators. The ties here formed

The committee on organization was prompt in the preparation of the programme of meetings, and the press of the city was most generous and helpful in its treatment of the congress. The sectional meetings, which continued during eight days, were held separately under the following heads:

1. Mathematics, pure and applied.
2. Physical and chemical sciences.
3. Natural sciences—biology, paleontology, geology, anthropology, etc.
4. Engineering.
5. Medicine and hygiene.
6. Jurisprudence.
7. Social sciences.
8. Pedagogic sciences.
9. Agriculture and zootechny.

The programme was followed, with necessary modifications from day to day. The majority of the papers were read in full or in extended abstracts, and discussion was free and often spirited. Naturally, popular interest centered largely about the sections dealing with practical problems, as education, sanitation, social science, and engineering; but the more abstract sciences were not neglected. Owing to the great range of the work of the congress and the multiplicity of papers presented in the various sections, no attempt can be made in this place to present the work and results in detail. The list of papers presented by members of the American delegation and forwarded by the other contributors from the United States is as follows: [a]

Astronomical Problems of the Southern Hemisphere. By H. D. Curtis.

The Electronic Theory of Matter. By W. B. Smith.

Recent Progress in Spectroscopy. By A. A. Michelson.

Statistics of the Use of Nitrate of Soda in the United States. By Charles E. Munroe.

The Economy of Fuels. By William Kent.

Recent Studies in Experimental Evolution. By Thomas Barbour.

Notes on the Origin of the North American Prairies. By C. H. Hall.

Origin of the Minnesota Iron Ores. By C. H. Hall.

The Peopling of America. By W. H. Holmes.

The Newer Geological Views Regarding Subterranean Waters. By James F. Kemp.

The Mineral Wealth of America. By W. R. Ingalls and R. W. Raymond.

The Shaler Memorial Expedition. By J. B. Woodworth.

The Application of Electricity to Railways. By Frank J. Sprague.

Sanitation in the Tropics with Relation to Malaria and Yellow Fever. By W. C. Gorgas.

Frequency and Prevention of Yellow Fever. By C. J. Finlay.

Notes on the Sanitation of Yellow Fever and Malaria from Isthmian Experience. By H. R. Carter.

Plagues: Methods of Control. By J. C. Perry.

America in the Pacific. By A. C. Coolidge.

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possess a significance far deeper than the personal satisfaction they imply. This visit can not help but enlarge our mental horizon, broaden our scientific activity, and strengthen the influence of our university instruction. We congratulate ourselves on the privilege of being present, and desire also to express our appreciation of the great service performed by this Republic in giving such vigorous impulse to the spirit of scientific solidarity.

[a] This list is in part a translation from the Spanish, and may be somewhat imperfect.

America's Contributions to International Law. By Paul S. Reinsch.

Public Opinion as a factor in our American Democracies. By L. S. Rowe.

Reasons why the English Colonies on Achieving their Independence Became a Single State, whereas the Latin-American Colonies did not Form a Federation or even a Confederation. By Hiram Bingham.

Geological Work in Brazil. By Orville A. Derby.

Foundations of the Spanish and English Colonial Civilization in America. By Bernard Moses.

Gold and Prices. By J. Lawrence Laughlin.

Uniformity and Conformity in the Census Methods of the Republics of the American Continent. By S. N. D. North.

The Influence of Urban Environment on the Life and Thought of the People. By L. S. Rowe.

The Treatment of Indian Tribes of the United States. By Francis E. Leupp.

Race Degeneration. By W. B. Smith.

The Reclaiming of Arid Lands in the United States. By F. H. Newell.

Instruction in Animal Husbandry in the Agricultural Colleges of the United States. By George M. Rommel.

National Sanitary Animal Police in the United States. By George M. Rommel.

The Tendencies of Female Education and its Bearing on the Social Mission of the Women of America. By Wm. F. Rice.

Standard Time System. By Prof. David Todd.

Adaptation of Instruction to the American Social Medium. By W. R. Shepherd.

Nurses as Assistants in the Medical Inspection of Schools. By Dora Keen.

Recent Advances in the Study of Typhoid Fever. By M. J. Rosenau.

Pensioning Mothers who Depend on the Labor of their Sons, to Enable the Latter to Pursue their Studies. By Dora Keen.

Plans and Gauges of Intercontinental Railways. By Wm. J. Wilgus.

Some Phases of the Early History of Mexico and Central America. By Alcée Fortier.

The Writing of History in the United States. By W. M. Sloane.

The Value of Gas Power. By Charles E. Lucke.

Uniformity of Commercial Law throughout the American Continent. By Roscoe Pound.

Pan-American Terminology. By C. O. Mailloux.

Car Lighting in America. By R. M. Dixon.

Reinforced Concrete Construction for South America. By Wm. H. Burr.

The New Philippine Currency System. By E. W. Kemmerer.

Water Supply of Cities and Towns. By Allen Hazen.

Use of Tertiary Coals in General Metallurgy and in the Manufacture of Coke. By Wm. Hutton Blauvelt.

The Supply of Potable Water. By Rudolph Hering.

An Analysis of Five Hundred Cases of Epidemic Meningitis Treated with the Antimeningitis Serum. By James W. Jobling and Simon Flexner.

American Agriculture in its Relation to Chilean Nitrate. By Wm. S. Myers.

The Processes for the Concentration of Ore. By Robert H. Richards.

Future Supply of Iron Ore. By Henry M. Howe.

These papers, with the exception of a small number which did not arrive in time to find a place in the programme, were presented in Spanish, which was the almost exclusive language of the congress.

The concluding session of the congress was held at the university in the forenoon of January 5, and various matters of general interest were disposed of. These included a discussion of methods of procedure, policy, and scope of future

congresses, relation of the congress to government and science, etc. A number of resolutions, passed by the sections or presented by the delegations, were offered and adopted.[a] An agreement was reached to urge upon the legislative bodies of the various countries represented the adoption of uniform laws dealing with commerce, citizenship, etc., and a plan providing for such uniformity was adopted and will be submitted to the several governments.

By a practically unanimous vote it was decided to hold the next meeting in Washington in October, 1912. This action was cabled to the State Department, and Secretary Root responded in the following message:

"Please express to the Pan-American Scientific Congress the satisfaction with which this Government receives the announcement that Washington has been selected as the meeting place of the congress in 1912."

A committee of five members[b] was appointed to arrange with the Department of State at Washington for the appointment of a permanent organization committee for the prospective meeting.

A farewell session was held in the Municipal Theater on the afternoon of January 5, at which fitting addresses were made by officials and delegates;[c]

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[a] Resolution, extending to the governing board and director of the International Bureau of the American Republics the thanks of the Pan-American Scientific Congress for the offer of cooperation:

Whereas the Pan-American Scientific Congress has received with much satisfaction the cordial message of greetings from the Bureau of the American Republics and the kind offer of cooperation; be it

Resolved, That the formal thanks of the congress be transmitted to the governing board and director of the bureau, and that it be recommended to the members of the organization committee of the next Scientific Congress to avail themselves in every possible way of the valuable services which the bureau can render.

Resolution, recommending the establishment of a section of American bibliography in the International Bureau of the American Republics:

Recognizing the importance of establishing closer relations between investigators throughout the American continent and of disseminating the results of scientific investigations, the Pan-American Scientific Congress

Resolves, To recommend to the governing board of the International Bureau of the American Republics:

1. That a special section be established in the International Bureau of the American Republics to be known as the "Section of American Bibliography."

2. That the director of the bureau invite authors and investigators to send their publications to the bureau, on receipt of which notice thereof will be published in the Bulletin, which notice shall include at least a brief summary of the contents of such publication and the price thereof.

3. That the bureau secure for investigators any such publications at a price to be indicated in the Bulletin.

4. That the bureau endeavor so far as practicable to secure official publications for investigators.

5. That the bureau keep a record of the published progress of larger schemes of scientific investigations of Pan-American bearing; and that it strive to bring into closer contact investigators in the same or related fields.

[b] L. S. Rowe, George H. Rommel, W. H. Holmes, John Barrett, director of the Bureau of American Republics, and Elmer E. Brown, commissioner of education.

[c] CLOSING ADDRESS OF DR. L. S. ROWE.

MR. PRESIDENT, LADIES AND GENTLEMEN: The honor conferred upon my country through the designation of Washington as the next meeting place of this

and at night a dinner was given in the hall of the university, at which there was a generous expression of good feeling and a striking display of oratory.

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great assembly is the more significant because of its spontaneous character. For this demonstration of confidence, good will, and fraternal solidarity I want to thank you, not only in the name of the delegation of the United States of America, but also on behalf of that larger body of scientists and investigators who are imbued with the same spirit that has actuated this congress, and who now look forward to the privilege of welcoming to our shores the men upon whose efforts the progress of this continent depends. We can not hope to surpass the hospitality of this great republic, but we can assure you that the welcome will be no less sincere, and the determination to place every possible facility at your disposal, no less effective than has been the case here in Chile.

Viewed in its proper perspective, this congress has been one of the most extraordinary assemblages of modern times; more extraordinary in many respects than either The Hague or the Pan-American conferences. That a large group of men, representatives of every section of a great continent, should be able to get together and, casting aside all petty prejudices, freely and frankly exchange the results of their careful investigations and ripe experience, is not only a tribute to the culture of this continent, but is also an indication of the extent to which our ideas have advanced beyond those which we inherited from our European mother countries.

The fact that we have met to place the results of the best scientific thought at the disposal of all the countries here represented, and through them at the service of the civilized world, contains a lesson of deep and lasting import which no other assembly of modern times has been able so clearly to impress upon the civilized world.

The historian of the intellectual development of the American continent, in reviewing the work of these assemblies, will probably give to the Santiago congress the honor of having clearly demonstrated that the republics of the American continent, because of their geographical position; because of the peculiar conditions under which they were settled; and because of the special racial problems which they present, are confronted by a series of problems distinctively American. The mere fact of the existence of these problems involves an obligation not only to ourselves, but to the civilized world to concentrate our efforts upon their solution. Through their solution we can make that contribution to the progress of mankind which the world has the right to expect of us.

We can best hope to do this by carrying to our respective countries the spirit that has hovered over this congress—that of service in its broadest and highest sense. This spirit of service must be made the keynote of our national and of our international relations. The republics of the American continent must demonstrate to the civilized world that the willingness and determination to be of service to our fellow-men is the corner stone of a philosophy which the nations of this continent are determined to make the guiding principle of their conduct.

I can see a time, not far distant, when with each conquest of science the question will immediately arise in the mind of every American, "How can these results be made of service to the democracies of this continent?"—a time when in every field of endeavor the American republics may call upon one another for counsel in the solution of their problems, and be certain to receive the best expert advice. Then, and not till then, shall we have developed a real continental spirit; then, and not till then, shall we have fulfilled the obligations

The social features of the congress were most noteworthy. The President of the Republic, besides giving the usual official reception, entertained the foreign delegates at dinner, invitations being extended to a limited number each day during the congress. Receptions were given under government auspices at the principal social clubs. The American minister, the French, Brazilian, and Argentine ministers, and numerous prominent citizens entertained the delegates. Members of the American and other delegations were guests at a number of charming haciendas in the vicinity of Santiago; and the American delegation entertained at dinner members of the organization committee, chairmen of various national delegations, and others. Visits were made to institutions of learning, museums, art galleries, hospitals, and manufacturing establishments, and no effort was spared by the officials of the congress to make the visit of the foreign delegates enjoyable and profitable. The writer wishes to express his personal appreciation of these courtesies and attentions, and to say that he approached South America somewhat oppressed by the thought that he should find himself a stranger in a strange land, but that, on the contrary, there was not a day of the two months spent in the Latin-American countries on which he was not made to feel entirely at home and among appreciative and generous friends.

The universal feeling at the close of the congress was that the meeting had fully justified the plans of its projectors; and the story is not entirely told when it is stated that the elaborate programme, covering nearly every branch of science, was successfully carried out. The more thoughtful find in this and in kindred assemblages much that is of significance for the future of the American republics. This congress was a decided step in the direction of bringing about a better understanding among the nations represented. It was a step toward a fuller appreciation of the common interests of each and every American nation. It was an appreciable forward step in the development of the means and methods of promoting the common interests of the continent. It was a step toward making the experience and the accumulated wisdom of each people represented the experience and wisdom of all. In the section of pedagogy the best that has been developed in the theory and practice of teaching was made the common property of all the American republics. In the section of sanitary and medical science the latest achievements of each nation in the battle with disease were made familiar to every participant. In the section of agriculture and zootechnics steps were taken in the direction of properly utilizing and conserving the resources of the continent in these important realms. In the section of engineering the best methods of overcoming the various physical obstacles to progress and of winning the riches of the earth were explained for the benefit of all America. In the section of government and law the principles of statecraft and the administration of justice were discussed for the benefit of every American government. In the section of the fiscal sciences practical methods of conducting the monetary affairs of the nations were presented and

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which our privileged position in the world's affairs has placed upon us. I can imagine no greater distinction for the next congress than the possibility of marking a further step in the development of this spirit of service and of continental solidarity.

And, now, in closing, let me again extend the thanks of the delegation of the United States of America to you, the members of the organizing committee, for your broad grasp of the purposes of the congress and the skill with which these purposes have been made real and effective; to you, our colleagues, for your cordial reception of newcomers in your midst, and finally to the Government and people of Chile for the warm-hearted hospitality which we have enjoyed.

explained. And in every other branch of science, practical and abstract, the various forces and agencies that contribute toward progress and enlightenment were in a measure the subject of serious attention. The congress was an initial step toward making the best of all the peoples of the Western Hemisphere. It was an initial step in making the best, for to-day and for all time, of the resources of the continent. It was an initial step which in many ways must make for the peace and prosperity of the continent. It was a noteworthy step in conformity with manifest destiny as expressed in the phrase "America for Americans."

The success of the congress of 1912 depends upon the interest displayed in it by the scientific world, and on the support accorded by the Pan-American governments. The time is ample, and the appointment of an organization committee representative of a wide range of scientific interests is the first step in making the Washington meeting an event worthy of the nation and its capital.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDING JUNE 30, 1909.

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, 1909, together with balances of previous appropriations.

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1909.

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		7,918.69
Total amount of fund in the United States Treasury		944,918.69

OTHER RESOURCES.

Registered and guaranteed bonds of the West Shore Railroad Company, part of legacy of Thomas G. Hodgkins (par value)	$42,000.00
Total permanent fund	986,918.69

Also four small pieces of real estate 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 August 10, 1846, organizing the Institution, and act of Congress 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, 1908, to June 30, 1909.

RECEIPTS.

Cash on deposit in the U. S. Treasury July 1, 1908		$18,766.41
Interest on fund deposited in the U. S. Treasury, due July 1, 1908, and January 1, 1909	$56,695.12	
Interest on West Shore Railroad bonds to January 1, 1909	1,680.00	
Repayments, rentals, publications, etc	6,144.70	
Contributions from various sources for specific purposes	20,250.00	
		84,769.82
		103,536.23

DISBURSEMENTS.

Buildings, care and repairs		$4,445.31
Furniture and fixtures		512.38
General expenses:		
Salaries	$14,468.19	
Meetings	305.00	
Stationery	664.21	
Postage, telegraph, and telephone	324.02	
Freight	124.55	
Incidentals	1,153.59	
Garage	[a] 4,342.77	
		21,382.33
Library		1,938.64
Publications and their distribution:		
Miscellaneous collections	2,430.79	
Reports	496.89	
Special publications	3,260.75	
Publication supplies	206.26	
Salaries	5,884.58	
		12,279.27
Explorations, researches, and collections		20,810.43
Hodgkins specific fund, researches and publications		3,053.50
International Exchanges		4,216.78
Legal expenses		2,717.62
Apparatus		3.27
		71,359.53
Balance June 30, 1909, deposited with the Treasurer of the United States.		32,176.70
		103,536.23

[a] Includes purchase of automobile in February, 1909, and maintenance, and also expenses of stable until abolished.

By authority, your executive committee employed Mr. William L. Yaeger, a public accountant of this city, to audit the receipts and disbursements of the Smithsonian Institution during the period covered by this report. His certificate of examination supports the foregoing statement and contains the following, which is hereby approved:

402 WESTORY BUILDING,
Washington, D. C., September, 1, 1909.

The EXECUTIVE COMMITTEE, BOARD OF REGENTS,
Smithsonian Institution.

SIRS: I have examined the accounts and vouchers of the Smithsonian Institution for the fiscal year ending June 30, 1909, and certify the following to be a correct statement:

Total receipts	$84,769.82	
Total disbursements	71,359.53	
Excess of receipts over disbursements		$13,410.29
Amount from July 1, 1908		18,766.41
Balance on hand June 30, 1909		32,176.70
Balance shown by Treasury statement June 30, 1909	$34,804.91	
Less outstanding checks	2,753.21	
	32,051.70	
Cash overdrawn on pay roll June 30, 1909	125.00	
True balance, June 30, 1909		32,176.70

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.

Yours, respectfully,

WILLIAM L. YAEGER,
Public Accountant and Auditor.

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 1909, 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, 1909.

Summary of appropriations.

	Available after July 1, 1908.	Balance June 30, 1909.
Smithsonian Institution, balance July 1, 1908	$18,766.41	....
Smithsonian Institution, receipts to June 30, 1909	84,769.82	....
	103,536.23	$32,176.70
Appropriations committed by Congress to care of the Institution:		
International exchanges, 1908	2,667.88	1.17
International exchanges, 1909	32,000.00	2,232.17
American Ethnology, 1907	10.26	a 10.26
American Ethnology, 1908	947.64	1.78
American Ethnology, 1909	42,000.00	1,175.47
Astrophysical Observatory, 1907	36.50	a 34.35
Astrophysical Observatory, 1908	2,155.35	81.19
Astrophysical Observatory, 1909	13,000.00	1,571.01
International Catalogue, 1907	11.24	a 11.24
International Catalogue, 1908	145.37	6.44
International Catalogue, 1909	5,000.00	75.11
Ruin of Casa Grande, 1907	.53	a .53
Ruin of Casa Grande, 1908	7.98	7.98
National Museum:		
Furniture and fixtures, 1907	133.79	a 133.79
Furniture and fixtures, 1908	1,813.83	30.98
Furniture and fixtures, 1909	50,000.00	22,307.16
Heating and lighting, 1907	137.70	a 137.70
Heating and lighting, 1908	1,345.14	43.80
Heating and lighting, 1909	22,000.00	2,967.48
Preservation of collections, 1907	471.89	a 409.28
Preservation of collections, 1908	4,767.33	496.78
Preservation of collections, 1909	190,000.00	4,869.31
Books, 1907	31.31	a 15.81
Books, 1908	935.04	92.21
Books, 1909	2,000.00	1,083.34
Postage, 1909	500.00	....
Building repairs, 1907	35.88	a 35.88
Building repairs, 1908	555.90	5.83
Building repairs, 1909	15,000.00	6,028.68
Rent of workshops, 1907	.08	a .08
Rent of workshops, 1908	.08	.08
Rent of workshops, 1909	4,580.00	.08
Printing and binding, 1909	72,600.00	9,398.58
National Zoological Park, 1907	1.82	a 1.82
National Zoological Park, 1908	4,821.57	11.41
National Zoological Park, 1909	95,000.00	2,443.69
Temporary occupancy of government buildings for tuberculosis congress	40,000.00	15,678.92
Transfer of Greenough statue of Washington	5,000.00	409.74
	713,250.34	....

a Balance carried June 30, 1909, to the credit of surplus fund, Treasury Department, under provisions of section 3691, Revised Statutes.

Statement of income from the Smithsonian fund and other revenues, accrued and prospective, available during the fiscal year ending June 30, 1910.

Balance June 30, 1909	$32,176.70
Less deposits for specific purposes	1,000.00
	31,176.70
Interest on fund deposited in the U. S. Treasury, due July 1, 1909, and January 1, 1910	56,695.00
Interest on West Shore Railroad bonds, due July 1, 1909, and January 1, 1910	1,680.00
Exchange repayments, sale of publications, rentals, etc	4,245.00
Total available for year ending June 30, 1910	93,796.70

Respectfully submitted.

J. B. HENDERSON,
ALEXANDER GRAHAM BELL,
JOHN DALZELL,
Executive Committee.

WASHINGTON, D. C., *November 8, 1909.*

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1909.

At the annual meeting of the Board of Regents held on January 22, 1908, the following resolution was adopted:

Resolved, That hereafter the Board of Regents of the Smithsonian Institution shall hold an annual meeting on the Tuesday after the second Monday in December and another meeting on the second Wednesday in February.

In accordance with this resolution the board met at 10 o'clock a. m. on December 15, 1908, and on February 10, 1909.

ANNUAL MEETING, DECEMBER 15, 1908.

Present: Hon. M. W. Fuller, Chief Justice of the United States (chancellor), in the chair; Hon. Charles W. Fairbanks, Vice-President of the United States; Senator S. M. Cullom, Senator Henry Cabot Lodge, Senator A. O. Bacon, Representative James R. Mann, Representative William M. Howard, Hon. John B. Henderson, Dr. James B. Angell, Dr. Andrew D. White, Dr. Alexander Graham Bell, Mr. Charles F. Choate, jr., and the secretary, Mr. Charles D. Walcott.

APPOINTMENT OF REGENT.

The secretary announced the appointment, by joint resolution approved by the President February 24, 1908, of Mr. Charles F. Choate, jr., of Massachusetts, as a Regent to succeed Mr. Richard Olney, resigned.

ACKNOWLEDGMENT FROM MR. RICHARD OLNEY.

The secretary read the following letter from Mr. Richard Olney in acknowledgment of the action of the Board of Regents upon his resignation as a Regent:

Boston, *January 25, 1908.*

Hon. Charles D. Walcott,
Secretary Smithsonian Institution, Washington, D. C.

My Dear Sir: I beg to acknowledge your favor of the 23d instant and to thank the Board of Regents through you for the complimentary terms of the resolution, copy of which you inclose.

I am also greatly obliged to you personally for your courteous and friendly expressions and remain,

Faithfully,

Richard Olney.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Mr. Henderson, chairman of the executive committee, offered the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1910, be appropriated for the service of the Institution, to be expended by the secretary, with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Mr. Henderson submitted the report of the executive committee for the fiscal year ending June 30, 1908, which, on motion, was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

Mr. Henderson, chairman of the permanent committee, presented the following report:

Hodgkins fund.—In addition to the sum of $100,000 bequeathed to the Institution by Thomas G. Hodgkins upon condition that the income be devoted to the increase and diffusion of knowledge regarding the nature and properties of atmospheric air, which sum is on deposit in the Treasury of the United States, there is now deposited in the Treasury to the credit of the Smithsonian fund the sum of $157,918.69 received from the Hodgkins estate, the income from which is, in accordance with the direction of the testator, devoted to the general purposes of the Institution. Besides the regular income of 6 per cent per annum on these portions of the fund, the Institution has received semiannually a dividend of 4 per cent on the West Shore Railroad bonds, of the par value of $42,000, accruing to the Institution from the Hodgkins estate. A number of grants have been authorized from the Hodgkins fund during the year for the promotion of researches relating to subjects embraced within the expressed purposes of the foundation, and a prize of $1,500 has been offered, in connection with the recent International Congress on Tuberculosis, for the best treatise "On the relation of atmospheric air to tuberculosis."

Andrews estate.—The decision of the supreme court of New York, appellate division, in April, 1907, affirming the decree below, which gave the residue of the estate of Mr. Wallace C. Andrews to the Andrews Institute for Girls, at Willoughby, Ohio, was, upon appeal by the Smithsonian Institution, affirmed on February 25, 1908, by the New York court of appeals. On motion of Mr. Frank W. Hackett and Mr. Edmund Wetmore, counsel for the Smithsonian Institution, a writ of error has been allowed by Mr. Justice Peckham,

of the Supreme Court of the United States, to the supreme court of the State of New York, the contention of counsel being that the court of appeals did not give full faith and credit to the constitution of Ohio in respect to prohibiting the general assembly of that State from passing special acts conferring corporate powers.

Avery estate.—The Institution has continued in possession of four parcels of real estate in Washington City, received under the bequest of Mr. Robert Stanton Avery. Three of these parcels are improved with frame dwellings, under rental.

Sprague and Reid bequests.—As has been previously stated to the board, the residual legacies accruing to the Institution under the wills of Mr. Joseph White Sprague and Mr. Addison T. Reid are subject to the demise of certain enumerated legatees, and it is probable that no actual income will be received from these bequests for some years to come.

On motion, the report was accepted.

ANNUAL REPORT OF THE SECRETARY.

The secretary presented his report for the fiscal year ending June 30, 1908, explaining that it had been already transmitted to the members of the board.

On motion, the report was accepted.

NATURAL HISTORY EXPEDITION TO AFRICA.

The secretary read the following letter:

THE WHITE HOUSE, WASHINGTON,
OYSTER BAY, NEW YORK, *June 20, 1908.*

MY DEAR DOCTOR WALCOTT: About the 1st of April next I intend to start for Africa. My plans are of course indefinite, but at present I hope they will be something on the following order:

By May 1 I shall land at Mombasa and spend the next few months hunting and traveling in British and German East Africa; probably going thence to or toward Uganda, with the expectation of striking the Nile about the beginning of the new year, and then working down it, with side trips after animals and birds, so as to come out at tide water, say, about March 1. This would give me ten months in Africa. As you know, I am not in the least a game butcher. I like to do a certain amount of hunting, but my real and main interest is the interest of a faunal naturalist. Now, it seems to me that this opens the best chance for the National Museum to get a fine collection not only of the big game beasts, but of the smaller mammals and birds of Africa; and looking at it dispassionately, I believe that the chance ought not to be neglected. I will make arrangements to pay for the expenses of myself and my son. But what I would like to do would be to get one or two professional field taxidermists, field naturalists, to go with me, who should prepare and send back the specimens we collect. The collection which would thus go to the National Museum would be of unique value. It would, I hope, include specimens of big game, together with the rare smaller animals and birds. I have not the means that would enable me to pay for the field naturalists or taxidermists and their kit, and the curing and transport of the specimens for the

National Museum. Of course the actual hunting of the big game I would want to do myself, or have my son do; but the specimens will all go to the National Museum, save a very few personal trophies of little scientific value which for some reason I might like to keep. Now, can you, in view of getting these specimens for the National Museum, arrange for the services of the field taxidermists, and for the care and transport of the specimens? As ex-President, I should feel that the National Museum is the museum to which my collection should go.

With high regard, sincerely yours,

THEODORE ROOSEVELT.

Hon. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution,
Washington, D. C.

The secretary went on to say: "A copy of this letter was forwarded to me in Montana, and I telegraphed that we would endeavor to provide the necessary funds. On my return to Washington I put myself in communication with several public-spirited men who are friends of the Institution, and succeeded in obtaining sufficient money to equip and send the expedition to Africa; and there are assurances of additional sums to meet the further expenses that will necessarily be incurred.

"As to the personnel of the expedition, the following gentlemen have been selected by the Institution to accompany the President:

"Maj. Edgar A. Mearns, a retired officer of the Medical Corps of the Army, will be in charge of the Smithsonian party. He will be the physician of the trip; he has had twenty-five years' experience as an army doctor, and is also well known as a naturalist and collector of natural history specimens; while on service in the Philippine Islands, he made large collections of birds, mammals, and other material for the National Museum.

"Mr. Edmund Heller, a graduate of Stanford University, is a thoroughly trained naturalist, whose special work will be the preparation and preservation of specimens of large animals. His former experience, when associated with Mr. D. G. Eliot and Mr. Ackley, of the Field Columbian Museum, in collecting big game animals in the same portions of Africa which Mr. Roosevelt will visit, will be a valuable asset to the expedition. Mr. Heller has had large experience in animal collecting in Alaska, British Columbia, United States, Mexico, Central America, and South America. In the year 1898 he made a collecting trip of eleven months to Galapagos Islands, starting from San Francisco. He is a born and enthusiastic collector and a well-equipped naturalist. He is also the author of scientific papers on mammals, birds, reptiles, and fishes. At present he is assistant curator of the Museum of Vertebrate Zoology of the University of California.

"Mr. J. Alden Loring is a field naturalist whose training comprises service in the biological survey of the Department of Agriculture

and in the Bronx Zoological Park, New York City, as well as on numerous collecting trips through British America, Mexico, and the United States. He is of ardent temperament and intensely energetic. In August, September, and October, 1898, he made the highest record for a traveling collector, having sent to the United States National Museum 900 well prepared specimens of small mammals in the three months journey from London through Sweden, Germany, Switzerland, and Belgium."

In regard to the matter of funds for the expedition, the secretary said that in addition to the statement he had just made he would read the following notice which had appeared in the public press:

"President Roosevelt decided last spring upon the proposed hunting trip to Africa, and during the summer Secretary Walcott learned that the President was willing to have one or two naturalists accompany him from the Smithsonian Institution, provided their expenses could be met; and also that the collections made by the President and these naturalists were to come to the Smithsonian Institution and be deposited in the United States National Museum.

"Mr. Roosevelt will pay all the expenses of himself and his son, Kermit, in connection with the proposed trip, including outfitting and transportation.

"The expenses of the three naturalists sent out from the Smithsonian Institution will be paid by funds provided for the purpose, no part of which is derived from any government appropriation or from the income of the Smithsonian fund.

"Mr. Roosevelt will not receive one penny of the fund for his own or his son's use or expenses; on the contrary, he makes a gift to the Government of specimens worth many thousands of dollars, and possibly of a value that can hardly be expressed. He will get nothing from the Government; he will give much of value to the Government; the Government's share will be limited to receiving the gift."

After discussion, the Vice-President offered the following resolution, which was adopted:

Resolved, That the Board of Regents of the Smithsonian Institution express to Theodore Roosevelt, President of the United States, its appreciation of his very generous offer contained in his letter of the 20th of June, 1908, to the secretary of the Institution, with respect to his expedition to Africa, and that it accept the same.

Doctor White said that he thought it might be well to complete the resolution which had been offered by the Vice-President by adopting another, in which the secretary should be requested to return the thanks of the board to the gentlemen who had so generously contributed to relieve the Smithsonian Institution of the expenses of the expedition. He spoke of the misunderstanding that had arisen by reason of the first published statement that the expedition would

be outfitted by the Institution, and he thought a resolution of thanks due the gentlemen who had displayed such public spirited citizenship. On motion, the following resolution was adopted:

Resolved, That the thanks of the Board of Regents of the Smithsonian Institution be conveyed by the secretary of the Institution to the donors who have so generously contributed funds to meet the expenses of naturalists who will accompany Mr. Theodore Roosevelt upon his expedition to Africa, the results of which will be presented by the President to the Smithsonian Institution for the National Museum.

PROPOSED LANGLEY MEDAL AND TABLET.

The secretary read the following letter:

BEINN BHREAGH, NEAR BADDECK, NOVA SCOTIA,
December 5, 1908.

Hon. C. D. WALCOTT,
Secretary Smithsonian Institution, Washington, D. C.

DEAR SECRETARY WALCOTT: The Wright brothers are being deservedly honored in Europe. Can not America do anything for them? Why should not the Smithsonian Institution give a Langley medal to encourage aviation?

Yours, sincerely,

ALEXANDER GRAHAM BELL.

The secretary said that Secretary Langley was undoubtedly the founder of the present school of aviation; that all the students of the subject were now adopting the principles which he announced, and it would appear to be a proper action on the part of the Board of Regents to recognize his work in this subject by the establishment of such a medal.

After discussion, the following resolution was adopted on motion of Senator Cullom:

Resolved, That the Board of Regents of the Smithsonian Institution establish a medal to be known as the "Langley medal," to be awarded for specially meritorious investigations in connection with the science of aerodromics and its application to aviation.

Senator Bacon said that further recognition should be given Secretary Langley by the erection in the Smithsonian building of a memorial tablet setting forth his services in this important subject, and, after discussion, Senator Lodge offered the following resolution, which was adopted:

Resolved, That the Secretary of the Smithsonian Institution be requested to report to the Board of Regents as soon as practicable upon the erection in the Institution building of a tablet to the memory of Secretary Langley, setting forth his services in connection with the subject of aerial navigation.

SECRETARY'S STATEMENT.

Resignation of Assistant Secretary Adler.—I greatly regret to report to you that Dr. Cyrus Adler, assistant secretary of the Smithsonian Institution, in charge of the library and exchanges, resigned that

position on October 1, 1908, removing to Philadelphia to assume the presidency of The Dropsie College for Hebrew and Cognate Learning.

Doctor Adler entered the service of the Institution in 1888 as an assistant curator in the National Museum. In 1892 he was appointed librarian of the Institution, and in 1905 became assistant secretary. His service of twenty years was marked by a wonderful grasp of detail, and he was an invaluable aid to the secretary in all matters pertaining to the scope of the Institution's work as well as to its administration. He was a man of keen judgment and wide culture and an exceedingly useful member of the Institution's executive force.

Death of Prof. Otis T. Mason.—It is with deep regret that I have to announce the death, on November 5, 1908, of one of our strong men, Prof. Otis T. Mason, who had been associated with the Institution since 1873, first as a collaborator in ethnology, next as curator of that branch, and finally as head curator of the department of anthropology. Professor Mason was born in 1838, so that his life has been almost contemporaneous with the Smithsonian Institution, and he bears an honorable share in its history. His agreeable qualities as a man, his earnestness in his work, and his contagious enthusiasm render this loss a most severe one to the Institution.

Tuberculosis Congress.—In compliance with the direction of the President, the new building for the National Museum was selected for the meetings and exhibits of the International Congress on Tuberculosis, $40,000 being placed at the disposal of the secretary for the requisite arrangements in this connection.

The plans for the adaptation of the building to this purpose were put in the hands of the superintendent of construction, Mr. Bernard R. Green. About 100,000 square feet of the building on the first and second floors, exclusive of the south wings, were used for the congress, and indebtedness is acknowledged to the War, Navy, and Treasury departments, and also to the Bureau of American Republics, which supplied the flags of the United States and of foreign nations for decorating the halls.

The congress opened on September 21 and adjourned on October 12. By November 3 all traces of the convention had been removed and the building was again ready for the resumption of construction operations. The amount expended in fitting up the building for the congress was $24,321.08.

Thirty-one independent nations and 45 States of the Union were represented. There were 438 contributors, of whom 312 were citizens of the United States. The total attendance to the congress was approximately 148,000.

Among the contributors to the exhibits, the Smithsonian Institution presented the results of an investigation among certain of the Indian tribes, for the Department of the Interior, with a view to

showing the actual amount of tuberculosis existing. This work was prepared by Dr. Aleš Hrdlička, of the National Museum, who visited the Menominee, Sioux, Quinault, Hupa, and Mohave tribes. The congress expressed its appreciation of it by awarding the Institution a gold medal.

The secretary added that the prize of $1,500 offered by the Institution for the best essay "On the relation of atmospheric air to tuberculosis" had aroused widespread interest among the students on this subject, and had resulted in the receipt by the Institution of eighty-one papers submitted in competition. All of these had been referred to a committee for consideration, but the award had not yet been made.

Use of B street north of National Museum as a market place.—The secretary stated that the new building for the National Museum would be occupied during the coming summer; that the occupation of B street north of this building as a market place was a serious objection and that it was very desirable that the street be vacated by hucksters and market men. On behalf of the executive committee he offered the following resolution, which, after discussion, was adopted:

Resolved, That in the judgment of the Board of Regents of the Smithsonian Institution, provision should be made at the earliest practicable moment for the abolition of the use of B street north of the National Museum, between Ninth and Twelfth streets, as a market place.

It was suggested that the Commissioners of the District of Columbia be communicated with before calling the attention of Congress to the matter.

Prize essay on fisheries.—In response to an invitation from the International Fishery Congress, the fourth session of which was held in Washington, September 22 to 26, 1908, the Institution made an allotment of $200 from the Smithsonian fund for the best essay or treatise on "International regulation of the fisheries on the high seas; their history, objects, and results."

As announced by the general secretary of the congress, the award was made to Mr. C. H. Stevenson, statistician, U. S. Bureau of Fisheries, and the amount has been paid to him.

Transfer of Greenough's Washington statue to the Smithsonian Institution.—The secretary said that on January 31, 1908, Representative James R. Mann introduced in the House a joint resolution (H. J. Res. 124) for the presentation to the Smithsonian Institution of the Greenough statue of Washington, located in the Capitol grounds, "to aid that Institution in its efforts to establish a national gallery of art in the city of Washington." The resolution was referred to the Committee on the Library, from which it was reported, striking out the reference to the national gallery of art. The joint resolution was agreed to in the House on March 17, 1908, and later reported

from the Senate Committee on the Library, with amendments, changing the words "presented to" to "transferred to the custody of," and modifying the title accordingly. The amendments were agreed to by the House and the measure received the President's approval in this form May 22, 1908.

The general deficiency act as approved May 30, 1908, appropriates $5,000 for the transfer of the statue from the plaza in front of the Capitol to the Institution, under the direction of the Secretary of the Smithsonian Institution and the Superintendent of the Capitol Building and Grounds. The expense of construction of a foundation and a marble base is to be provided from the sum named.

The statue has been moved to the lawn to the south of the west wing of the Smithsonian building, where it is now temporarily housed. It will be permanently placed as soon as the necessary foundation has been constructed in the hall at the end of the west wing of the building.

Freer collection.—The secretary stated that in response to a suggestion from him, Mr. Charles L. Freer had sent him a condensed list of art objects, the title to which had already been passed by him to the Smithsonian Institution. The list follows:

Pictures by D. W. Tryon in oil, water color, and pastel	33
Pictures by Thomas W. Dewing in oil, water color, pastel, and silver point	24
Pictures by Abbott H. Thayer in oil and water color	10
Pictures by J. McNeill Whistler in oil, water color, pastel, pen and pencil drawings, engravings, etchings, and lithographs	1,079
Oriental paintings:	
Screens	143
Panels	64
Kakemono	309
Makimono	13
Albums	4
Tibetan paintings	13
Oriental pottery	1,140
Bronzes	13
Miscellaneous Egyptian and other objects	28
Total number of objects	2,873

The secretary continued that during the past year Mr. Freer had secured a great deal of valuable material that would be added to the collection, and it was very probable that with these additions the entire collection at present represented a total cost to the donor of about $1,000,000.

Use of Smithsonian building for national gallery of art.—The secretary said that in the coming spring and summer it was expected to begin the removal of material to the new building for the National Museum, which would be devoted to the natural history collections. The present Museum building would be assigned to the industrial art

exhibits, and the Smithsonian building would be used for the fine arts, if suitable provision for the reception of the paintings could be made.

At its last meeting the board recommended that an appropriation of $60,000 be asked of Congress to be used in adapting the large anthropological hall of the Smithsonian building to this purpose. The estimate was submitted but had not been acted upon by Congress. It was hoped that the matter would be taken up at an early day, as it was becoming more and more necessary to make adequate provision for the collections that were being presented to the national gallery of art.

REGULAR MEETING, FEBRUARY 10, 1909.

Present: Hon. M. W. Fuller, Chief Justice of the United States (chancellor), in the chair; Senator Henry Cabot Lodge, Representative James R. Mann, Dr. James B. Angell, Hon. George Gray, and the secretary, Mr. Charles D. Walcott.

AWARD OF LANGLEY MEDAL.

The secretary stated that since the adoption of the resolution establishing the Langley medal he had appointed a committee of award composed of the following gentlemen of recognized attainments in the science of aerodromics:

Mr. Octave Chanute, of Chicago, chairman.

Dr. Alexander Graham Bell.

Maj. George O. Squier, U. S. Army.

Mr. John A. Brashear, Allegheny, Pennsylvania.

Mr. James Means, formerly editor of the Aeronautical Annual, Boston, Massachusetts.

Senator Lodge said that the results attained by the Wright brothers would certainly entitle them to the Langley medal. He had been in Paris last summer during the flights of Wilbur Wright and had noticed the great interest aroused by them and the marked recognition given Wright by foreign nations. He thought that the United States should also honor these citizens for their great work in this science, and he was very anxious that they should be the first recipients of the Langley medal. Therefore, while he did not desire to interfere with the committee of award appointed by the secretary, he was anxious that immediate action be taken, and he thought that the committee's hands might be strengthened by a formal expression of the board. He therefore offered the following resolution, which, after discussion, was adopted:

Resolved, That the Langley medal be awarded to Wilbur and Orville Wright for advancing the science of aerodromics in its application to aviation by their successful investigations and demonstrations of the practicability of mechanical flight by man.

CHANGE OF DAY FOR MEETING.

The secretary spoke of the practical impossibility of getting a full attendance of the Congressional Regents on Wednesday, owing to committee engagements. It was then suggested that Thursday be substituted for Wednesday, and Senator Lodge offered the following resolution, which was adopted:

Resolved, That hereafter the Board of Regents of the Smithsonian Institution shall hold their annual meeting on the Tuesday after the second Monday in December, and another meeting on the second Thursday in February.

DARWIN CELEBRATION.

The secretary stated that in June next the University of Cambridge would celebrate the one hundredth anniversary of the birth of Charles Darwin, and that he had thought of attending the commemoration as the representative of the Smithsonian Institution.

Doctor Angell suggested that it would be appropriate for the board to formally designate the secretary as the representative of the Institution at the Darwin celebration, and he offered the following resolution, which was adopted:

Resolved, That the Secretary of the Smithsonian Institution be designated the special representative of the Institution at the commemoration of the centenary of Charles Darwin's birth, to be held at the University of Cambridge, England, June 22 to 24, 1909.

MISCELLANEOUS.

The secretary spoke briefly upon the progress in the several departments of work under the direction of the Institution since the last meeting of the board.

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION AND ITS BRANCHES.

[Continued from previous Reports.]

[Sixtieth Congress, first session.]

SMITHSONIAN INSTITUTION.

SMITHSONIAN GROUNDS: For improvement, care, and maintenance of Smithsonian grounds, three thousand dollars. (Approved March 4, 1909; Statutes XXXVI, 994.)

WATCHMEN, SMITHSONIAN GROUNDS: For day watchmen as follows: One in Franklin Park; one in Lafayette Park; two in Smithsonian grounds; one in Judiciary Park; one in Lincoln Park and adjacent reservations; one at Iowa Circle; one at Thomas Circle and neighboring reservations; one at Washington Circle and neighboring reservations; one at Dupont Circle and neighboring reservations; one at McPherson and Farragut parks; one at Stanton Park and neighboring reservations; two at Henry and Seaton parks; one at Mount Vernon Park and adjacent reservations, one for the greenhouses and nursery; two at grounds south of Executive Mansion; one at Garfield Park; one at Monument Park; and one at Monument Park Annex (Potomac Park); twenty-one in all, at seven hundred and twenty dollars each, fifteen thousand one hundred and twenty dollars.

For night watchmen as follows: Two in Smithsonian grounds; one in Judiciary Park; two in Henry and Seaton parks; one in grounds south of Executive Mansion; one in Monument Park; one at Monument Park Annex (Potomac Park); and two in Garfield Park; ten in all, at seven hundred and twenty dollars each, seven thousand two hundred dollars. (Approved March 4, 1909; Statutes XXXVI, 881.)

PRINTING AND BINDING: For the Smithsonian Institution, for printing and binding the Annual Reports of the Board of Regents, with general appendixes, ten thousand dollars; under the Smithsonian Institution, for the Annual Reports of the National Museum, with general appendixes, and for printing labels and blanks and for the Bulletins and Proceedings of the National Museum, the editions of which shall not exceed four thousand copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library, thirty-four thousand dollars; for the Annual Reports and Bulletins of the Bureau of American Ethnology, and for miscellaneous printing and binding for the bureau, twenty-one thousand dollars; for miscellaneous printing and binding for the International Exchanges, two hundred dollars; the International Catalogue of Scientific Literature, one hundred dollars; the National Zoological Park, two hundred dollars; the Astrophysical Observatory, two hundred dollars; and for the Annual Report of the American Historical Association, seven thousand dollars; in all, seventy-two thousand seven hundred dollars. (Approved March 4, 1909; Statutes XXXVI, 1022-3.)

APPORTIONING ALLOTMENTS FOR PRINTING AND BINDING: Except the appropriations for salaries in the office of the superintendent of documents, and for stores and general expense for the office of the superintendent of documents, all appropriations made herein under "Government Printing Office" shall be considered in apportioning the allotments for printing and binding to the Congress and the several executive departments, bureaus, and independent offices of the Government: *Provided*, That no other fund appropriated by this act, or any other act, shall be used for services or other purposes in the Government Printing Office, or in the office of the superintendent of documents, of the character specified in the foregoing paragraphs, except in cases of emergency arising after the passage of this act, and then only on the written order of the Public Printer; and the aggregate of all salaries or other expenses thus paid, in addition to those specifically appropriated for above, shall be reported to Congress each year in connection with the annual estimates. (Approved March 4, 1909; Statutes XXXVI, 1021.)

SMITHSONIAN DEPOSIT (LIBRARY OF CONGRESS): For custodian, one thousand five hundred dollars; assistant, one thousand four hundred dollars; messenger, seven hundred and twenty dollars; messenger boy, three hundred and sixty dollars; in all, three thousand nine hundred and eighty dollars. (Approved March 4, 1909; Statutes XXXVI, 857.)

IMPORTATION OF CERTAIN INJURIOUS BIRDS AND ANIMALS:

* * * * * * *

SEC. 241. The importation into the United States, or any Territory or District thereof, of the mongoose, the so-called "flying foxes" or fruit bats, the English sparrow, the starling, and such other birds and animals as the Secretary of Agriculture may from time to time declare to be injurious to the interests of agriculture or horticulture, is hereby prohibited; and all such birds and animals shall, upon arrival at any port of the United States, be destroyed or returned at the expense of the owner. No person shall import into the United States or into any Territory or District thereof, any foreign wild animal or bird, except under special permit from the Secretary of Agriculture: *Provided*, That nothing in this section shall restrict the importation of natural history specimens for museums or scientific collections, or of certain cage birds, such as domesticated canaries, parrots, or such other birds as the Secretary of Agriculture may designate. The Secretary of the Treasury is hereby authorized to make regulations for carrying into effect the provisions of this section.

SEC. 242. It shall be unlawful for any person to deliver to any common carrier for transportation, or for any common carrier to transport from any State, Territory, or District of the United States, to any other State, Territory, or District thereof, any foreign animals or birds the importation of which is prohibited, or the dead bodies or parts thereof of any wild animals or birds, where such animals or birds have been killed or shipped in violation of the laws of the State, Territory, or District in which the same were killed, or from which they were shipped: *Provided*, That nothing herein shall prevent the transportation of any dead birds or animals killed during the season when the same may be lawfully captured, and the export of which is not prohibited by law in the State, Territory, or District in which the same are captured or killed: *Provided further*, That nothing herein shall prevent the importation, transportation, or sale of birds or bird plumage manufactured from the feathers of barnyard fowls.

SEC. 243. All packages containing the dead bodies, or the plumage, or parts thereof, of game animals, or game or other wild birds, when shipped in interstate or foreign commerce, shall be plainly and clearly marked, so that the name and address of the shipper, and the nature of the contents, may be readily ascertained on an inspection of the outside of such package. (Approved March 4, 1909; Statutes XXXVI, 1137.)

REARRANGEMENT OF ESTIMATES WHEN NOT TRANSMITTED IN PROPER FORM:

* * * * * * *

SEC. 4. When estimates hereafter transmitted to the Treasury for submission to Congress do not in form and arrangement comply with the provisions of section four of the legislative, executive, and judicial appropriation act, approved June twenty-second, nineteen hundred and six, they shall, under direction of the Secretary of the Treasury, be rearranged so as to comply with said requirements of law. (Approved, March 4, 1909; Statutes XXXVI, 907.)

MEMORIAL TO JOHN WESLEY POWELL: For the purpose of procuring and erecting on the brink of the Grand Canyon, in the Grand Canyon Forest Reserve in Arizona, a memorial to the late John Wesley Powell, with a suitable pedestal, if necessary, in recognition of his distinguished public services as a soldier, explorer, and administrator of government scientific work, five thousand dollars: *Provided*, That the design for said memorial and the site for the same shall be approved by the Secretary of the Interior. (Approved March 4, 1909; Statutes XXXVI, 992.)

ALASKA-YUKON-PACIFIC EXPOSITION: The United States Government Board of Managers of the Alaska-Yukon-Pacific Exposition is authorized to rent such workshops, storage and office rooms in the District of Columbia as may be required in connection with the preparation, safe-keeping, and return of the government exhibit authorized by act of Congress, approved May twenty-seventh, nineteen hundred and eight. (Approved March 4, 1909; Statutes XXXVI, 963.)

INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, thirty-two thousand dollars. (Approved March 4, 1909; Statutes XXXVI, 964.)

TRANSMISSION OF PUBLIC DOCUMENTS THROUGH SMITHSONIAN EXCHANGE SERVICE: For repairs to buildings, fixtures, and fences, furniture, gas, chemicals, and stationery, freight (including transmission of public documents through the Smithsonian exchange), foreign postage, and expressage, plants, fertilizers, and all contingent expenses, three thousand dollars. (Approved March 4, 1909; Statutes XXXVI, 885.)

DISTRIBUTION OF CONGRESSIONAL RECORD THROUGH INTERNATIONAL EXCHANGES TO FOREIGN COUNTRIES: *Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That for the purpose of more fully carrying into effect the provisions of the convention concluded at Brussels on March fifteenth, eighteen hundred and eighty-six, and proclaimed by the President on January fifteenth, eighteen hundred and eighty-nine, the Public Printer is hereby authorized and directed to supply to the Library of Congress such number as may be required, not exceeding one hundred copies, of the daily issue of the Congressional Record 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, such documents, when received, to be deposited in the Library of Congress. (Approved March 4, 1909; Statutes XXXVI, 1169.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians and the natives of Hawaii, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, forty-two thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building. (Approved, March 4, 1909; Statutes XXXVI, 964.)

For removing the office furniture, records, manuscripts, documents, and other appurtenances from the present quarters to the space to be assigned in the Smithsonian Building, one thousand dollars, or so much thereof as may be necessary. (Approved March 4, 1909; Statutes XXXVI, 964.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, and miscellaneous expenses, thirteen thousand dollars. (Approved March 4, 1909; Statutes XXXVI, 964.)

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

For the cooperation of the United States in the work of the International Catalogue of Scientific Literature, including the preparation of a classified index catalogue of American scientific publications for incorporation in the International Catalogue, the expense of clerk hire, the purchase of necessary books and periodicals, and other necessary incidental expenses, six thousand dollars, the same to be expended under the direction of the Smithsonian Institution. (Approved March 4, 1909; Statutes XXXVI, 964.)

NATIONAL MUSEUM.

For cases, furniture, fixtures, electrical and other appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, two hundred thousand dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, sixty thousand dollars.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, and all other necessary expenses, two hundred and fifty thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum.

For purchase of books, pamphlets, and periodicals for reference in the National Museum, two thousand dollars.

For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material, fifteen thousand dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars.

For moving collections, furniture, and other property of the National Museum in connection with the occupancy of the new building for the National Museum,

including all expenses incidental thereto, to be immediately available, four thousand dollars. (Approved March 4, 1909; Statutes XXXVI, 964.)

DEFICIENCY APPROPRIATION, 1909: For preservation of collections, National Museum, one dollar and nineteen cents. (Approved March 4, 1909; Statutes XXXVI, 942.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals; including salaries or compensation of all necessary employees, and general incidental expenses not otherwise provided for, including purchase, maintenance, and driving of horses and vehicles required for official purposes, and not exceeding one hundred dollars for the purchase of necessary books and periodicals, ninety-five thousand dollars; one half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. (Approved March 4, 1909; Statutes XXXVI, 965.)

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1909

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 thirty 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 1909.

THE FUTURE OF MATHEMATICS.[a]

By Henri Poincaré,

Member of the Académie des Sciences and the Académie Française, Professor at the Sorbonne.

(Translated by permission from Revue générale des Sciences pures et appliquées, Paris, 19th year, No. 23, December, 1908.)

The true method of forecasting the future of mathematics lies in the study of its history and its present state.

And have we not here, for us mathematicians, a task in some sort professional? We are accustomed to extrapolation, that process which serves to deduce the future from the past and the present and so well know its limitations that we run no risk of being deluded with its forecasts.

In the past there have been prophets incapable of seeing progress, those who have so willingly affirmed that all problems capable of solution have been solved and that nothing remains for future gleaning. Happily the example of the past reassures us. Often enough, already, it has been believed that all problems capable of solution have been solved or at least stated. Then the sense of the word solution becomes broadened and the insolvable problems become the most interesting of all and undreamed-of problems have arisen. To the Greeks a good solution must employ only the rule and compass; later it became that obtained by the extraction of roots; still later that obtained by the use of algebraic or logarithmic functions. These prophets of no advance thus always outflanked, always forced to retreat, have, I believe, been forced out of existence.

As they are dead I will not combat them. We know that mathematics still develops and our task is to find in what sense. Some one replies, "in every sense;" and in part that is true. But, if absolutely true, it would be somewhat startling. Our riches would soon

[a] Address delivered April 10, 1908, at the general session of the Fourth International Congress of Mathematicians (Rome, April 6–11, 1908); previously published in pamphlet form by and at the expense of the Mathematical Society of Palermo. M. Poincaré was unable to deliver this lecture and M. Darboux graciously undertook the task. To M. Guccia we express our gratitude for the authority which he has courteously extended for its reproduction.

become an incumbrance and their increase produce an accumulation as incomprehensible as all the unknown truth is to the ignorant.

The historian, the physicist himself, must make his selection from among the facts; the brain of the scholar—but a small corner of the universe—could never contain this entire universe; so among the countless facts which nature presents, some must be passed by, others retained. It is as true, a fortiori, in mathematics for neither may the mathematician himself gather pellmell all the facts which come before him. Rather it is he—I was going to say his caprice—which creates them. It is he who constructs from the facts a new combination. Nature does not in general bring this to him ready-made.

Doubtless it happens sometimes that the mathematician approaches a problem set by the needs of physics, as when the physicist or the engineer asks of him the calculation of some number in view of an application. Shall we say, we mathematicians, that we must content ourselves to await these commands and, instead of cultivating our science for our pleasure, to have no other care than accommodating ourselves to the tastes of our clients? If there were no other objects for mathematicians than to come to the aid of those who are studying nature it would be from them then that we must await the word of command. Yet is this the right point of view? Certainly not; if we had not cultivated the exact sciences for themselves our mathematical machine would not have been created, and on the day when the word of command came from the physicist we would have been without arms.

Nor do the physicists, before studying some phenomenon, wait until some urgent need of life has made the study a necessity, and they are right; had the scientists of the eighteenth century neglected the study of electricity because in their eyes it was but a curiosity of no practical interest we would not have in the twentieth century either the telegraph, or electro-chemistry, or our electrical machinery. The physicist, when forced to choose, is not guided in his selection solely by utility. What brings about then his selection from among the facts of nature? We can not easily say. The phenomena which interest him are those which may lead to the discovery of some law. Those facts interest him which bear some analogy to many other phenomena, which do not appear as isolated facts but closely grouped with others. An isolated fact can be observed by all eyes; by those of the ordinary person as well as of the wise. But it is the true physicist alone who may see the bond which unites several facts among which the relationship is important though obscure. The story of Newton's apple is probably not true, but it is symbolical; so let us think of it as true. Well, we must believe that many before Newton had seen apples fall, but they made no deduction. Facts are sterile until there are minds capable of choosing between them and

discerning those which conceal something and recognizing that which is concealed; minds which under the bare fact see the soul of the fact.

That is exactly what we do in mathematics; out of the various elements at our disposal we could evolve millions of different combinations, but one of these combinations by itself alone is absolutely void of value. Oftentimes we take much trouble in its construction, but that serves absolutely for naught, unless possibly to give a task for further consideration. But it will be wholly different on the day that that combination takes its place in a class of like results and we have noted this analogy. We are no longer in the presence of a bare fact but of a law. And the true inventor is not the workman who has patiently built some few of these combinations, but he who has shown their relationships, their parentage. The former saw only the mere fact, the other alone felt the soul of the fact. Oftentimes for the indication of this parentage it has served the inventor's purpose to invent a new name and this name becomes creative; the history of science will supply us with innumerable such instances.

The celebrated Viennese philosopher, Mach, states the rôle of science to be the production of economy of thought just as a machine produces economy of labor. And that is very just. The savage counts with his fingers or with his assemblage of pebbles. By teaching the children the multiplication table we spare them later innumerable countings of pebbles. Someone, sometime, has discovered with his pebbles, or otherwise, that 6 times 7 makes 42; it occurred to him to note the fact and he thus spared us the necessity of doing it over again. He did not waste his time even though his calculation was only for his own pleasure; his operation cost him but two minutes; it would have cost two thousands of millions of minutes had a thousand of million of men to recompute it after he had.

The importance of a fact is known by its fruits, that is to say, by the amount of thought which it enables us to economize.

In physics, the facts of great fruitage are those which combine into some very general law, because they then allow us to predict a great number of other facts, and it is just the same with mathematics. I have devoted myself to a complicated calculation and have come laboriously to a result; but I will not feel repaid for my pains if I am not now able to foresee the results of other analogous calculations and to pursue such calculations with sure steps, avoiding the hesitations, the gropings of the first time. I shall not have wasted my time, on the contrary, if these gropings have ended in revealing to me in the problem which I have just treated some hidden relationship with a far more extended class of problems. If at the same time they have shown me resemblances and differences; if, in short, they have made me forsee the possibility of a gen-

eralization, then it is not merely a new answer which I have acquired; it is a new force.

An example which comes at once to mind is the algebraic formula which gives us the solution of a class of numerical problems when its letters are replaced by numbers. Thanks to the formula, a single algebraic demonstration spares us the pains of going over the same ground time after time for each new calculation. But this gives us only a very rough illustration. Everyone knows that there are analogies, some most valuable, which can not be expressed by a formula.

If a new result has value it is when, by binding together long-known elements, until now scattered and appearing unrelated to each other, it suddenly brings order where there reigned apparent disorder. It then allows us to see at a glance the place which each one of these elements occupies in the ensemble. This new fact is not alone important in itself, but it brings value to all the older facts which it now binds together. The brain is as weak as the senses, and it would be lost in the complexities of the world were there not harmony in that complexity. After the manner of the short-sighted, we would see only detail after detail, losing sight of each detail before the examination of another, unable to bind them together. Those facts alone are worthy of our attention which bring order into this complexity and so render it comprehensible.

Mathematicians attach great importance to the elegance of their methods and results; nor is this pure dilettanteism. Indeed, what brings to us this feeling of elegance in a solution or demonstration? It is the harmony among the various parts, their happy balancing, their symmetry; it is, in short, all that puts order among them, all that brings unity to them and which consequently gives us a certain command over them, a comprehension at the same time both of the whole and of the parts. But as truly it is that which brings with it a further harvest, for, in fact, the more clearly we comprehend this assemblâge, and at a glance, the better we will realize its relationships with neighboring groups, the greater consequently will be our chances of divining further possible generalizations. Elegance may arise from the feeling of surprise in the unexpected association of objects which we had not been accustomed to group together; it occurs frequently from the contrast between the simplicity of the means employed and the complexity of the given problem; we consequently reflect as to the reason of this contrast and almost without fail we find the cause not in pure hazard, but in some unexpected law. In a word, the sentiment of mathematical elegance is naught else than the satisfaction due to some, I know not just what, adaptation between the solution just found and the needs of our mind, and it is because of this adaptation itself that the solution becomes an

instrument to us. This æsthetic satisfaction is therefore connected with the economy of thought. Thus the caryatides of the Erechtheum engender in us the same feeling of elegance, for example, because they carry their heavy load with such grace, or we might say so cheerfully, that they produce in us a feeling of economy of effort.

It is for the same reason that when a somewhat long calculation has led us to a simple and striking result we are not fully satisfied until we have shown that we could have foreseen, if not the whole result, at least its most characteristic details. Why? What is it that prevents our satisfaction with this accomplished calculation giving all which we seemed to desire? It is because our long calculation would not again serve in another analogous case and because we have not used that mode of reasoning, often half intuitive, which would have allowed us to foresee our result. When our process is short we may see at a glance all its steps, so that we may easily change and adapt it to whatever problem of the same nature may occur, and then, since it allows us to foresee whether the solution of the problem will be simple, we can tell at least whether the problem is worth undertaking.

What we have just said suffices to show how vain would be any attempt whatever to replace by any mechanical process the free initiative of the mathematician. To obtain a result of real worth it will not suffice to grind it out or to have a machine for putting our facts in order. It is not alone order but the unexpected order which is of real worth. The machine may grind upon the mere fact, but the soul of the fact will always escape it.

Since the middle of the last century mathematicians have been more and more anxious for the attainment of absolute rigor in their processes; they are right, and that tendency will increase more and more. In mathematics rigor is not everything, but without it there would be nothing; a demonstration which is not rigorous is void. I believe no one will contest this truth. But to take this too literally would bring the conclusion, for example, that before 1820 there was no mathematics. That is surely going too far; then the geometricians assumed willingly what we explain by a prolix discussion. This does not mean that they did not realize their omission, but they passed it over too rapidly, and for greater surety they would have had to go through the trouble of giving this discussion.

But is it necessary to repeat every time this discussion? Those who, first in the field, had to be preoccupied with all this rigor have given us demonstrations which we could try to imitate; but if the demonstrations of the future must be built upon this model our mathematical treatises would become too long, and if I fear this length it is not only because I dread the incumbrance of our libraries, but

also because I fear that in this lengthening of our demonstrations they will lose that appearance of harmony of which I have just shown the so serviceable rôle.

We should always aim toward the economy of thought. It is not enough to give models for imitation. It must be possible to pass beyond these models and, in place of repeating their reasoning at length each time, to sum this in a few words. And this has now and then been already accomplished; for instance, there was a whole type of demonstrations which were perfectly similar and repeatedly occurring; they were perfectly rigorous, but tedious; one day some one thought of applying the word *convergence* and that word has taken their place. There is now no need of repeating these processes, for they are understood. Those who have cut our difficulties in quarter have rendered us double service—first, they have taught us to do as they have done when there is need, but above all to avoid this process as often as we can without the loss of this rigor.

We have just seen, through an example, the importance of words in mathematics, but I could cite many more cases. It is scarcely credible, as Mach said, how much a well-chosen word can economize thought. I do not know whether or not I have said somewhere that mathematics is the art of giving the same name to different things. We must so understand it. It is meet that things different in substance but like in form should be run in the same mold, so to speak. When our language is well chosen it is astonishing to see how all the demonstrations made upon some known fact immediately become applicable to many new facts. Nothing has to be changed, not even the words, since the names are the same in the new cases.

There is an example which comes at once to my mind; it is quaternions, upon which, however, I will not dwell. A word well chosen very often causes the disappearance of exceptions to rules as announced in their former forms; it was for this purpose that the terms negative quantities, imaginary quantities, infinite points, have been invented. And let us not forget that these exceptions are pernicious, for they conceal laws.

Very well then, one of those marks by which we recognize the pregnancy of a result is in that it permits a happy innovation in our language. The mere fact is oftentimes without interest; it has been noted many times, but has rendered no service to science; it becomes of value only on that day when some happily advised thinker perceives a relationship which he indicates and symbolizes by a word.

The physicists also do just the same way. They invented the term energy, a word of very great fertility, because through the elimination of exceptions it established a law; because it gave the same name to things differing in material but similar in form.

Among the words which have had this happy result I will mention the group and the invariant. They make us perceive the gist of many mathematical demonstrations; they make us realize how often mathematicians of the past must have run across groups without recognizing them and how, believing these groups such isolated things, they have found them in close relationship without knowing why.

To-day we would say that they were looking right in the face of isomorphic groups. We feel now that in a group the substance interests us but very little; it is the form alone which matters, and so, when we once know well a single group, then we know through it all the isomorphic groups; thanks to the words groups and isomorphism, which sum in a few syllables this subtle law and make it at once familiar to us all, we take our step at once and in so doing economize all effort of thought. The idea of group, moreover, is bound up with that of transformation. Why then do we attach so much value to the invention of a new transformation? Because from a single theorem we may deduce ten or twenty; it has a value similar to the addition of a zero at the right of an integral number.

We now realize what has determined the direction of the advance of mathematics in the past and the present and it is as certain what will determine it in the future. But the nature of the problems which come up will contribute equally. We must not forget what should be our goal; according to me that end is double. Our science confines itself at the same time to philosophy and to physics, and it is for these two neighbors that we work. And so we have always seen and always will see mathematics progressing in two opposite directions.

In one sense mathematics must return upon itself and that is useful, for in returning upon itself it goes back to the study of the human mind which has created it rather than to those creations which borrow the least bit from the external world. That is why certain mathematical speculations are useful, such as those whose aim is the study of postulates, of unusual geometries, of functions having peculiar values. The more these speculations depart from our common conceptions and consequently from nature or practical applications, the better they show us the working of the human mind which constructs them when it becomes freed from the tyranny of the external world, and the better, in consequence, it comes to know itself.

But it is to the opposite side—the side of nature—against which we must direct the main corps of our army.

There we meet the physicist or the engineer who says to us: "Can you integrate for me such a differential equation? I must have it within eight days because of a certain construction which must be finished by that time." "That equation," we reply, "is not of an integrable type; you know there are many like it." "Yes, I know

that; but of what use are you then?" More often, however, there is a better understanding. The engineer does not need his integral in finite terms. He needs only a rough value of the integral function, or perhaps only a certain numerical result which he could easily deduce from such a value of the integral if he had it. Ordinarily we could get this numerical result for him if we knew just how accurate it must be—that is, with what approximation.

Formerly an equation was not considered solved except when the solution was expressed by means of a finite number of known functions; but that is possible scarcely once in a hundred times. What we can always do, or rather what we may always try to do, is to solve the problem *qualitatively*, so to speak—that is, to find the general shape of the curve which the unknown function represents.

It remains, then, to find the *quantitative* solution of the problem; but if the unknown can not be determined as a finite result it can always be represented by means of an infinite convergent series which will allow the numerical calculation. May we regard this as a true solution? It is related that Newton once communicated to Leibnitz an anagram something like this:

aaaaabbbeeeeii, etc.

Leibnitz naturally was wholly at a loss as to its meaning; but we who have the key know the signification of that anagram and translating it into ordinary language it becomes: I know how to integrate all differential equations; and we are led to say to ourselves that Newton had strange good luck with such a singular illusion. He would have said *all simply*, that he could form (by the method of undetermined coefficients) a series of powers satisfying formally the given equation.

Such an apparent solution would no longer satisfy us to-day; and that for two reasons, because its convergence would be too slow and because the terms would follow one another according to no definable law. On the other hand, the series Θ seems to us to leave nothing to be desired, first, because it converges very rapidly (and that because the engineer wishes his result as quickly as possible), and then because we may see at a glance the law of its terms (that, for the satisfaction of the esthetic needs of the mathematician).

But there are no longer some problems which are solved and others which are not; there are only problems more or less solved accordingly as they are represented by a series converging more or less rapidly and following a law more or less harmonious. It occurs sometimes that an imperfect solution leads to a better one. Sometimes the series converges so slowly that calculations from it are impracticable, and we have shown only the possibility of a solution. And then the engineer thinks the solution only derisory, and he is right, as it will not allow him to finish his construction on the given date. He cares little

whether the solution will be useful to the engineer of the twenty-second century; we feel otherwise, and are sometimes as happy if we have saved for our grandson as for our contemporaries.

Sometimes, trying this way and that, empirically, we might say, we happen upon a formula sufficiently convergent. "What more do you want?" we ask the engineer; and yet, despite that, we are not satisfied ourselves. Why? Could we have foreseen it the first time, we might a second. We have reached a solution; that is a small matter to us if we have no sure hope of getting it a second time.

As a science grows it becomes more and more difficult to know it all. Then we cut it up into bits and each one contents himself with a bit; in a word, we specialize. If this process continues it will become a vexatious obstacle to the progress of our science. We have said that it is the unexpected bringing together of diverse parts of our science which brings progress. Too much specialization prevents this. Let us hope that a congress like this, bringing us into closer relationships with each other and spreading before the eyes of each his neighbor's fields, obliging us to compare these fields, so that we set forth for awhile from our own little villages, will annul this danger to which I have just called attention.

But I have stopped too long over generalities. Let us pass in review the diverse parts which form the whole science of mathematics, let us see what each branch has done, whither each tends and what we may hope from each. If the views we have just expressed are right, the great advances of the past will be found where two of these branches have approached each other, where the similarity of their forms despite the dissimilarity of material has become evident, where one has been modeled upon the other in such manner that each takes profit from the other. At the same time we should foresee the progress of the future in interlockings of the same nature.

I. ARITHMETIC.

The progress of arithmetic has been slower than that of algebra or analytical geometry, and the reason is very evident. Arithmetic does not present to us that feeling of continuity which is such a precious guide; each whole number is separate from the next of its kind and has in a sense individuality; each in a manner is an exception and that is why general theorems are rare in the theory of numbers; and that is why those theorems which may exist are more hidden and longer escape those who are searching for them.

But if arithmetic is less developed than algebra and analytical geometry it may well model itself upon those branches and take profit by their advances. The arithmetician must take for his guide the analogies with algebra. These analogies are many, and if often they

have not so far proved very useful yet they have at least been known for some time; the language itself of the two branches shows this; for instance when we speak of transcendental numbers and when we take into account that the future classification of these numbers images that of transcendental functions; still it is difficult to see how we can pass from one classification to the other; however, the step has already been taken, so it is no longer the task of the future.

The first example which comes to mind is the theory of congruents where we find a perfect parallelism with that of algebraic equations. And we will certainly complete this parallelism which must exist between the theory of algebraic curves and that of congruents of two variables, for instance. And when the problems relative to congruents of several variables are solved we shall have taken the first step toward the solution of many of the questions of indeterminate analysis.

Another example where the analogy has not always been seen at first sight is given to us by the theory of corpora and ideals. For a counterpart let us consider the curves traced upon a surface; to the existing numbers correspond the complete intersections, to the ideals the incomplete intersections, and to the prime ideals the indecomposable curves; the various classes of ideals thus have their analogs.

There can be no doubt that this analogy can throw light upon the theory of ideals, or upon that of surfaces, or perhaps on both at the same time.

The theory of forms, and in particular that of quadratic forms, is intimately bound with that of ideals. Among the theories of arithmetic this was one of the first to take shape and it came when the arithmeticians introduced unity through the considerations of groups of linear transformations.

These transformations permitted classification and consequently the introduction of order. Perhaps we have obtained all the fruit which could be hoped for; but if these linear transformations are the parents of geometrical perspectives, analytical geometry may furnish many other transformations (as, for example, the birational transformations of an algebraic curve) for which it may be well worth our while to look for arithmetical analogs. Doubtless these will form discontinuous groups of which we must first study the fundamental parts as the key to the whole. I have no doubt that in this study we will make use of Minkowski's Geometrie der Zahlen (Geometry of Numbers).

An idea from which we have not yet taken all that is possible is the introduction by Hermite of continuous variables in the theory of numbers. Let us start with two forms F and F′, the second quadratic determinate, and apply to both the same transformation; if the form F′ transformed is reduced, we will say that the transformation is

reduced and also that the form F transformed is reduced. It then follows that if the form F can be transformed to itself it can have many reductions; but this inconvenience is essential and can be avoided by no subterfuge. On the other hand these reductions do not prevent a classification of the forms. It is clear that this idea which has hitherto been applied only to limited classes of forms and transformations can be extended to groups of nonlinear transformations and we may yet hope to have a harvest greater than has ever been reaped from it.

An arithmetical domain where unity seems absolutely absent is found in the theory of prime numbers; the laws of asymptotes have been found and we must not hope for others; but these laws are isolated and are reached only by different paths which seem to have no intercommunication. I believe that I have a glimpse of the wished for unity, but I see it only vaguely; all leads back without doubt to the study of a family of transcendental functions which, through the study of singular points and the application of the method of M. Darboux, will permit the calculation asymptotically of certain functions of very great numbers.

II. ALGEBRA.

The theory of algebraic equations will still hold for a long while the attention of geometricians; the sides from which it may be approached are numerous and diverse; the most important is that of the theory of groups, to which we will return. But there is also the question of the calculation of the numerical value of roots and the discussion of the number of real roots. Laguerre has shown that not all was said upon this point by Sturm. Then there is the study of the system of invariants which do not change sign when the number of real roots remains the same. We may also form series of powers representing functions which may have for singular points the various roots of an algebraic equation (for instance, rational functions of which the denominator is the first member of this equation); the coefficients of the terms of high order will furnish one of the roots with an approximation more or less close; there is here the germ of a process of numerical calculation to which a systematic study could be given.

During a period of forty years the study of invariants of algebraic forms seems to have absorbed all algebra; they are to-day laid aside, although the subject has not been exhausted; but we must no longer limit the study to the invariants of linear transformations; it is to be extended to those referring to any group whatever. The theorems acquired in the past have suggested others more general which are grouping about them much as a crystal grows from a solution. And as to the theorem of Gordan that the number of distinct invariants

is limited, the demonstration of which Hilbert has so happily simplified, it seems to me that it leads to a problem much more general: If we have an infinity of whole polynomials, depending algebraically from a finite number among them, can we always deduce them from a finite number among them by addition and multiplication?

We must not believe that the task of algebra is finished because we have found rules for all the possible combinations. We have still to search out the interesting combinations, those which satisfy such and such conditions. Thus there will be established a sort of indeterminate analysis in which the unknowns will not be whole numbers but polynomials. Then in this case algebra will model itself upon arithmetic and take as a guide the analogy of the whole number, either as a whole polynomial of any coefficients whatever or as a whole polynomial of whole coefficients.

III. DIFFERENTIAL EQUATIONS.

Much has already been done for linear differential equations and it remains to perfect what has been commenced. But with nonlinear differential equations there has been much less advance. The hope of an integration by the aid of known functions has been given up long since; therefore we must study for themselves the functions defined by these differential equations and then attempt a systematic classification: the study of the mode of change in the neighborhood of singular points doubtless will furnish the first elements of such a classification, but we will be satisfied only when we shall have found a group of transformations (for instance, the transformations of Cremona) which will play with respect to the differential equations the same rôle as the group of birational transformations does for the algebraic equation. We can then group in the same class all the transformations of the same equation. We shall have for our guide the analogy with a theory already made—that of birational transformations and the genus of an algebraic curve.

We may propose to lead back the study of these functions to that of uniform functions, and this in two ways: We know that if $y=f(x)$, we can, whatever may be the $f(x)$, express y and x by uniform functions of an auxiliary variable t; but, if $f(x)$ is the solution of a differential equation, in what case will the uniform auxiliary functions themselves satisfy the differential equation? We do not know; neither do we know in what cases the general integral can be put in the form F (x, y)=arbitrary constant, where F (x, y) is a uniform function.

I will urge the qualitative discussion of the curves defined by differential equations. In the simplest case, that in which the equation is of the first order and the first degree, this discussion leads to the

determination of the number of limited cycles. It is very sensitive and what will help us is the analogy with the method of the determination of the number of real roots of an algebraic equation; whenever any step whatever shows the real status of this analogy we may be sure of a very great advance.

IV. EQUATIONS WITH PARTIAL DERIVATIVES.

Our knowledge of equations containing partial derivatives has taken recently a very considerable step in advance by means of the discoveries of M. Fredholm. If we examine closely the basis of these discoveries we will find that this difficult theory is modeled upon another more simple, that of determinants and of systems of the first degree. In the greater part of the problems of mathematical physics the equations to be integrated are linear; they serve to determine unknown functions of several variables, functions which are continuous. Why? Because we have made the equations in conformity with the supposition that matter is continuous. But matter is not continuous; it is formed of atoms; had we wished to write equations as they should be for an observer whose sight is sufficiently keen to see these atoms, we would not have had a small number of *differential* equations serving to determine certain unknown *functions;* we would have had a very great number of *algebraic* equations for determining a great number of unknown *constants.* And these algebraic equations would have been linear and of such a nature that with infinite patience we could have applied directly to them the methods of determinants.

But, since the brevity of our lives will not allow us this luxury of infinite patience, we must proceed otherwise; we must pass to the limit and suppose matter continuous. There are two ways of generalizing the theory of equations of the first degree in passing to the limit. We can consider an infinity of separate equations with an infinity, equally independent of unknowns. This has been done, for example, by Hill in his theory of the moon. We will then have infinite determinants which are to ordinary determinants as series are to finite sums.

We can take an equation of partial derivatives representing, we may say, a continuous infinity of equations, and use them to determine an unknown function representing a continuous infinity of unknowns. We then have other infinite determinants which are to ordinary determinants as integrals are to finite sums. Fredholm used this method; his success moreover came from his utilization of the following fact: If, in a determinant, the elements of the principal diagonal are equal to unity and the other elements are homogeneous and of the first order, we can arrange the development

of the determinant by combining in a single group all the homogeneous terms of the same degree. The infinite determinant of Fredholm may be so arranged and it happens that we thus obtain a converging series.

Has this analogy which certainly guided Fredholm given us all it ought to? Certainly not. If his success came from the linear form of the equations we should be able to apply ideas of the same nature to all problems having equations of linear form, and, indeed, to ordinary differential equations, since their integration may be always reduced to that of linear equations of partial derivatives of the first order.

Recently the problem of Dirichlet and those connected with it have been approached by another method, returning to the original one of Dirichlet and searching for the minimum of a definite integral except that this is now done by rigorous processes. I do not doubt that these two methods without much difficulty will be made comparable and advantage taken of their mutual relationships. Nor do I doubt that both will have much to gain by such a comparison. Thanks to M. Hilbert, who has been doubly an initiator, we are already on that path.

V.—THE ABELIAN FUNCTIONS.

The principal question remaining to us for solution concerning Abelian functions we know. The Abelian functions begot by the integrals relative to an algebraic curve are not the most general ones; they belong only to a particular case, so we may call them special Abelian functions. What is their relationship to the general functions and how shall we classify these latter? But a short time ago the solution of these problems seemed far distant. I believe that it is virtually solved to-day, now that MM. Castelnuovo and Enriques have published their recent memoir upon the integrals of total differentials of the varieties of more than two dimensions. We know now that there are Abelian functions belonging to a curve and others to a surface, and that it will never be necessary to extend them to more than two dimensions. Combining this result with what we may obtain from the works of M. Wirtinger we will doubtless reach the end of all our difficulties.

VI. THE THEORY OF FUNCTIONS.

It is especially with regard to functions of two and of several variables that I wish to speak. The analogy with the functions of a single variable gives a valuable but insufficient guide; there is an essential difference between the two classes of functions, and every time a generalization is attempted by passing from one to the other

an unexpected obstacle has been encountered which has sometimes been overcome by special artifices, but which so far has more often remained insurmountable. We must therefore search for facts from first principles to make clear to us this difference between functions of one variable and those containing several. We should look first more closely at the devices which have brought success in certain cases to see what they may have in common. Why is a conformal representation more often impossible in the domain of four dimensions and what shall we substitute for it? Does not the true generalization of functions of one variable come in the harmonic functions of four variables of which the real parts of the functions of two variables are only particular cases? Can we make use of what we know of algebraic or rational functions in the study of transcendental functions of several variables? Or, in other words, in what sense may we say that the transcendental functions of two variables are to transcendental functions of one variable as rational functions of two variables are to rational functions of one variable?

It is true that if $z=f(x, y)$ we can, whatever the function f may be, express x, y, z, respectively, as uniform functions of two auxiliary variables, or, to employ an expression which has become common for this process, can we make uniform the functions of two variables as we do those of one? I limit myself to the setting of the problem, the solution of which may perhaps come in the future.

VII. THE THEORY OF GROUPS.

The theory of groups is an extensive subject upon which there is much to be said. There are many kinds of groups, and whatever classification may be adopted we will always find new groups which will not fit it. I wish to limit myself and will speak here only of the continuous groups of Lie and the discontinuous ones of Galois, both of which we are now wont to classify as groups of finite order, although the term does not apply to both groups in the same sense.

In the theory of the groups of Lie we are guided by a special analogy; a finite transformation is the result of the combination of an infinity of infinitessimal transformations. The simplest case is that where the infinitessimal transformation is equivalent to the multiplication by $1+\epsilon$, where ϵ is very small. The repetition of these transformations gives rise to the exponential function; that was Neper's method of procedure. We know that an exponential function can be expressed by a very simple and very convergent series, and analogy should then show us what path to follow. Moreover, that analogy may be expressed by a special symbolism upon which you will excuse me from dwelling. We are already well advanced along this path, thanks to Lie, Killing, and Cartan; it remains only

to simplify the demonstrations and to coordinate and classify the results.

The study of the groups of Galois is much less advanced, and for a very simple reason, that sáme reason which makes arithmetic behindhand to analytical geometry, that lack of continuity which is of such great use for our advances. But happily there is a manifest parallelism between the two theories and we must try to put this more and more in evidence. This analogy is exactly parallel to that which we have noted between arithmetic and algebra and we should derive from it similar aid.

VIII. GEOMETRY.

It seems at first sight as if geometry could contain nothing which is not already presented to us in algebra and analytical geometry; for the facts of geometry are nought else than the facts of algebra and analytical geometry expressed in another language. One might think then, after the review which we have just made, that there would remain nothing further to say specially about geometry. But we would then be unmindful of a well-built language, mode of argument, of something which adds to the things themselves a mode of expressing them and consequently of grouping them.

And, moreover, geometrical considerations lead us to propose new problems; they are, indeed, if you so choose to call them, analytical problems, but they would never have been proposed through analytical geometry alone. Meanwhile analytical geometry profits from these just as it has profited from the problems it has been called upon to solve for physics.

Common geometry has a great advantage in that the senses may come to the help of our reason and aid it in finding what path to follow, and many minds prefer to put their problems of analytical geometry in the ordinary geometrical form. Unfortunately our senses can not lead us so very far, and they fail us when we try to escape from the classical three dimensions. Must we say that, departing from the limited domain where our senses seem to wish to confine us, we must no longer count upon pure analysis and that all geometry of more than three dimensions is vain and useless? In the generation which preceded us the greatest masters would have replied "yes." We have nowadays become so familiar with this notion of more than three dimensional space that we may speak of it even in the university without arousing astonishment.

But what purpose can geometry serve? It gives us, close at hand, a most convenient language which can express very concisely what the language of analytical geometry can express only in very prolix phraseology. Moreover, its language gives the same name where

there are resemblances and affirms analogies so that we do not forget them. And even more, it guides us into that space which is too vast for us and which we may not see; it does this by ever bringing to mind the relationship of the latter space to our ordinary, visible space, which without doubt is only a very imperfect image, but which nevertheless is an image. Here further, as in all the preceding instances, this analogy with what is simple allows us to comprehend that which is complex.

This geometry of more than three dimensions is not a simple analytical geometry; it is not purely quantitative; it is also qualitative, and it is in the latter sense that it becomes especially interesting. The importance of the *Analysis Situs* is very great; I can not insist too much on that; the advance which it has taken from Riemann, one of its chief creators, is enough to indicate this. It is essential that it should be constructed completely in hyperspace. We would be then furnished with a new sense, one capable of seeing really into hyperspace.

The problems of the *Analysis Situs* would perhaps not have been thought of had there been only the language of analytical geometry; or rather, I am wrong, they would certainly have been set, since their solution is necessary for many of the questions of analytical geometry; but they would have been set one after another with no indication of a common bond between them.

It is the introduction of the ideas of transformations and groups which has contributed especially to the recent progress in geometry. We owe to these that geometry is no longer an assemblage of more or less curious theorems which follow each other with no resemblances; they have now acquired a unity; and, furthermore, we must not forget in our history of science that it was for the sake of geometry that a systematic study was started of continuous transformations, so that pure geometry has contributed its part to the development of the idea of the group so useful in the other branches of mathematics.

The study of groups of points upon an algebraic curve, according to the method of Brill and Noether, has given us also fruitful results either directly or as serving as models for analogous theories. We have thus seen develop a whole chapter of geometry where the curves traced upon a surface play a rôle similar to that of a group of points upon a curve. And from this very day on, we may hope to see in this way light thrown on the last mysteries which exist in the study of surfaces and which have been so difficult to solve.

The geometricians have thus a vast field from which to reap a harvest. I must not forget enumerative geometry, and especially infinitesimal geometry, cultivated with such brilliancy by M. Darboux, and to which M. Bianchi has added such useful contributions.

If I do not say more upon this subject it is because I have nothing to add after the brilliant lecture by M. Darboux.[a]

IX. CANTORISM.

I have already spoken of the need we have of continually going back to the first principles of our science and the profit we may thus obtain in the study of the human mind. It is this need which has inspired two attempts which hold an important place in the more recent part of mathematical history. The first is Cantorism, whose services to science we all know. One of the characteristic traits of Cantorism is that in place of generalizing and building theorems more and more complicated on top of each other and defining by means of these constructions themselves, it starts out from the genus supremum and defines, as the scholastics would have said, per genus proximum et differentiam specificam. What horror would have been brought to certain minds—that of Hermite, for instance, whose favorite idea was comparing the mathematical to the natural sciences! With the most of us these prejudices have passed away, but it still happens that we come across certain paradoxes, certain apparent contradictions which would have overwhelmed Zénon d'Elée and the school of Mégore with joy. I think, and I am not the only one who does, that it is important never to introduce any conception which may not be completely defined by a finite number of words. Whatever may be the remedy adopted, we can promise ourselves the joy of the physician called in to follow a beautiful pathological case.

X. THE RESEARCH OF POSTULATES.

And yet, further, we are trying to enumerate the axioms and postulates, more or less deceiving, which serve as the foundation stones of our various mathematical theories. M. Hilbert has obtained the most brilliant results. It seems now as if this domain must be very limited and that there will not be any more to be done when this inventory is finished, and that will be very soon. But when all has been gathered together there will be plenty of ways of classifying them, and a good librarian will always find something to busy himself with and each classification will be instructive to the philosopher.

I stop this review, which I could not hope to make complete, for many reasons, and because I have already drawn too much on your patience. I believe that my examples will have been sufficient to show you by what means the mathematical sciences have progressed in the past and along what paths they must proceed in the future.

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[a] See G. Darboux: Les origines, les méthodes et les problèmes de la Géométrie infinitésimale (The origin, methods, and problems of infinitesimal geometry). Revue générale des Sciences, 15 Nov., 1908.

WHAT CONSTITUTES SUPERIORITY IN AN AIR-SHIP.[a]

By Commandant PAUL RENARD.

The question has been much discussed as to what type has the most noteworthy qualities among the numerous devices which are to-day carrying men through the air. Some are partisans of the aeroplane, others of the dirigible, and these two camps are always in rivalry, sometimes in open enmity, so that unanimity is far from prevailing.

In aviation there are monoplane and biplane enthusiasts, those who prefer aeroplanes without a tail, such as the Wrights' machines,[b] or with a tail, like all the others. In aerostation, or ballooning, some contend for the flexible type like the *Ville de Paris*, others for the semirigid type like the *Republique*, and lastly, others who vaunt the merits of the rigid type, like the *Zeppelin*.

How can anyone know where to stand in the face of all these opinions? From a technical point of view, excellent arguments can be found in favor of each of the present types of air-ships as well as for those which may be later devised; specialists can discuss these questions indefinitely. Although as far as I am concerned I have a well-established opinion on this point, it is not from the theoretical standpoint that I wish to express myself to-day, but without wishing to pass judgment it seems to me worth while to at least indicate the considerations on which such a judgment should be based. In a word I should like to determine here what, from a practical point of view, are the qualities which can be demanded in an air-ship, and from among these qualities to choose those which are of the greatest importance and which as a consequence should preferably serve as a criterion in passing judgment on a structure of a new kind.

According to the point of view, very different sorts of performances, if I may use such an expression, may be expected of an air-ship. You may, for example, wish to rise as high as possible in the air, and the capacity for upward ascension in such a case is evidently a quality

[a] Translated by permission from Revue des Deux Mondes, vol. 54, Nov. 1, 1909, pp. 181–190.

[b] The Wright aeroplane is now provided with a tail, or rear horizontal rudder.—Ed.

to be considered. It is not enough merely to rise, however, but it is also necessary to stay there. The period during which the air-ship shall remain suspended in the air without touching the ground, therefore, is also one of the elements of interest in the question.

Another phase of the question is that any engine of locomotion must be able to cover distances; the distance which separates the point of departure from the finishing point is therefore one of the essential characteristics of a voyage. In fact one might be tempted to say that the best air-ship is the one that can travel the greatest distance in a single flight before touching the earth.

Finally, it is not only necessary that a certain given distance shall be covered, but it must take the shortest possible time to accomplish it. In other words, speed is the most highly valued quality at the present day. In all types of locomotion, whether by bicycle, automobile, railroad trains, steamboat, or motor boat it seems that the principal aim is speed, always speed, and still more speed. This search for acceleration in means of transportation is one of the characteristics of our epoch; and it is not to be wondered at, for although all space is open to us, still our time is parsimoniously dealt out to us, and the best way we can use it is to carefully economize it by the use of the powerful mechanical means at our disposal.

Aerial navigation does not escape from this general law of locomotion. Speed is therefore one of the important elements in the measurement of the value of an air-ship. But a distinction must here be made, for there are two kinds of speeds to be considered, termed absolute speed, and individual speed. The absolute or effective speed is the one commonly considered. It is the speed measured with regard to the ground over which the air-ship is passing. If a dirigible starts from Paris at 8 in the morning and at 11 o'clock is above Auxerre, the distance between the two cities being 150 kilometers as the crow flies, we would say that its absolute velocity had been on the average 50 kilometers an hour. This absolute speed is the one of practical interest. It is the plain fact, all modifying circumstances being removed from the calculation.

From the point of view of merit in a device, however, it is precisely these modifying circumstances that should be considered. The effective velocity results from the combination of two other velocities, namely, the individual velocity of the vehicle, which will be defined shortly, and the velocity of the wind.

Everyone knows what the velocity of the wind means. As for the individual velocity of an air-ship, its definition is very simple; it is the velocity which the air-ship could attain if there were no wind, or, again, it is the velocity in calm air, or finally, its velocity in comparison with the ambient air, considering this to be at rest.

Of these two elements, the combination of which determines the absolute velocity, one, the individual velocity, depends on the construction of the air-ship; and the efforts of all aeronautic engineers are directed toward giving this as great a value as possible; the other element, the velocity of the wind, is entirely beyond us and we must submit to it, whatever it is. But according to the direction and the velocity of the wind, it is necessary to have very different individual velocities to obtain a determined effective velocity.

If, for example, on the day when our dirigible traveled from Paris to Auxerre in three hours, the wind had blown exactly in the desired direction with a velocity of 50 kilometers an hour, the wind alone would have been sufficient to accomplish the voyage in the time given without any intervention of the individual velocity. The aeronaut could have stopped his motor and thus would have made the journey at little cost. The effective speed would be the same as the velocity of the wind, the individual speed zero; the wind would have done all and the machine nothing.

If the wind, however, although blowing in the proper direction from Paris to Auxerre, had had a velocity of only 30 kilometers an hour the aeronaut, if he were contented with allowing himself to be carried by the wind, would have taken five hours to make the journey instead of three. To attain the previous speed of 50 kilometers per hour he would have to add to the velocity of the wind the 20 kilometers lacking, and this difference would be nothing else but his individual speed. In such a case we should say that the velocity of the wind had been 30 kilometers an hour, the individual velocity 20, and the effective or absolute velocity 50 kilometers per hour. Instead of doing all the work as before, the wind had only done the greater part and the motor the rest.

If the velocity of the wind had been but 10 kilometers, the motor this time would have had to add not 20 kilometers but 40. In this case the motor would have deserved the principal credit for the voyage, and the wind would have furnished only a slight supplementary velocity.

Let us suppose now that the air is absolutely calm, that is, the velocity of the wind is zero. The motor alone can be counted on here, and it is due to it that the speed of 50 kilometers an hour is attained. The effective velocity will be equal to the individual velocity, and the motor will have done all and the wind nothing.

Finally, if the wind, with a velocity of 30 kilometers an hour, is blowing not in such a direction as to be astern from Paris to Auxerre, but in the opposite direction, the motor will be required to furnish an individual speed of 80 kilometers an hour. The first 30 are used up merely in compensating for the unfavorable effects of the wind, the other 50 alone being effective. This time the motor

has not only done everything, as in calm air, but it has done more, for in addition to the absolute velocity it has had to furnish a surplus of individual velocity to counterbalance the hindering effect of the wind.

In a word, in order to attain the same practical result as before, that is, an absolute velocity of 50 kilometers an hour, the motor should be capable of giving to the air-ship an individual velocity of 0, 20, 40, 50, or 80 kilometers an hour.

We have considered here only the simplest case—when the wind blows in the direction of the place to be reached or in exactly the opposite direction. This is almost never the case in practice, so that it becomes necessary in each case to determine what the individual velocity must be to attain a certain absolute speed. The problem is now a little more complicated, but the conclusions are the same, and the individual velocity is necessarily sometimes less, sometimes more, than the absolute velocity, and at times the two may even be equal. To sum up, all that may be said is that the wind can be either a help or a hindrance to the progress of air-ships, and in exceptional cases neither obstructs nor is favorable to their evolutions.

By those with a different point of view, it may finally be asked if there is not opportunity to measure the value of an air-ship by the amount of useful weight carried, in personnel or in material. The power of transporting is certainly one of the qualities sought for in certain vehicles.

All the qualities which we have passed in review—altitude, duration of voyage, distance covered, velocity, power of transportation—have the common characteristic that they may be measured exactly, their value can be expressed in precise figures, and thus they furnish a fixed mathematical standard of comparison between different types of air machines, for they are based on rigorous observations, and questions of sentiment have not intervened. For instance, if the altitude attained should be taken as the criterion of the value of a dirigible, the one that has ascended to a height of 1,500 meters is incontestibly superior to one that has only attained a height of 1,200 meters. If it is a matter of distance covered, the one which in a single flight has traveled 800 kilometers is superior to one which has only covered 600. That much is perfectly clear.

There are other qualities, however, less exact in their nature, which nevertheless are not negligible, such as security, comfort, and pleasure of voyages.

I do not care to enter into a detailed examination of these phases of the subject, partly because they can not be exactly valued, and further because they are readily attained by devices of secondary importance. Thus by the use of flexible cushions and backs with head rests the

traveler's comfort is easily increased. These are questions to be referred to the skill of an upholsterer and not to an engineer.

There is, however, one property that is highly important for safety and comfort in a voyage—the stability of the vehicle. This stability is obtained by mechanism of a technical nature; it is often very difficult to obtain and therefore should be considered in connection with the more exact qualities first discussed. In a given vehicle, stability can be interpreted in several ways. The center of gravity of the apparatus can describe a very regular trajectory, but the vehicle may nevertheless be exceedingly unstable; it may go through oscillatory movements which are highly uncomfortable and occasionally dangerous. These movements have been given different names according to the direction they follow. When they are in a horizontal plane they are said to be zigzag movements or yawing. If it is a question of vertical movement, it may be of two sorts—in a longitudinal direction it is called pitching, and if in a tranverse direction it is rolling.

Although displacements of this kind do not affect the trajectory of the center of gravity, and consequently can not prevent the vehicle from following its course, they are none the less disagreeable, especially if several of them are combined. Stability of direction, longitudinal stability, and transverse stability, which will enable us to avoid, respectively, yawing, pitching, and rolling, are therefore qualities highly desirable.

There is a fourth sort of stability that is a special quality of air-ships. This is stability of altitude. Land vehicles are forced to keep to the level of the ground on which they rest. Aquatic carriers float on the surface of the water; air-ships, on the contrary, and with them must be classed submarines, are submerged in a fluid and can ascend and descend through the gaseous or liquid mass. When the air-ship remains at the altitude chosen by the pilot, or when it mounts or descends at his will, it is said to have stability of altitude. It does not have this quality when its vertical movements are involuntary and beyond the control of the aeronaut.

II.

We have thus completed the enumeration of the qualities which an air-ship may possess. The question is now to choose from among them those most important in determining the value of the conveyance. But before making this choice it is indispensable to know from what point of view it is to be made. One may inquire as to which of these qualities is the most difficult to obtain. If the technical standing of engineers were to be determined that would be the course to pursue, and we should proclaim the superiority of the constructor who had endowed his machine with the qualities which are the hardest to

attain. But it is not a question of awarding prizes to engineers. We want to know what air-ships have the greatest practical advantages. In making our choice of qualities we shall not demand, therefore, those most difficult of attainment, but those most desirable in themselves. We can afterward inquire if the most desirable qualities are more or less difficult to realize; this will be merely an accessory matter.

We are therefore called upon to pass judgment upon the practical advantages in types of air-ships. The first consideration is not to lose sight of the conditions under which by definition itself an air-ship is operated, conditions different from those which a boat or a railway train meets; no one can justly make an estimate of such dissimilar devices without recognizing the fundamental conditions of their utilization; that is, the nature of the supporting medium in which they move, the earth, water, or air.

Locomotion on land brings into touch all the habitable places on the earth except those separated from each other by expanses of water impossible to bridge. But with this advantage there is still an element of great disadvantage. To attain on land perfect conditions for speed and carrying power, it has not been enough merely to train animals or create powerful and ingenious machines. These achievements would not have counted for much unless the route had been prepared by the construction of roadways, involving an enormous amount of labor and money. Without highways and railways, automobiles and locomotives would be powerless. This is so true at the present day that the importance and the perfection of the ways of communication are considered the principal criteria of material civilization, and where these means are lacking we are no further advanced than were those of the days of Joshua.

A water transportation line, and herein lies its inferiority, only admits of the joining together of a very limited number of places, those along the shores of seas or along navigable streams. There is, however, the enormous advantage of not requiring a preliminary preparation of roadways. To travel by water, with all the perfection possible to obtain, it is only necessary to have good ships. The sea has at all times been the chief means of communication between the various countries of the globe; all the ocean shores have been fairly well known for a long period, while there have remained immense tracts of country unexplored in the interior of the continents. If to venture an hypothesis, there existed in the center of Africa, or in the midst of the deserts of Asia, an unknown but populous city, the center of a flourishing civilization, the explorers who had discovered it could tell of its marvels on their return, but this newly discovered city would still remain apart from general civilization simply because it was not connected with other countries by per-

fected ways of communication. If, on the contrary, there should be discovered in the solitudes of the Pacific an islet, in itself of little importance, it could be brought into direct communication with New York, Marseille, and Sidney, and enter immediately into the circle of mundane affairs.

Aerial navigation combines the advantages of its older sisters and is free from their inconveniences. It can connect Paris and Rio de Janeiro as well as Madrid and St. Petersburg. It no more requires the preliminary construction of roads of communication than does maritime transportation. It creates direct bonds of communication without intermediary agencies, and to utilize it it is only necessary to have appropriate vehicles. Thanks to this means, all points on the globe may enjoy the privilege which has hitherto been reserved to the shores of the sea, and in a few years the atmosphere will certainly be the great medium for bringing people together just as the ocean has been for a long time in its more limited and less perfect fashion.

III.

These general considerations are not mere digression from the question which we are considering to-day. We must not lose sight of them if we wish to estimate things clearly. Do we not often hear the remark: "Of what importance are dirigibles or aeroplanes? They do not travel as fast as railroad trains; they have much less carrying capacity than boats; would it not be worth while rather to perfect the time-honored land or maritime means of travel than to search for a new method of transportation?"

If aerial navigation did not differ in its essential properties from these other modes of locomotion known from the most ancient times this presentation of the case would be entirely rational, but when men pursue so indefatigably the conquest of the air and the public follows its progress with such interest, it is not because they hope to discover in this way the means of possessing in a higher degree the qualities of speed and capacity desirable in any vehicle, it is because of qualities found alone in aerial navigation. If this were not so the conquest of the air would still certainly be an important question, but it would not be worth all the efforts that it brings forth and the excited interest that it arouses.

We can not actually realize what is before us, but there is to-day an idea latent in every mind that the investigation into aerial locomotion is not a vain caprice of mankind, but springs from a deep and instinctive feeling that extraordinary changes are impending in the conditions of humanity.

We must now go a step further into the detailed study of the qualities which we have enumerated and choose the most important.

The first quality which I mentioned is the faculty of ascending to the greatest possible height. The means for accomplishing this end are different, according to whether the machines are heavier or lighter than air. In the first case it is necessary to have at your disposal a motive power greater than that necessary to sustain and move the machine in a horizontal plane. It is therefore a question of the power of the motor.

If, however, the air-ship is a dirigible balloon, the motor does not come into consideration. It is only necessary to throw off a definite weight of ballast, and the greater this quantity is for a given balloon the higher it will ascend. Besides the weight of the motor and the mechanism itself and the weight of the fuel and other supplies and of the passengers, arrangements must also be made for a supplementary weight that can be sacrificed. It is not enough to increase the volume of the gas envelope in order to increase the dispensable ballast in the same proportion, for the altitude attained does not depend on the absolute amount of ballast thrown off but on the ratio of this weight to the volume of the balloon. If, for example, with a balloon of 1,000 cubic meters an altitude of about 2,300 meters should be attained by releasing 250 kilograms of ballast, to attain the same altitude with a balloon of 2,000 cubic meters capacity not 250 kilograms, but 500, must be thrown off. If the weight of the air-ship itself, the motor mechanism, the supplies, and the passengers increased proportionately with the volume of the gas envelope, we would always have the same proportion of ballast and could ascend no higher in one case than in the other. This, however, is not the fact, for large balloons can carry a larger proportion of ballast than small ones, and it is with these that high altitudes are most easily attained. The altitude is therefore to a great degree a question of volume.

It may be remarked that if lighter motors for a given power are provided, or greater power for a given weight—in other words, if the weight is reduced, there would be more dispensable weight, more ballast per horsepower, and, consequently, a greater capability of ascension. It is also evident that to attain an extreme elevation the weight carried should be reduced as much as possible. Thus the number of passengers should be reduced to a minimum and little or no extra material carried. By doing this, in the case of a dirigible, the dispensable ballast can be increased to the extent of the economy which has been realized in the rest of the equipment. In the case of an aviation machine if its total weight is diminished and, consequently, the expenditure of motive power necessary to sustain the machine, the excess power available for attaining altitudes is thereby also increased. To sum up, in all air-ships, of whatever kind, altitude may be attained with a facility corresponding to the power available for

a given weight, but with dirigibles the principal method of reaching higher altitudes is by increasing the dimension of the gas envelope.

An aerial voyage can be prolonged as long as supplies remain available, whether the air-ship be lighter or heavier than air. The most important of these supplies is fuel for the motor and the accessory lubricating oils, the weight of which is comparatively small. In dirigibles there must also be a supply of ballast proportionate to the length of the voyage. The quality of duration is therefore a question of transporting capacity, and the methods of obtaining it are the same.

The distance that can be covered is evidently proportional to the duration of the trip, and is also proportional to the absolute velocity of the air-ship. We have just considered the duration; as for the absolute speed, it is a quality that must be considered by itself. We have, therefore, as regards distance only one thing to keep in mind, and that is, it is obtained by combining the means used to attain duration and velocity.

As already stated, absolute velocity is a resultant of two velocities, that of the wind and that of the air-ship; with the wind we can do nothing, but the individual velocity is another matter. It may be remarked that if the individual velocity should be less than that of the wind, the machine would not advance but would recede more or less from its point of departure. Such a machine, however, would not be dirigible and would not deserve the name of "air-ship." We mean to consider here only devices really dirigible, that is, those whose velocity is greater than that of the prevailing wind. In this case, whether flying against the air or with it, the absolute velocity will increase with the individual velocity. Let us suppose that the wind blows 50 kilometers an hour. The air-ship with an individual velocity of 60 kilometers will make 10 kilometers an hour against the current and 110 with it. If it has an individual velocity of 70 kilometers, it can travel 20 kilometers an hour against the wind and 120 with it. In either case it is evident that the absolute velocity increases with the individual velocity. One can even demonstrate mathematically that when an air-ship describes a closed circuit corresponding approximately to the form of a circle or a regular polygon, whatever may be the velocity and direction of the wind the one that possesses the greatest individual velocity will have the greatest average absolute speed around the whole course.

As we can not affect the velocity of the wind, to seek to increase the absolute velocity is in fact to seek the greatest individual velocity. We have just seen how desirable this quality of speed is in itself. Without it dirigibility is impossible; and the greater it is the more frequent are the occasions when we can travel in all directions and the greater will be the distances covered. Speed is, therefore, in respect

to importance, the principal quality in an air-ship, without which it is but the plaything of the winds, and it is toward the improvement of this feature that all efforts should be directed.

How may this individual velocity be obtained? In dirigibles all resistance to forward movement must be diminished as far as possible; this is accomplished by appropriate design of form. This form must be permanently maintained, powerful motors must be provided, driving good propellers. To sum up, every improvement which can be devised with regard to dirigible balloons should be directed principally if not solely toward the increase of their individual velocities.

The same is true with regard to aviation apparatus, but in this direction the difficulty is much less, for because of their light design they offer much less resistance to forward motion than the dirigibles, condemned to drag along their enormous bags filled with hydrogen. For a given motive power therefore the former can attain much greater speeds than balloons, as experience has superabundantly demonstrated.

However that may be, for the one or the other the individual velocity is a question of motive power, and since in an air-ship only a limited weight can be allowed for the motor, this must have as great a specific power as possible; in other words, the weight of the gas engine should be reduced as much as practicable. The question of individual velocity thus depends on the lightness of the motors. This motive power must, furthermore, be utilized to the best possible advantage, which can be done by proper propellers. The resistance to forward movement must be diminished, and this can be accomplished by careful design. The air-ship must also be stable in all directions—horizontally, longitudinally, or transversely—for yawing, pitching, and rolling, apart from the wearying effect on passengers and the dangers they may present, are formidable obstacles to the best speed. When a dirigible moves sidewise it presents an enormous surface to the air of a shape deplorable from the point of view of resistance, and the speed is diminished to an inconceivable degree.

One can almost sum up in a word what can be said about individual velocity. It is this, that for an air-ship to possess this quality in the highest degree it must be endowed with all the others.

There remains now the carrying capacity. Here the question appears in quite a different light, according to whether the apparatus is lighter or heavier than air.

With a dirigible it is simply a question of the volume of the balloon. It must not be thought, however, that by increasing indefinitely the volume of the gas envelope that the carrying power of an air-ship can be increased without limit. To enlarge the volume means to increase the fabric surface and this will demand greater

strength in a large balloon than a small one, which will increase the weight of a square meter of the envelope and accordingly result in a double cause of increase in the total weight. This will also be true with regard to the suspension cords and all the material constituting the dead weight.

It can be demonstrated that in balloons of different volumes this dead weight increases nearly as the fourth power of the linear dimensions; that is, more rapidly than the volume. Thus in a balloon of twice the volume the dead weight will not be multiplied by 2 but by 2.52, and with triple the volume the dead weight will be multiplied not by 3 but by 4.33 and so on. In spite of this unfavorable circumstance, however, we may say in the limits of practice, that the carrying capacity increases with the volume. It increases also with the lightening of the motors, for if the motor is lighter for a given power the economy in weight so realized can be used to increase the weight carried; in general, however, it is preferred to profit by this lightening by increasing the motive power and consequently the speed.

In a dirigible the total ascensional force is the product of the volume of the balloon by the lifting power of a cubic meter of gas. This latter quantity depends entirely on the specific gravity of the air and of the gas employed. As long as no gas lighter than hydrogen can be found there can be no hope of a change in the present conditions, and even if such a gas should be discovered, we should always be limited by the weight of a cubic meter of air, 1.293 kilograms. This figure represents the extreme limit of weight that a cubic meter of the gas could lift, if it weighed nothing. However, a cubic meter of pure hydrogen weighs only 0.090 kilogram; a cubic meter of this gas therefore raises a weight of 1.203 kilograms, and even if there existed a gas of zero density only 90 grams per cubic meter would be gained over the lifting power of hydrogen.

Consequently, it is true at the present day and always will be, that the total lifting power of a balloon can be increased only by an enlargement of its volume.

In an apparatus heavier than air this total ascensional force is again equal to the product of two factors; in this case, however, it is the surface of the sustaining planes, and the supporting power per square meter. To increase this total ascensional force it thus becomes necessary to increase one or the other of these factors.

Theoretically, the dimensions of the sustaining planes can be increased, but in practice it is difficult, for these surfaces become much heavier as they increase in size and thus absorb a large part of the increase of ascensional power attained thereby. If this is carried still further the weight of the sustaining surfaces can be increased to such an extent that all the benefit of the increase in size is lost,

and even more. We should, therefore, endeavor to increase the carrying power per square meter of the sustaining planes.

This carrying power may be increased partly by an increase in the sustaining quality of the bearing surface, and it is research in this direction that practically leads to the perfection of devices heavier than air. It is a question of form, dimensions, and orientation which must be taken up in detail. This problem constitutes in reality nine-tenths of the problem of aviation.

In another way the load that can be carried per square meter of sustaining surface in a given apparatus, increases with the available motive power. The greater this power is in comparison with the weight of the machine the larger may be the load imposed on each square meter of sustaining surface. The increase is not proportional, but it is rather rapid, as may be shown by a few figures. If an aeroplane provided with a 25-horsepower motor can carry 10 kilograms per square meter, the same aeroplane with a motor of 50 horsepower can carry 16 kilograms; with a 75-horsepower motor, 21; and with a 100-horsepower motor 25 kilograms per square meter.

There is one very interesting point to note here, and that is, for a given aeroplane the capacity per square meter varies with the velocity. Let us suppose that our aeroplane, with a 25-horsepower motor and carrying 10 kilograms per square meter, makes a speed of 60 kilometers per hour. When it is provided with a motor of 50 horsepower, which will permit it, as we have just seen, to carry 16 kilograms per square meter instead of 10, its velocity will be increased. It will no longer be 60, but 76 kilometers per hour. In the same way, if it has a 75-horsepower motor due to which its carrying capacity increases to 21 kilograms, its velocity will at the same time reach 86 kilometers. Finally, with the motor of 100 horsepower and a load of 25 kilograms per square meter it will have a velocity of 95 kilometers.

The individual velocity and the carrying capacity therefore increase with the power of the motor; nothing of the kind occurs with dirigibles.

However that may be, whether dirigibles or aviation apparatus are concerned, the carrying capacity is dependent on the lightness of the motors and the general perfection of the whole device; but these features have a much greater effect in the heavier than air system than in the lighter than air. In dirigibles there intervenes in this question a preponderating element, that of the volume of the gas bag whose influence dwarfs all others. This element does not exist in the aviation devices.

We have still to examine stability in all its forms, but, as we have already seen, this property is indispensable if we desire to attain an individual velocity of any magnitude whatever. There is, therefore,

no necessity to analyze it in detail. We will simply remember that a rapid air-ship is necessarily stable.

IV.

From the foregoing the conclusion may be drawn that the different qualities which an air-ship may possess are not independent of each other but may be reduced to two fundamental properties, the individual velocity and the carrying capacity. The first of these qualities, the individual velocity, is highly desirable in itself, for without it dirigibility is impossible. Furthermore, it is the only means by which we can increase the absolute velocity, which is of such practical importance. Finally, the absolute velocity is one of the factors determining the distance that can be covered in a single flight. When the individual velocity is increased, for the same reason both the absolute velocity and the distance covered are increased. If we also add the consideration that the possession of this speed necessarily implies the possession of stability in all directions, we must conclude that in it we have a quality that is essentially fundamental.

The carrying capacity of such a machine can be measured by the amount of weight of every kind which it can carry in excess of the weight of the air-ship proper, its motor, propellers, and all the parts indispensable to its operation.

Given this weight it can be used in different ways. It can be employed in transporting a number of passengers or a considerable weight of merchandise. In the form of ballast it helps to attain the greatest altitude, and thus contributes to the duration of the aerial voyage. In the form of fuel supply it assures the duration of the voyage, thus affecting one of the two factors entering into distance covered.

Individual velocity can not be present in a high degree if the property of stability is not also present. This permits of the attainment of an absolute velocity which, coupled with duration of voyage, goes to make up distance traveled. The carrying capacity has no relation to stability. It can be utilized either for its own sake or to attain altitude, or to prolong the voyage and thus contribute in increasing the distance traveled.

These different qualities may therefore be divided into two groups, those dependent on the individual velocity and those on the carrying capacity. As for the distance traveled, it is a common resultant of the two groups, for it is the product of absolute velocity by duration of flight, qualities belonging to the different groups.

If we wish to obtain a synthetic idea of the value of an air-ship, it is by the ratio of the distances covered that their merit should be measured, but this quality is only the product of two others—the

absolute velocity and the duration of the voyage. These two factors may play a varying rôle in the final result.

The factor of duration is certainly less important than the velocity. To obtain duration the machine need not even be dirigible; a simple free balloon can possess this quality, while up to the present time it is the spherical balloons which have made the longest uninterrupted voyages, so that while recognizing the valuable index which the distance traveled affords in the estimation of the merit of an air-ship, still, of the two elements which go to make it up, we must attach more importance to the absolute velocity than to the duration of flight.

It should be recalled, however, that these two qualities are not fundamental. The absolute velocity itself depends on the wind and the individual velocity, and from our point of view it is only important if it is attained by the caprice of the wind but in the direction desired by the pilot. To accomplish this, there must be individual velocity, a fundamental property.

The duration of flight is itself dependent on the carrying capacity. We must, therefore, conclude that of these two fundamental properties it is the individual velocity that stands first and the capacity of transport takes second place.

As stated in the beginning of this discussion, I have arrived at these conclusions simply from utilitarian considerations. If we examine the question from the point of view of the difficulties to be overcome, what rank shall we assign to these two essential qualities of an air-ship? For an aeroplane the question is very simple; the difficulties are the same in acquiring one as in acquiring the other. With an increase in the individual velocity, the possible load per square meter of sustaining surface is increased. Consequently, in making an advance in one a gain is made in the other. The question can be summed up by saying that an aeroplane should be as perfect as possible; that is, it should be stable, have carrying surfaces endowed with the best sustaining qualities, a good propeller, and a powerful and light motor. If it possesses such perfection it can be used in any way desired; it can travel swiftly and yet carry a considerable weight that may be utilized either as useful load or to increase the duration of the flight. If its load is lightened its speed will be diminished, but its abundant motive power will enable it to ascend. To conclude, with a perfect aeroplane the aviator may obtain whichever quality he desires or combine them in whatever proportion he deems convenient.

In the case of aeroplanes, therefore, we may say that the question of difficulties to be overcome is negligible, and that utilitarian considerations alone determine their value. In these machines it is the individual velocity, as it is in all other types, which is the most im-

portant quality, but the others can be obtained without modifying the construction in the slightest degree, and except for attaining altitude, without losing any velocity, but even gaining it, with an increase in the carrying capacity and in the qualities which are dependent on it.

This is not the case with dirigibles. To be sure, with them as with aeroplanes, general perfection of apparatus—motor, propellers, forms of small resistance—is indispensable to velocity and can likewise exert a favorable influence on the carrying capacity and its resulting consequences, but another factor intervenes, the volume of the balloon. This exerts an enormous influence on the carrying capacity, which dwarfs that resulting from the general perfection of the apparatus. Although by increasing the individual velocity we can indirectly increase in a slight degree the carrying capacity, we possess, moreover, a means of increasing this quality absolutely independent of those which produce velocity. I may add that this method has no great merit in its application. It is not very difficult to add a few hundred cubic meters to a balloon, or even more. I would not go as far as to say that the problem is of extreme simplicity, but it is a small matter beside those that have to be solved in increasing the individual velocity of a dirigible. Consequently, as far as machines lighter than air are concerned, if from a utilitarian point of view the carrying capacity is an inferior quality, it is equally so from a technical standpoint, for it is much easier to attain than individual velocity.

Thus there are in an air-ship only two fundamental qualities from which all the others are derived, individual velocity and carrying capacity; and from a practical standpoint the latter is much less important than the former.

In considering the difficulties to be overcome, in an aeroplane the question does not arise, for in such apparatus the qualities sought for are so involved one with the other that every added improvement allows of the increase according to choice of one or the other of the properties desired in an air-ship. With dirigibles this is not the case, for carrying capacity is much more easily obtained than individual velocity, and the technical considerations which are involved in machines lighter than air are merely those that are basic in the utilization of an air-ship.

Simply because a colossal dirigible has accomplished long journeys and covered great distances, the superiority of this type of air-ship over all others should not necessarily be proclaimed. The machine that should interest us most is the one capable of the greatest individual velocity, and as this velocity is difficult to measure, we should estimate it from the absolute velocity attained in flying in a closed circuit in such a way as to eliminate from the final result, as much as possible, the effect of the wind.

I believe that in this respect our air-ships have nothing to envy in those of foreigners. I even believe frankly that ours are superior.

We can continue to be proud, then, of our air-ships; they possess to a higher degree than others the first of all qualities, individual velocity. They are gaining in this respect from day to day, and when our engineers desire it they can provide them besides with the carrying capacity of which our rivals are so proud.

France is in no danger, as has been frequently loudly announced, of losing the empire of the air.[a]

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[a] These lines were written before the catastrophe of the dirigible *Republique*. This tragic event, nevertheless, does not alter the conclusions of this article in the slightest degree.—RENARD.

RESEARCHES IN RADIOTELEGRAPHY.[a]

(With 2 plates.)

By Prof. J. A. Fleming, M. A., D. Sc., F. R. S.

Radiotelegraphy, popularly called wireless telegraphy, has outlived the tentative achievements of its precocious infancy and obtained for itself a settled but important position amongst our means of communication.

This stage, however, has only been reached after a long struggle with experimental difficulties and much labor in analyzing the processes involved. As many of these matters are of general scientific interest, it is proposed, during the present hour, briefly to summarize the results of some recent research.

You are doubtless all aware that every radiotelegraphic station comprises three elements. There is, first, the external organ called the air wire or antenna, by which the electromagnetic waves are radiated and absorbed. This antenna consists of one or more wires extending up into the air, either vertically or sloping, or partly vertical and partly horizontal. These wires are insulated at the upper ends and may be arranged fan fashion, or may form one or more nearly closed loops, placed in a vertical position. The antenna is, so to speak, the mouth or ear of the station, by which it speaks through the ether, or by which it hears the etherial whispers coming to it from other stations. The ether waves are produced by very rapid electric currents moving to and fro in the antenna wires, and these, like the vibrations of a violin string, or the aerial oscillations in an organ pipe, set up a periodic disturbance in the surrounding medium, which in the electrical case consists of alternating electric and magnetic forces taking place at each point in space around the antenna.

There are, then, appliances in the station collectively called the transmitter, which have for their function to create these powerful electric oscillations in the antenna, and to control them so as to send out short or long trains of ether waves in accordance with the dot or dash signals of the Morse alphabet. Lastly, there is the receiving

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[a] Lecture before the Royal Institution of Great Britain, Friday, June 4, 1909. Reprinted by permission from pamphlet copy published by the Royal Institution.

apparatus, which, when connected to the antenna, serves to detect the presence in it of the very feeble oscillations which are being generated in the antenna by the powerful oscillations in the antenna of some far-distant sending station. It is usual to employ the same antenna at any one station both for sending and receiving, and to switch it over from the transmitter to the receiver according as we wish to send or receive messages, although methods have been described and are being developed for using the antenna simultaneously for both purposes.

By way of preface let me illustrate by a few experiments the manner in which these electric oscillations are set up in the air wire, and the nature of the effects produced by them in the surrounding space. We have here a very long wire which, for the purpose of keeping it within a small compass, is coiled upon an ebonite tube. Two such spirals, H_1 and H_2, are placed side by side and connected at the bottom through two other small coils of wire S (see fig. 1). In contiguity to these last two coils of wire are two others, P, which are in series with a condenser or battery of Leyden jars, C, and a spark gap. If we charge the condenser by an induction coil, I, and let it discharge across the gap, we produce rapidly succeeding trains of electric oscillations in the condenser circuit, and these induce other currents in the open or helix circuit of similar kind. The result is that electricity rushes up and down the spiral wires, which we may consider to represent two very long air wires or antennæ. We have therefore, alternately, free charges of electricity at the top ends of the wires and electric currents passing to and fro across the middle point. We may compare this movement of electricity in the helix to the oscillations of a liquid in a U-tube when it is disturbed. In the electrical case we have at each spark discharge 20 or 30 electrical swings or oscillations separated by relatively long intervals of silence, the intervals between two swings in the train being about one four-hundredth-thousandth of a second, while the interval between the groups or trains of swings is about one-fiftieth of a second.

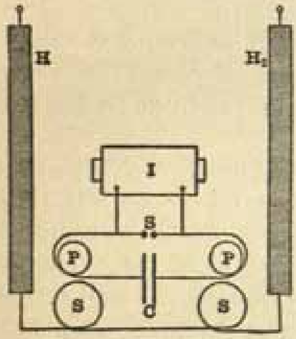


FIG. 1.

Such electrical oscillations in the wire produce two effects in external space, called, respectively, electric and magnetic force. In the case of a simple vertical air wire the magnetic force is distributed along concentric circular lines embracing the wire while the electric force is distributed along certain looped lines in the plane of the wire. If, however, we employ a close-wound spiral antenna, as in our experiment, the positions of the electric and magnetic forces are interchanged as compared with those of the single vertical wire.

As the currents in the air wire reverse their direction the magnetic and electric effects in the external space also reverse, but not everywhere at the same moment. The magnetic and electric forces are affections or states of the ether, and in virtue of the inertia and elasticity of the medium they are propagated from point to point with a finite velocity which is the same as that of light. We can then explore the field near the antenna and obtain an approximate idea of its nature and intensity by the use of a Neon vacuum tube, which glows when held in the electric field with greater or less brilliancy. At certain intervals of distance in the space the magnetic and electric forces reverse direction in the same way at the same instant, and this distance is called a wave length.

In the case of a straight air wire, the magnitude of the forces at considerable distances varies inversely as the distance from the antenna, and the antenna radiates equally in all directions. If, however, we employ a U-shaped antenna, as in the present experiment, the currents being in opposite directions in the two branches, then along a median line transverse to their common plane their actions will neutralize each other, and the radiation will be symmetrical only with respect to the plane of the antenna. In constructing an antenna intended to radiate in all directions, it is necessary to connect the lower end to a large plate of metal or network of wires either sunk in the earth or placed just above the surface. In the former case, this plate is called an earth plate, and in the latter a balancing capacity. It is necessary that this balancing capacity, if insulated, should be of sufficient size to take up all the electricity which rushes out of the antenna at each oscillation without sensible rise in potential. If we are only employing an antenna of moderate capacity for short distance signaling, then an insulated balancing capacity would not be of unwieldly dimensions and may be constructed of a number of wires stretched out or laid on the ground or insulated a little way above it. When, however, we have to employ a very large antenna of great capacity for long distance work, then the provision of a suitable balancing capacity would involve constructive difficulties which are best obviated by making the earth itself the balancing capacity—in other words, by connecting the base of the antenna to an extensive network of wires or large metal plates buried in the ground. It has been asserted that the direct earth connection damps out the free oscillations in the antenna more quickly than would be the case if an insulated balancing capacity is employed. Although this may be true to a certain extent, we have to set against it the fact that the use of an insulated balancing capacity is out of the question in many cases—as on board ship, where a connection to the hull of the vessel is always made. Also for any but small antennæ the necessary insulated balancing capacity may be somewhat large, and it is

in every way better to put it below ground, in other words, to employ an earth plate and compensate for any slight earth damping by an antenna of rather larger capacity.

This matter is, however, only part of a much larger question, viz, the function of the earth in radiotelegraphy. It is well known that the nature of the earth's soil or surface between the sending and receiving stations has a great effect upon electric waves passing over it. Various imperfect explanations were given of this action in early days, but the basis for a better knowledge has been laid by the experimental researches of Admiral Sir Henry Jackson and the theoretical discussions of M. Brylinski and Doctor Zenneck. To follow their explanations it must be borne in mind that high-frequency electric currents, as used in radiotelegraphy, are confined chiefly to the surface of conductors by means of which they are conducted. Such a current does not distribute itself uniformly over the whole cross section of a wire carrying it, but is confined to a thin skin or surface layer. This can be proved by the following experiment: We take a copper wire spiral or loop and make it part of a circuit in which a high-frequency current exists. If we measure in any way the current in that circuit we find it has a certain value. If we substitute for the copper wire an iron wire of the same size, we find that the current in the circuit is then much less. This can be discovered by placing near the circuit in question another testing circuit comprising an inductance and a capacity and some means for testing the amplitude of the oscillations set up in this secondary circuit. This decrease is not due to the mere fact that the iron has a greater resistance than copper, but to the fact that the iron is magnetizable, and such magnetization absorbs energy owing to so-called hysteresis. If, however, we dip the iron for a moment into molten zinc and deposit on it a thin surface layer of zinc, or galvanize it, we find it then becomes almost as good as a solid copper wire for conveying high-frequency currents. On the other hand, if we burn off the zinc from a piece of galvanized-iron wire, we render it a worse conductor for high-frequency oscillations. This experiment proves that such oscillations are conveyed by a thin surface layer of the conductor. In the case of a copper wire for oscillations having a frequency of one million, the current penetrates about one-third of a millimeter, and in the case of an iron wire, about one-fortieth of a millimeter into the metal.

For nonmagnetic substances the depth to which a current of a given frequency penetrates into a conductor is greater in proportion as the conductivity of the material is less. Hence high frequency currents penetrate farther into carbon than into metal. Accordingly a much thicker layer of carbon than of zinc would be needed to shield the iron spiral in our last experiment. The same thing happens in

the case of an electric wave propagated over a terrestrial surface. If the surface is a very good conductor the wave hardly penetrates into it, but glides over the surface. If it is a poor conductor the wave penetrates into it to a greater extent, and the worse the conductivity the deeper the penetration.

The materials of which the earth's crust is composed, with some exceptions, owe their electric conductivity chiefly to the presence of water in them. They are called electrolytic conductors. Substances like marble and slate when free from iron oxide are fairly good insulators. Dry sand or hard dry rocks are poor conductors, but wet sand and moist earth are fairly good conductors. Sea water, owing to the salt in it, is a much better conductor than fresh water. The following table gives some figures, which, however, are only approximate, for the specific resistance of various terrestrial materials in ohms per meter cube. It will be seen that dry sand or soils are of very high specific resistance, and damp or wet sand or clay fairly low.

TABLE I.—*Approximate conductivity and dielectric constant of various terrestrial materials.*

Material.	Specific resistence in ohms per meter cube.	Dielectric constant. Air=1.
Sea water	1	80
Fresh water	100 to 1,000	80
Moist earth	10 to 1,000	5 to 15
Dry earth	10,000 and upward	2 to 6
Wet sand	1 to 1,000	9
Dry river sand	very large	2 to 3
Wet clay	10 to 100	..
Dry clay	10,000 and upward	2 to 5
Slate	10,000 to 100,000	..
Marble	5,000,000	6
Mercury	.000001	Infinity

If our earth's surface had a conductivity equal say to that of copper, then the electric radiation from an antenna would glide over the surface without penetration. In the case of the actual earth there is, however, considerable penetration of the wave into the surface, and therefore absorption of energy by it.

Brylinski and also Zenneck have calculated the depth to which electric waves of such frequency as are used in radiotelegraphy penetrate into the sea or terrestrial strata of various conductivities. For mathematical reasons it is customary to define it by stating the depth in meters or centimeters at which the wave amplitude is reduced to $1/\epsilon=0.367$ of its amplitude at the surface. I have represented in a diagram some of Zenneck's results calculated for waves of 1,000 feet in length, and for terrestrial surface materials of various kinds, conductivities, and dielectric constants (see fig. 2). You will see that in the case of sea water an electric wave traveling over it penetrates only to the depth of a meter or two, whereas in

the case of very dry soil it would penetrate much deeper. Owing to the conductivity of the soil, this movement of lines of magnetic force through it sets up currents of electricity which expend their energy in heat. This energy must come from the original store imparted to the sending antenna, and therefore the wave is robbed of its energy as it travels over the surface.

It should be clearly understood that when a wireless telegraph antenna is in operation it sends out into the surrounding space a nearly hemispherical electrical wave, which spreads out in all directions. There are five causes which weaken the wave as it travels outward:

(1) The distribution of the energy continually over a larger and larger area. The wave amplitude diminishes inversely as the distance, and the wave energy inversely as the square of the distance. This is proved theoretically from first principles by Hertz's equations, and

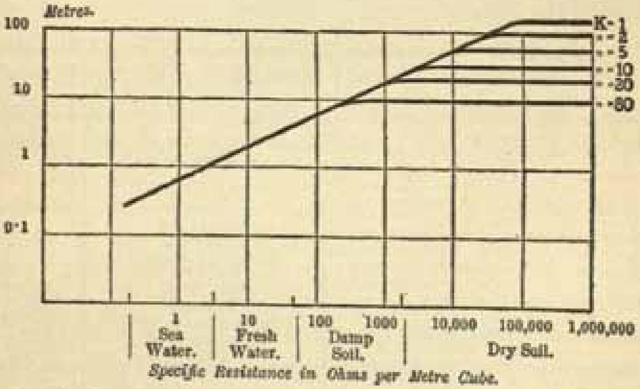


FIG. 2.—Depth of penetration of waves 1,000 feet in length (Doctor Zenneck).

has been confirmed experimentally by the experiments of Messrs. Duddell and Taylor and of Professor Tissot.

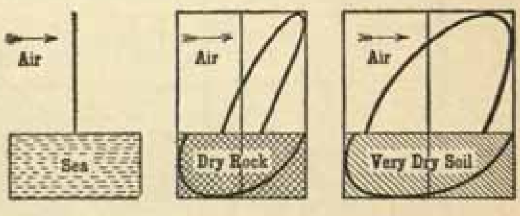
(2) There is a certain absorption of energy due to the ionization of the atmosphere by daylight and to other causes, but this is only detectable over long distances and for the present moment we shall neglect it. We include, however, under this head, obstructions due to special atmospheric conditions, electrical or material.

(3) There is a diminution, due to earth curvature, which is operative only over long distances.

(4) There is some reduction of intensity which results from obstacles—such as hills, trees—especially from cliffs of ironstone or conductive rocks, due to distortion of the electric field.

(5) Lastly, there is the weakening due to the dissipation of energy by the penetration of the waves into the surface over which they travel.

We shall consider the last-named cause alone at the present moment. Doctor Zenneck has discussed mathematically, in a very interesting paper, the effect of the conductivity and dielectric constant of the terrestrial surface, soil, or sea, on the propagation of a plain electric wave over it, assuming the radiation to be from an ordinary vertical antenna, and the electric force therefore normal to the earth and magnetic force parallel to it. The result is to show that there are, broadly speaking, three cases to consider. First, supposing the surface material to be a good conductor, then the wave moves over the surface and penetrates a very little way into it. The electric force in the air over the surface is a purely alternating force vertical to the earth's surface, and the magnetic force is an alternating force parallel to it, and there is very little subterranean electric or magnetic force (see fig. 3A). This is realized approximately or most nearly in the case of radiotelegraphy over sea water. Secondly, let the earth be assumed to have a very poor conductivity and not a very large dielectric constant; then analysis shows that the electric force in the air has two components, one perpendicular to the earth's surface and one parallel to it, and the resultant is an alternating and a rotating force, the direction of its maximum value being inclined to the surface and leaning forward (see fig. 3B). The wave front therefore slopes forward. Also, there is a subterranean electric force, showing that the wave is penetrating into the soil, and there is therefore dissipation of energy owing to the conductivity of the soil as the wave travels over the surface. This case is realized when the wave travels over land composed of dry soil having a small dielectric constant. Thirdly, let the earth be a very poor conductor, having a small dielectric constant from 2 to 3 and a specific resistance of about 10,000 ohms per meter cube—for example, very dry earth or sand. Then the investigation shows that the electric force in the air has two components, one parallel to the earth's surface and one perpendicular to it differing in phase, and the resultant is represented by the rotating radius of an ellipse, the maximum value or major axis of which is inclined forward in the direction of the wave motion (see fig. 3C). At the same time there is some penetration of the wave into the earth and consequent dissipation of energy.



A — $r = 1$ ohm per metre cube. $K = 80$.
B — $r = 100{,}000$ ohms per metre cube. $K = 2 - 3$.
C — $r = 10{,}000$ ohms per metre cube. $K = 1 - 3$.
r = Resistivity. K = Dielectric constant.

FIG. 3.

Doctor Zenneck has considered the case of electric waves 1,000 feet in wave length, and has represented the final result by some interesting curves. He defines the effect of the absorption of energy by the soil by stating the distance in kilometers at which the wave amplitude would be reduced by the effect of this absorption to $0.367 = 1/\epsilon$ of its amplitude at the sending station, altogether apart from the weakening due to the spreading of the waves out in a hemisphere, which we may call the spherical or space decrease. These curves are plotted to abscissæ representing the specific resistance of the soil (see fig. 4). You will see from this diagram that when a plane electric wave having the above wave lengths is propagated over sea water, it would have to travel 10,000 kilometers before its ampli-

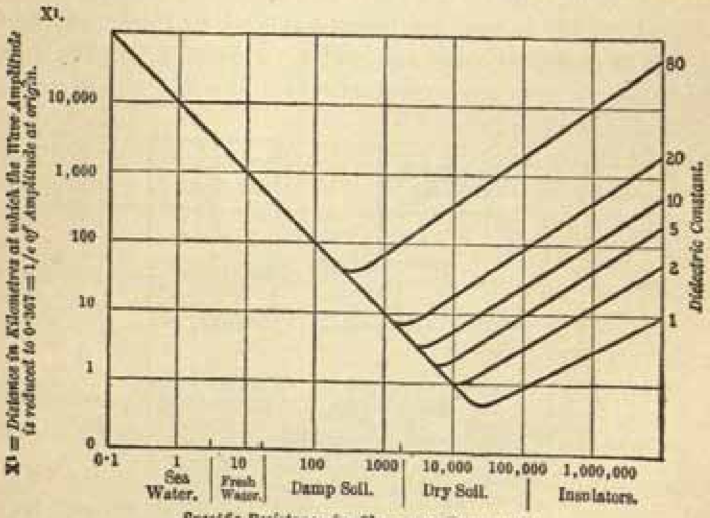


FIG. 4.—Curves showing the distance in which electric waves 1,000 feet (300 meters) in length have amplitude reduced to $1/\epsilon$ by traveling over various surfaces (Doctor Zenneck).

tude would be reduced in the assigned ratio; and over fairly dry soil, about 100 to 1,000 kilometers; but over very dry soil, having a small dielectric constant, only about 1 to 10 kilometers. Also you will notice that the curves rise up again for still higher resistivities. This, of course, is as it should be. All the practical cases lie between two ideal extremes—the case of an infinitely perfect conducting earth, in which case the waves would not penetrate into it at all, and the other case, an infinitely perfect nonconducting earth, in which the wave would penetrate into it, but would suffer no dissipation of energy. This theory is quite in accordance with practical experience in radiotelegraphy. Every receiving apparatus associated with an antenna of a certain height and kind must be subjected to waves of a certain minimum amplitude to give any appreciable signal. For

all lower amplitudes that particular receiving arrangement is perfectly deaf. Now, it is a matter of common experience that with a given radiotelegraphic apparatus and antenna, it is possible to receive signals for greater distances over sea water than over dry land, and that if the soil is very dry the distance may be cut down very considerably indeed. This is not due merely to the difficulty of making what the telegraphists call a good earth at the sending station, it is due to the absorption of the wave by the earth for the whole distance which extends between the two stations. Hence, also, it is a common experience that when particularly dry weather is succeeded by wet weather, the radiotelegraphic communication between two stations on land is considerably improved.

In another paper Doctor Hack has shown that even underground water is an advantage in facilitating radiotelegraphic communication. Since a shore station must always be established on shore for

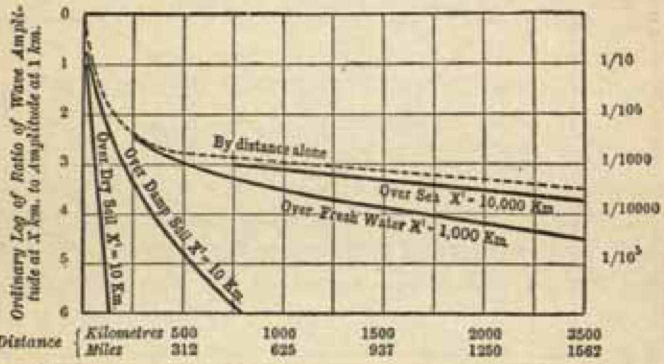


FIG. 5.—Curves showing decrease in wave amplitude with distance for waves 1,000 feet in length (Doctor Zenneck).

communication with ships, it is in consequence generally the custom to select a site for that station as near as possible to the coast, and to take pains to get a very good conducting connection between the foot of the antenna and the soil, and also if necessary between the antenna earthplate and the sea. Fessenden has suggested for this purpose the use of what he calls a wave chute, which is merely a metallic network extending some distance outward from the antenna in cases where this antenna is established in the center of towns or dry districts.

Doctor Zenneck has also given a series of curves which show in a remarkable manner the reduction in wave amplitude due to both distance and surface absorption, calculated for waves of 1,000 feet in length, and for various coefficients of absorption (see fig. 5). Thus, for example, if we are propagating plane waves 1,000 feet long over a surface which by itself would reduce the wave amplitude to 0.367 of its initial amplitude in 1,000 kilometers, then, when we consider the decrease by distance as well, we have to take account of the fact that this last cause reduces the wave amplitude at 1,000 kilometers to

0.001 of that which it is at 1 kilometer distance. I have represented in the diagram some of Doctor Zenneck's curves. The dotted line shows the decrease of amplitude by distance alone, and the firm lines that due to distance and terrestrial absorption in various cases. We are able to see from them the large effect due to travel over large distances of very dry soil. Thus, for instance, if the absorption is such as to cut down the amplitude in the ratio of 1:0.367 at 1,000 kilometers, then at a distance of 3,000 kilometers the amplitude of a wave of 1,000 feet in length would be cut down in the ratio of 3,000 to 1 by distance alone, but in the ratio of 60,000 to 1 by distance and terrestrial absorption combined.

An important matter is the question of the influence of wave length on this absorption. It can be shown from theory that an increase of wave length reduces the energy dissipation by the earth. Thus in certain cases increasing the wave length from 1,000 to 10,000 feet increases the range of effective communication one hundred times. The absorption is also determined by the decrement of the wave train being greater the larger the decrement.

One practical deduction to be made from this investigation is that the reduction in wave amplitude which takes place when the wave moves over very dry soil is as much due to small dielectric constant of the material as to high resistivity. We see also that the wave front is very far from being vertical when the waves travel overland, and hence it is an advantage in that case for the receiving antenna to slope away from the direction in which the waves are traveling or from the radiant point. Lastly, it points to the advantage of a long wave for overland working. Generally speaking, then, we find that electric wave telegraphy is conducted with much greater ease over sea than over dry land, the reason being that the dielectric constant is large and the conductivity of sea water is sufficient to prevent much penetration of the electric wave in the sea, and therefore there is not much dissipation of its energy by absorption due to the surface over which it travels. We have here an instance of economy in nature. Over sandy deserts, where we can, if need be, put up telegraph posts and wires, radiotelegraphy has had some natural difficulties placed in its way, but on sea, where connection between moving stations is the important matter, and telegraph posts are impossible, special facilities seem to have been afforded us for conducting it.

The next point in connection with the antenna to be noticed is the means adopted of setting up the oscillations in it. The universal custom at present is to excite oscillations in a reservoir circuit consisting of a condenser and an inductance by means of the spark or arc. If the spark method is used, then the condenser is one of relatively large capacity and the inductance is kept small. If the capacity is measured in electrostatic units, and the inductance in electromagnetic units, the ratio of capacity to inductance may be

something of the order of 5:1 of even 20:1. In this case the condenser is charged by means of an induction coil or transformer, and discharged across a spark gap, and this discharge consists of intermittent trains of electric oscillations with a periodic time equal to the free natural period of the oscillatory circuit. These discharges are made to succeed each other from 50 to 600 times a second, by using an induction coil with an appropriate interrupter, or else an alternator and a transformer. If the arc method of exciting the oscillations is employed, then the ratio of capacity to inductance must be much smaller and the oscillations are excited in this circuit by a continuous current arc worked with a voltage from 200 to 400 volts or more, the arc being traversed by a strong magnetic field and generally being placed in a chamber kept free from oxygen. The oscillations set up in the condenser circuit are then persistent or unbroken. The oscillations are excited in the antenna by coupling it inductively or directly with the condenser circuit (see fig. 6). If the former method is employed, then an oscillation transformer is used consisting of two coils of wire, one coil being inserted in the condenser circuit and one in the antenna circuit, and according as these coils are near or far apart, they are said to be closely or loosely coupled. These two circuits have then each their own natural period of electric vibration, like tuning forks, and they have to be adjusted to syntony. It is well known that under these conditions oscillations set up in one circuit immediately create oscillations of two frequencies in both circuits. This action can be easily illustrated by two pendulums which are of the same length and are hung side by side on a loose string distinguished by red and blue bobs. If one pendulum is set swinging, it imparts little jerks to its other and sets the latter in motion, but to do this the first must part with its own energy, and hence is gradually brought to rest. Then the operation is repeated in the reverse direction. The motion of each pendulum may then be represented by the ordinates of a curve such as those in figure 7. This kind of motion can, by a well-known theorem,

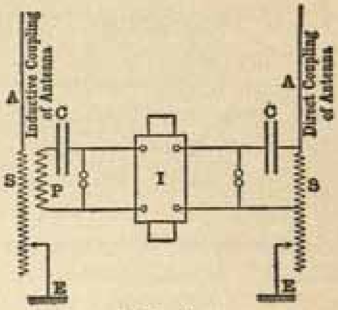


FIG. 6.

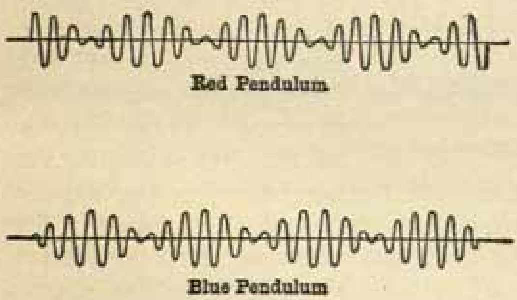


FIG. 7.

be resolved into the sum of two oscillations of different frequencies. Hence, each pendulum may be said to possess two rates of vibration. The same thing happens in the case of two closely coupled syntonic electric currents. If one circuit has free oscillations set up in it, the action and reaction of the circuits generates oscillations of two frquencies. Accordingly, when an antenna circuit is coupled to a condenser circuit, we have oscillations of two frequencies set up in it, and waves of two wave lengths radiated from the antenna. The presence of these two waves can be detected either by measurements made with the cymometer or by an oscillograph vacuum tube. In the first case all that is necessary is to place a cymometer in proximity to the antenna and vary its oscillation constant. It will be found that there are two settings of the handle for which the Neon tube glows brightly, and the scale of the instrument will indicate the wave lengths of the two waves respectively. Some instructive measurements of this kind have been made by Prof. W. G. Pierce in a recent research, and he has shown that the wave lengths given by the formulæ which can be deduced from the theory of the operations are in agreement with actual measurements (see fig. 8). Another striking confirmation can be obtained by the oscillograph vacuum tube, invented by Doctor Gehrcke, of the Reichsanstalt, Berlin. This consists of a glass tube having two strip electrodes in it nearly touching, which are made of nickel or aluminum. The tube is filled with pure nitrogen and exhausted to a pressure of about 10 to 20 mm. If such a tube has a high voltage applied to its terminals, a glow light extends along the electrodes, the length of which varies with the electromotive force. Hence, if the tube is connected to a circuit in which an oscillatory discharge is taking place, the glow light along the tube will rapidly extend and contract. If the electrodes are examined in a revolving mirror, making from fifty to a hundred turns a second, the images of the glowing electrodes corresponding to each oscillation will be separated out, and if the oscillations are persistent or undamped, we see a series of short bright lines alternately above and below a central line.

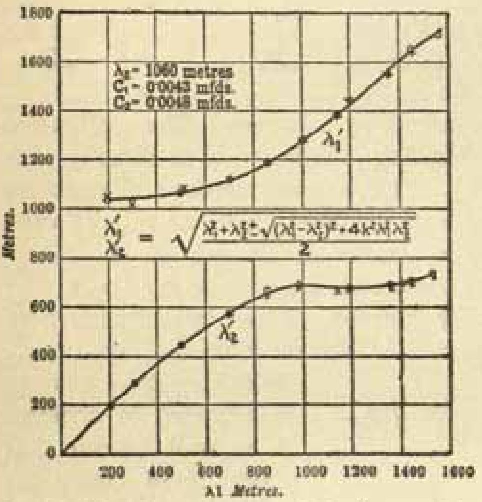


FIG. 8.—Pierce's experiments on inductive coupling.

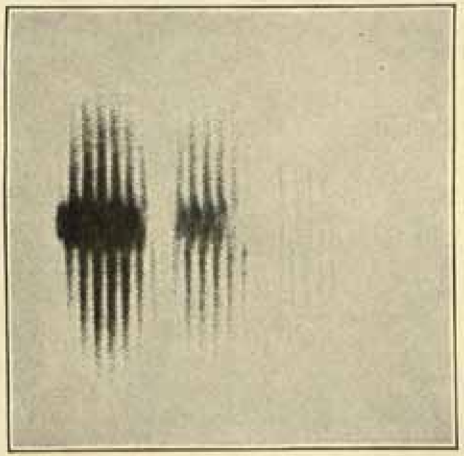


FIG. 9.—OSCILLOGRAM OF DAMPED OSCILLATION (ANTENNA NOT CONNECTED) TAKEN WITH THE GEHRCKE OSCILLOGRAPH VACUUM TUBE.

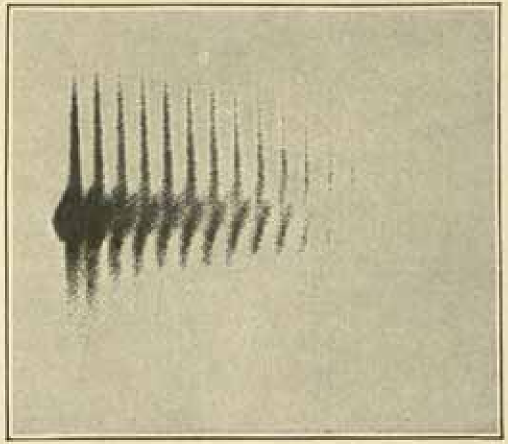


FIG. 10.—OSCILLOGRAM OF SECONDARY OSCILLATION (ANTENNA CONNECTED) TAKEN WITH GEHRCKE VACUUM TUBE.

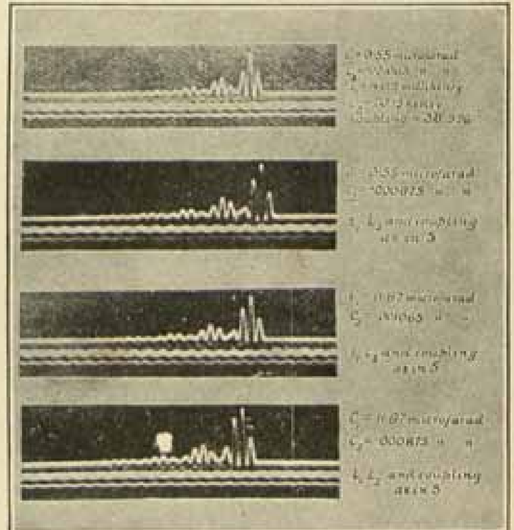


FIG. 10A.—OSCILLOGRAMS OF OSCILLATIONS IN COUPLED CIRCUITS BY PROF. E. TAYLOR-JONES.

If, however, the oscillations are damped, then we see in the mirror a train of images each decreasing in length (fig. 9, pl. 1). On applying such an oscillograph vacuum tube to the circuit of an inductively coupled antenna, and examining in a revolving mirror the image of the electrodes, they will be seen to present an appearance as in fig. 10, pl. 1, taken from photographs kindly given me by Herr Hans Boas, of Berlin. These oscillograms indicate that there are two oscillations present of different frequency, producing an effect similar to beats in music. Owing to the difference in frequency, the oscillations alternately reenforce and extinguish each other throughout the period, and as this type of oscillogram is only obtained with an inductively coupled antenna, it is a proof that in such a case there are two oscillations present of different frequencies. A similar result has been obtained by Prof. E. Taylor Jones with low-frequency oscillations in coupled inductive circuits by means of an electrostatic oscillogram of his own invention. Looking at these photographs, it will be seen that each represents a single train of damped oscillations gradually dying away, but that in each train of oscillations there is an alternate waxing and waning of the amplitude, which indicates that it may be considered to be composed of two superimposed oscillations of different frequency (fig. 10A, pl. 1).

Accordingly, in the case of wireless telegraph antennæ inductively coupled, we have in general two waves radiated of different lengths, and either of these can be made to affect suitably tuned receiving circuits. These waves have different damping and different maximum amplitudes.

One of the disadvantages of close inductive coupling is, therefore, that we must divide the energy given to the antenna between two waves of different length. As the receiving antenna is generally only tuned to one of these wave lengths, we then capture and absorb only the energy conveyed by the waves of that wave length. To meet this difficulty it has been the custom to employ a feeble coupling between the circuits of the oscillation transformer, so as to generate waves of only one wave length. The objection then arises that the energy conveyed to the antenna is much reduced. It is, however, possible, as I have shown, to duplicate the receiving circuits so as to capture the energy of both the waves even with close coupling of the transmitter transformer [a] (see fig. 11).

A method of creating feebly damped oscillations has, on the other hand, recently been developed, generally known in Germany as Wien's

[a] Since the delivery of this lecture my attention has been drawn by Mr. J. Hettinger to an article by himself in the "Electrical Engineer" of October 26, 1906, in which he describes an almost identical arrangement devised by him for capturing both the waves of an inductively coupled transmitter, and refers to a prior invention for the same purpose by Dr. G. Seibt.

method, or the method of quenched sparks, which is based on the fact that if we can quench or stop the spark in the condenser circuit after the first few oscillations, the oscillations of the antenna then take place freely and with a single frequency (see fig. 11A).

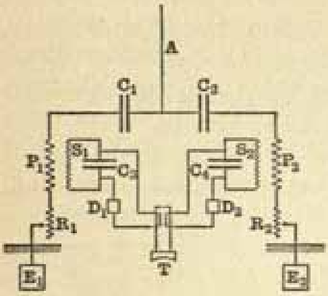


FIG. 11.—Method of utilizing waves of both frequencies emitted by inductively coupled transmitting antenna.

The principle which underlies this method is the well-known fact, to which particular attention was called by Prof. M. Wien, of Danzig, in 1906, that the damping effect of very short sparks is extremely large. Hence, if we form a spark gap consisting of a large number of very small spark gaps in series, say 10 gaps each of 0.3 mm., and if we keep the spark surfaces cool, then not only can no arc form between these surfaces but the condenser spark is immediately quenched. Moreover, if we supply this spark gap, either from a high frequency alternator, or from a low resistance transformer, we can produce as many as 2,000 sparks per second. A form of discharger for this purpose has been devised in Germany which consists of a series of copper disks or copper boxes cooled with water, the flat surfaces of which are placed in contiguity, but separated by very thin rings of mica. The interspace between the boxes is not more than one one-hundred-and-twenty-fifth of an inch, and ten or twelve of these disks or boxes are placed in series (see fig. 11B). The row of boxes takes the place of the ordinary spark balls, and is connected to the secondary terminals of a transformer, fed by a high frequency alternator, and also connected to an oscillatory circuit. When the transformer is in action it produces a very large number, 1,000 or more, of oscillatory discharges of the condenser per second, each of which has a large initial amplitude, but quickly dies out. The inductively or directly coupled antenna hence receives a very large

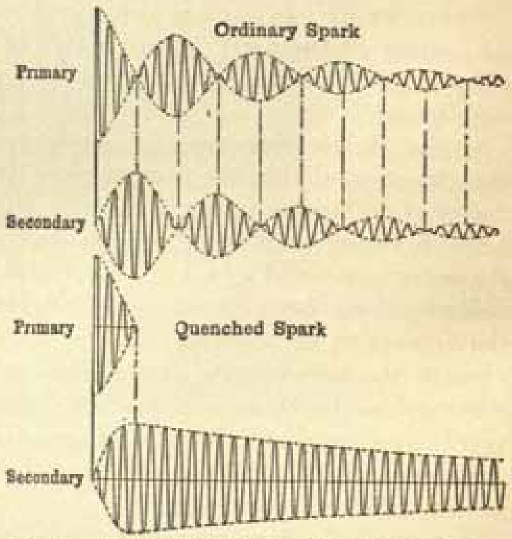
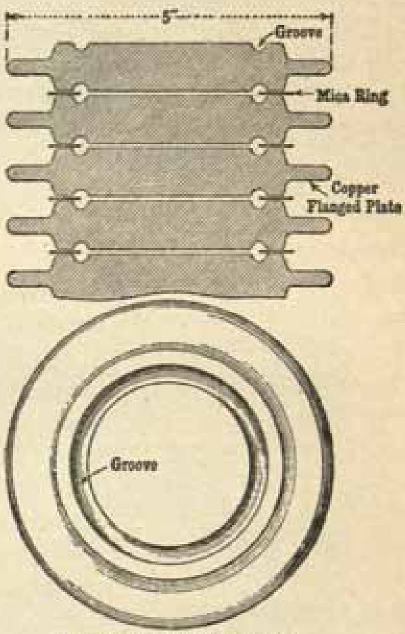


FIG. 11A. Oscillations in inductively coupled circuits.

number of impulses per second, each of which sets up in it free electrical oscillations of one definite period.

A discharge composed of a single pair of metal plates with interposed separating paper ring has been devised and employed by Von Lepel. In this case the plates are connected to the terminals of a high-voltage direct-current dynamo, and are shunted by a circuit having inductance and capacity, one of the plates being also connected to an antenna and the other to a balancing capacity.

These dischargers, however, have not stood the test of prolonged practical use, and we can not say therefore that they are comparable in value for telegraphic purposes with the well-proved inventions of Mr. Marconi.



Plan of Copper Flanged Plate

FIG. 11B. Plan and section showing portion of discharger.

In connection with spark telegraphy it has been clearly seen, lately, that much can be done by attention to details of construction to increase the number of oscillations in each wave train in the case of spark apparatus, in other words, to lessen the damping by obviating energy losses in all parts of the apparatus. It is not a matter of indifference what kind of glass we use in Leyden jars or what form of stranded wire we employ in oscillation transformers, or type of spark discharger. By appropriate selection of apparatus, we can considerably increase the number of oscillations in damped trains of small amplitude, and therefore increase the possibilities of utilizing the principle of resonance.

Before leaving the subject of the antenna we may notice some recent improvements in directive antennæ, that is, in devices for more or less confining the radiation to one direction, and for locating the position of the sending station.

In a previous discourse explanations were given of the property of a closed or partly closed antenna of radiating more in some directions than others, and the action of Marconi's bent antenna was described. Two other inventors, Messrs. Bellini and Tosi, have taken advantage of this fact to construct antennæ of a very interesting character. They erect an antenna consisting of two wires, each bent

into a triangular form, the top ends nearly meeting, the planes of these triangles being at right angles to one another, and both of them vertical. The nearly closed antenna circuits are then inductively coupled with a condenser circuit, which is capable of being swivelled around in various directions. If the said condenser circuit is placed in such a position as to be coupled with one of the triangular antennæ, it will cause the maximum radiation to take place in the plane of that antenna, but none at all at right angles to it. If it is coupled with the other antenna, it will cause radiation to take place to a maximum degree in the plane of that second antenna. If, however, the oscillatory circuit is placed in an intermediate position, so as to act inductively upon both the nearly closed triangular antennæ, then it can be shown both mathematically and experimentally that the radiation of the combined system is a maximum in the direction of the plane of the oscillatory circuit which is coupled with the antenna. Hence, with such a combined antenna, we have it in our power to create radiation most strongly in one direction, although not entirely suppressed in all other directions. By combining together, however, a single vertical antenna with two nearly closed circuit antennæ at right angles to one another, Messrs. Bellini and Tosi have constructed a complex antenna which has the property of producing radiation almost entirely limited to one-half of the circumjacent space (see fig. 12). It therefore corresponds to a certain extent in effect to the optical apparatus of a light-house, with catoptric or dioptric apparatus, which projects the light from the lamp largely in one direction. It is not yet possible to make with electric radiation of long wave length that which corresponds precisely with a beam of light wholly concentrated along a certain cone or cylinder, but it is possible, by the use of a complex antenna as described, to greatly limit the diffusion of the radiation. Since radiating and absorbing power go hand in hand, it is obvious that such a directive antenna also enables the position of a sending station to be located. Messrs. Bellini and Tosi have accordingly applied their methods in the construction of a radiogoniometer and receiving antenna, by means of which they can locate the direction of the sending station without moving the antenna, but merely by turning around a secondary circuit into a position in which the maximum sound is heard in a telephone connected with the receiver. By the kindness of Captain Tosi I am able to exhibit to you their ingenious apparatus (see fig. 13, pl. 2).

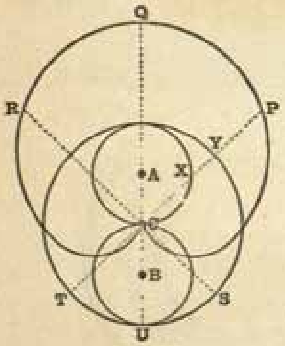


FIG. 12.

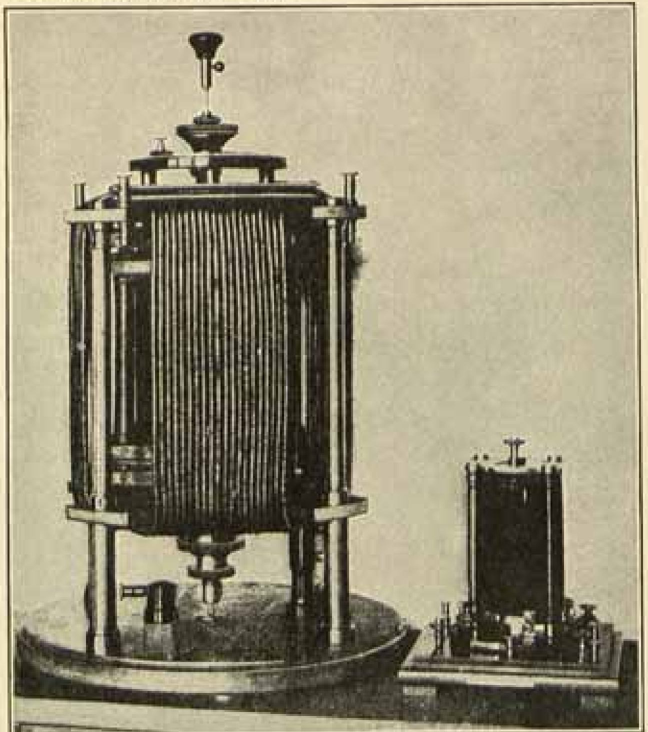


FIG. 13.—BELLINI AND TOSI'S RADIOGONIOMETERS FOR DIRECTIVE RADIOTELEGRAPHY.

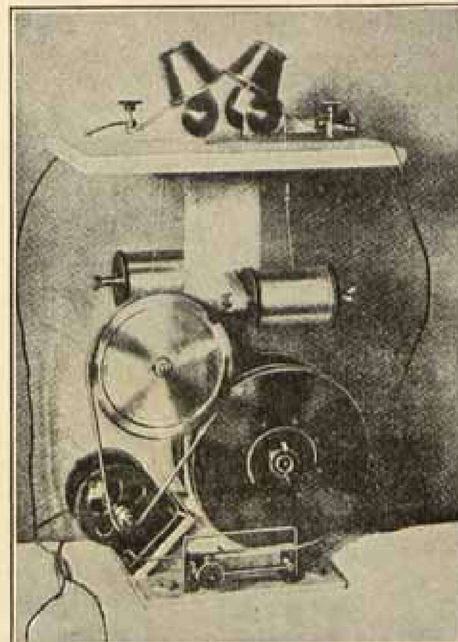


FIG. 21.—ERNST RUHMER'S HIGH-TENSION ALUMINIUM ARC FOR PRODUCING PERSISTENT OSCILLATIONS FOR RADIOTELEPHONY.

The space occupied by such closed antennæ has hitherto prevented their employment on ships. There is still, therefore, an opening for the invention of apparatus capable of being used on board ship which will enable one ship to locate, within narrow limits, the direction of another ship sending signals to it, and therefore of ascertaining immediately the direction from which some call for help is proceeding.

Closely connected with this part of the subject is the question so frequently discussed as to the isolation or secrecy of radiotelegraphic communication. Up to the present moment the only really practical method of isolating any particular receiver so as to make it sensitive only to signals coming from a certain direction, is to avail ourselves to the utmost of the principle of resonance and to tune the sending and receiving circuits to exact correspondence. The question then arises, What is it which determines the effectiveness of this tuning? If waves of one particular wave length are impinging on a receiving antenna and creating signals, by how much can the wave length be varied or the tuning of the receiver upset or changed without preventing these signals being received? It is clear that the narrower this range the more perfect the isolation of the receiver. It can be shown that it depends upon the form of the resonance curve of the sending and receiving circuits. If the sending station is emitting waves of a certain constant wave length and damping or decrement, then in the receiving circuit of all other stations within range there will be produced oscillations having a certain mean square value measurable by appropriate instruments. If any receiving circuit is gradually brought by adjustment of its capacity and inductance into exact syntony or tune with the sending station, then this receiver current reaches its maximum value and there is a definite lesser value of the receiver current for every particular degree of want of tuning or dissonance between the two. The curve which by its ordinates expresses this receiver current corresponding to each particular tuning or natural frequency of the receiving circuit, is called a resonance curve (see fig. 14). If this curve has a very sharp peak, then it clearly indicates that a slight want of tuning or syntony between the stations will greatly reduce the receiver current. The peakiness of

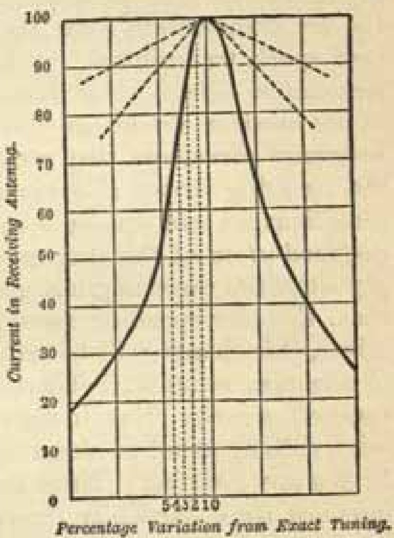


Fig. 14.—Resonance curves.

the curve depends upon the sum of the decrements of the sending and receiving circuits. By the term "decrement" of a circuit is meant the logarithm of the ratio of the amplitudes of two successive oscillations in the train.

To obtain very sharp tuning we have therefore to employ either undamped oscillations or very feebly damped oscillations in the transmitter, and also a receiving circuit in which there is as little dissipation of energy by resistance and other causes as possible. It is then possible to cause a change of even less than one-half of 1 per cent, or 5 parts in 1,000 in the wave length of the received waves to cease to actuate the receiver. This means that we can distinguish between two waves 1,000 and 1,005 or 1,010 feet in length, respectively, and that our receiver may be tuned to respond to one and not to the other. The persistent or undamped oscillations created by the arc transmitters have, therefore, an advantage in this respect over spark transmitters, in that the damping or decrement of the transmitter is less; but it should be borne in mind that the damping of the receiver circuit has also a large influence on the form of the resonance curve, and that good isolation can not be obtained unless the receiving circuit also has a small decrement. Under favorable conditions we can employ a sending key, which does not interrupt the production of the electric waves at the sending station, but simply alters the wave length slightly by about one-fourth per cent. If, then, the corresponding receiving station has a feebly damped receiver, this change will be sufficient to cut up the continuous record or telephone sound at that station into Morse dots and dashes, and so transmit signals. But another station not so tuned will either receive nothing at all or else a continuous unbroken line or sound not having any meaning. There are other methods by which signals not intended for a particular receiver can be rejected by it. Fessenden has described for this purpose an interference detector, in which the impulses it is not desired to receive are made to divide between two paths, the oscillations in which are then caused to neutralize each other's effect on the oscillation detector. On the other hand, the waves of the wave length it is desired to receive do not so neutralize themselves, but produce a signal by their operation on the detector.

We must pass on to notice in the next place some improvements in oscillation detectors, and means of testing them. As already explained, the ether waves sent out by the transmitting antenna fall on the receiving antenna and create in it or some other circuit connected to it very feeble oscillations. These oscillations being very feeble alternating currents of high frequency, can not directly affect either an ordinary telegraphic instrument or a telephone, but we have to interpose a device of some kind called an oscillation detector, which is affected by oscillations in such a manner that it undergoes some

change which in turn enables it to create, increase, or diminish a local current produced by a local battery and so affect a telephone or telegraphic relay. One kind of change the oscillations can produce in certain devices is a change in their electric resistance, which in turn is caused to increase or diminish a current through a telephone or telegraphic relay generated by a local battery. To this type belong the well-known coherers of Branly, Lodge, and Marconi, which require tapping or rotating to bring them back continually to a condition of sensitiveness. Coherers, however, have been devised which require no tapping. Thus it has been found by Mr. L. H. Walter that if a short length of very fine tantalum wire is dipped into mercury there is a very imperfect contact between the mercury and tantalum for low electromotive forces. This may perhaps arise from the fact that tantalum, like iron, is not wetted by mercury. If, however, feeble electric oscillations act between the mercury and tantalum, the contact is improved whilst they last. If, then, the terminals of a circuit containing a telephone in series with a shunted voltaic cell are connected to the mercury and tantalum, respectively, and if damped or intermittent trains of electric waves fall on an antenna and excite oscillations which are allowed to act on the mercury tantalum junction, then at each train the resistance of the contact falls, the local cell sends current through the telephone and produces a short sound, and if the trains come frequently enough this sound is repeated and will be heard as a continuous noise in the telephone (see fig. 15). This sound can be cut up into dot and dash signals by a key in the sending instrument. If the transmitter is sending persistent oscillations, then some form of interrupter has to be inserted in the receiving circuit to enable us to receive a continuous sound in the telephone which can be resolved into Morse dot and dash signals by the key in the transmitter. The operator usually wears on his head a double telephone, and listens to these long and short sounds in the telephone and writes down each letter or word as he hears it. The reception of signals in modern radiotelegraphy is most usually effected by ear, by means of some type of oscillation detector capable of actuating a telephone. It is important then to notice that, to obtain the highest sensitiveness when using the telephonic method of reception, the spark frequency or number of oscillation trains or the number of interruptions of the persistent train per second must take place at such a rate that it agrees with the natural time period of the diaphragm of the telephone

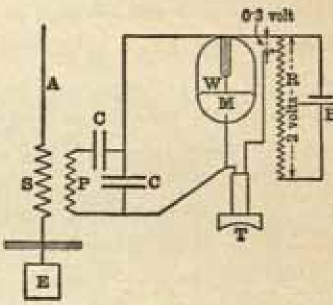


Fig. 15.—Walter's tantalum detector.

used. An ordinary telephone receiver is most sensitive, according to the researches of Lord Rayleigh and M. Wien, for some frequency lying between 500 and 1,000. Thus Lord Rayleigh (see Phil. Mag., vol. 38, 1894, p. 285) measured the alternating current in microamperes required to produce the least audible sound in a telephone receiver of 70 ohms resistance at various frequencies, and found values as follows:

TABLE II.

Frequency	128	192	256	307	320	384	512	640	768
Least audible current in microamperes	28	2.5	0.83	0.49	0.32	0.15	0.07	0.04	0.1

M. Wien found for a Siemens telephone somewhat different results viz:

Frequency	64	128	256	512	720	1,927	1,500
Least audible current in microamperes	12	1.5	0.13	0.027	0.006	0.013	0.024

Both, however, agree in showing a maximum sensitiveness for currents of a frequency between 600 and 700. This is due to the fact that the frequency of the actuating current then agrees with the natural frequency of the ordinary telephone diaphragm. Hence, alternators for large power radiotelegraphic stations are now designed to give currents with a frequency of about 300 or 600 alternations per second, so that, when producing discharges of a condenser, the number of sparks per second may be at least 600, and fulfill the conditions for giving maximum sound in the telephone of the receiver per microampere. Another class of oscillation detector recently discovered comprises the crystal detectors which depend on the possession by certain crystals of the curious property of acting as an electrical valve, or having greater conductivity in one direction than the other, and also on not obeying Ohm's law as conductors. It was discovered by General Dunwoody of the United States Army, in 1906, that a mass of carborundum, which is a crystalline carbide of silicon formed in electric furnaces, can act as a detector of electric oscillations if inserted in the circuit of an antenna, the crystal mass being held strongly pressed between two spring clips, which are also connected by a shunted voltaic cell in series with a telephone. When feeble oscillations are set up in the antenna, a sound is heard in the telephone. This property of carborundum has been carefully investigated by Prof. G. W. Pierce, of Harvard, and he showed that a single crystal of carborundum has remarkable unilateral conductivity for certain voltages when held with a certain contact pressure between metallic clips. Thus for a crystal held with a pressure of 1 kilogram, and subjected to an electromotive force of 30 volts, the conductivity in one direction through the crystal was 4,000 greater

than in the opposite direction (see fig. 16). The result of these experiments was also to show that the current voltage curve or characteristic curve of a carborundum crystal is not linear—that is to say, the crystal as a conductor does not comply with Ohm's law, for the resistance of the crystal decreases as the current is increased. Hence the conductivity of the crystal is a function of the voltage acting on it (see fig. 16A). Accordingly, if we pass a current from a local cell through a crystal under a voltage say of 2 volts, a telephone being inserted in series with the cell, and if we apply an oscillatory voltage also to the crystal, which varies say between +0.5 and −0.5 volt, then the crystal is alternately subjected to a voltage of 2.5 and 1.5 volts, but the corresponding currents would be say 8.4 and 1.8 microamperes, as shown by an experiment with one particular crystal employed by Professor Pierce. The mean current would then be 5.1 microamperes, whereas the steady voltage of 2 volts would only pass a current of 4 microamperes. Hence, apart from the unilateral conductivity, and merely in virtue of the fact that the characteristic curve is not a straight line, we find that such a crystal or even a confused mass of crystals can act as a radiotelegraphic detector. There are, therefore, two ways in which a crystalline mass of carborundum can be used as a radiotelegraphic detector. It consists of a conglomeration of crystals arranged in a disorderly manner, or not so symmetrically as to neutralize one another's unilateral conductivity. Hence the mass of crystals, like the single crystal, possesses unilateral conductivity, and also a conductivity which is a function of the voltage applied to it. We may then use it without a local cell, and avail ourselves of its valve property to rectify the trains of oscillations in the antenna and convert them into short unidirectional trains which can affect a galvanometer or telephone; or secondly, we may place the crystal between the ends of a circuit containing a telephone and a shunted voltaic cell, and then on passing oscillations

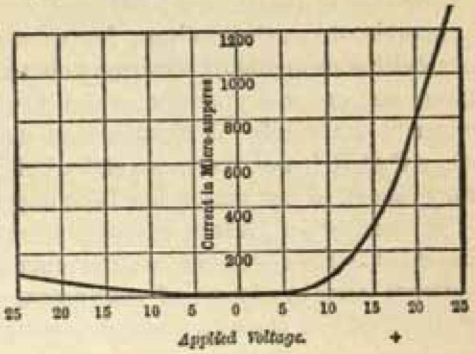


FIG. 16.—Characteristic curves of carborundum crystal.

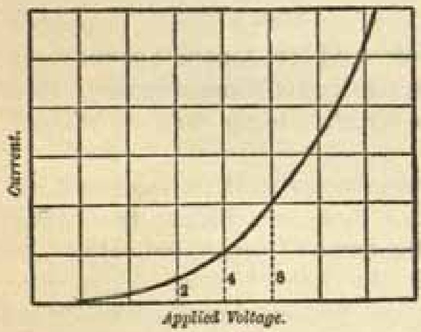


FIG. 16A.

through the crystal we hear sounds in the telephone due to the fact that the conductivity is a function of the voltage, and is therefore increased more by the addition than it is diminished by the substraction of the electromotive force of the oscillations to or from the steady voltage of the local cell. The telephone, therefore, detects this change in the average value of the current by a sound emitted by it. Professor Pierce has discovered that several other crystals possess similar properties to carborundum, for example, hessite, which is a native crystalline telluride of silver or gold; an anatase, which is an oxide of titanium; and molybdenite, which is a sulphide of molybdenum. As regards the origin of this curious unilateral conductivity, it seems clear that it is not thermoelectric, but at present no entirely satisfactory theory of the action has been suggested.

A number of forms of oscillation detector have recently been invented which depend on the curious fact that a slight contact between certain classes of conductors possesses a unilateral conductivity, and can therefore rectify oscillations. One such detector now much used in Germany consists of a plumbago or graphite point, pressed lightly against a surface of galena. It has been found by Otto von Bronk that a galena-tellurium contact is even more effective. To the same class belongs the silicon-steel detector of Pickard. If such a contact is inserted across the terminals of a condenser placed in the receiving circuit, and if it is also in series with a telephone, the trains of oscillations are rectified or converted into more or less prolonged gushes of electricity in one direction through the telephone. These coming at a frequency of several hundred per second, corresponding to the spark frequency, create a sound in the telephone, which can be cut up by the sending key into Morse signals. According to the researches of Professor Pierce and Mr. Austin it seems clear in many cases that this rectifying action is not thermoelectric, since the rectified current is in the opposite direction to the current obtained by heating the junction.

I may, then, bring to your notice some recent work on another form of radiotelegraphic detector, which I first described to the Royal Society about five years ago under the name of oscillation valve. It consists of an electric glow lamp, in the bulb of which is placed a cylinder of metal which surrounds the filament but does touch it. This cylinder is connected to a wire sealed through the glass. Instead of a cylinder, one or more metal plates are sometimes used. The filament may be carbon or a metallic filament, and I found some year or more ago that tungsten in various forms has special advantages. The bulb is exhausted to a high vacuum, but of course this means it includes highly rarefied gas of some kind. When the filament is rendered incandescent it emits electrons, and these electrons or negative

ions give to the residual gas a unilateral conductivity, as shown by me in a Friday evening lecture given here nineteen years ago. Moreover, the ionized gas not only possesses unilateral conductivity, but its conductivity, like that of the crystals just mentioned, is a function of the voltage applied to it. Hence, if we apply an electromotive force between the hot filament and the cool metal plate, we find that negative electricity can pass from the filament to the plate through the ionized gas, and that the relation between the current and voltage is not linear, but is represented by a characteristic curve bending upward which has changes of curvature in it (see fig. 17). The sharp bend upward at one place implies a large increase in the current corresponding to a certain voltage, which means that, corresponding to a certain potential gradient and therefore velocity of the electrons, considerable ionization of the residual gas is beginning to take place. The current, however, would not increase indefinitely with the voltage, but would before long become constant or saturated. It will be seen, therefore, that at points on the curve where there is a bend or change of curvature the second differential coefficient of the curve may have a large value. Hence, if we consider the current and voltage corresponding to this point, it will be seen that any small increase in the voltage increases the current more than an equal small decrease in voltage diminishes it. If then we superimpose on a steady voltage corresponding to a point of inflexion of the curve an alternating voltage, the average value of the current will be increased. This then points out two ways in which this oscillation valve or glow lamp can be used as a radiotelegraphic detector. First, we may make use of the unilateral conductivity of the ionized gas in the bulb and employ the glow lamp with cylinder around the incandescent filament as a rectifier of trains of oscillations to make them affect a galvanometer or telephone. This method was described by me in papers and specifications in 1904 and 1905. In that case the valve is arranged in connection with a receiving antenna, as shown in figure 18, and used with a galvanometer or telephone. Mr. Marconi subsequently added an induction coil and condenser, and employed in 1907 the arrangements shown in figure 19. In this case the trains of oscillations set up in the antenna could not by themselves affect a galvanometer or a tele-

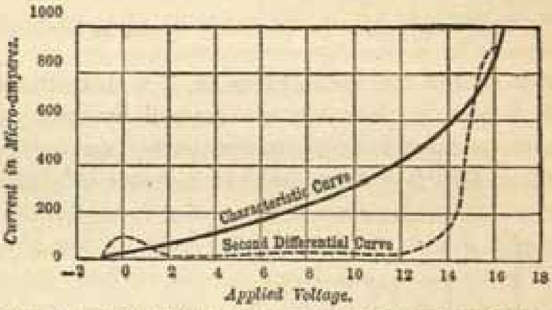


FIG. 17.—Characteristic curve of rarefied gas ionized by hot negative electrode.

phone, but when rectified by the valve they become equivalent to an intermittent unidirectional current, and can then affect the telephone or a galvanometer, or any instrument for detecting a direct current.

On the other hand, we may take advantage, as I have more recently shown, of the nonlinear form of the characteristic curve. In other words, of the fact that the conductivity of the ionized gas is a func-

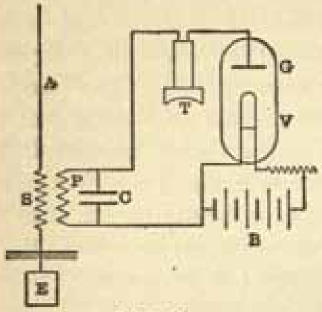


FIG. 18.

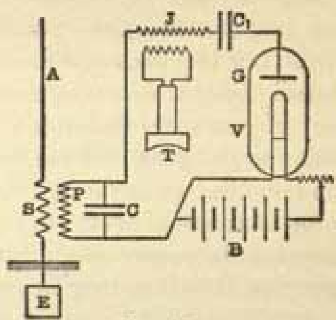


FIG. 19.

Connections for oscillation valve used as radiotelegraphic detector.

tion of the voltage applied to it, and in this second method the valve and receiving circuits are arranged as shown in figure 20. In this case, we have to apply to the ionized gas a unidirectional electromotive force which corresponds to a point of inflexion on the characteristic curve, and then to add to this voltage the alternating voltage of the oscillations set up by the incident electric waves in the receiving circuit. The result is to cause a change in the average value of the current through the telephone, and therefore to produce a sound in it, long or short, according to the number of trains of waves falling on the antenna. This last method, then, requires the application in the telephone circuit of an accurately adjusted steady electromotive force, not any electromotive force, but just that value which corresponds to a point on the characteristic curve at which there is a sudden change of curvature.

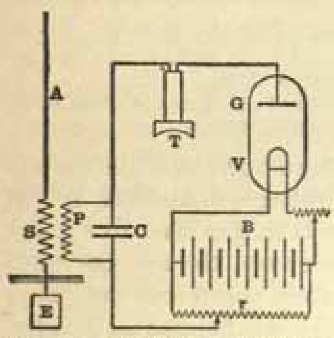


FIG. 20.—Connections for oscillation valve used as a radiotelegraphic detector.

At this point we may notice a broad generalization which has already been made by H. Brandes, viz, that any materials such as the crystals mentioned, or ionized gases, which do not obey Ohm's law as regards the independence of conductivity on impressed voltage, can be used as radiotelegraphic receivers. It is necessary to be able to test the relative sensibility of detectors to know whether any new

form is an improvement. It is not always possible for an inventor to get these tests made at real wireless telegraph stations. Moreover, it is no use to test over short distances, because then all detectors appear to be equally good. I have found, however, that we can make these comparative tests very easily within quite moderate distances by employing closed sending and receiving circuits which are poor radiators. All the devices called wave detectors are really only oscillation detectors, and we can therefore test their value simply by ascertaining how feeble an alternating current or alternating voltage they will detect. If we then set up in one place a square circuit of wire a few feet inside, and complete the circuit by a condenser and a spark gap, we can set up oscillations in it by means of an induction coil. I find that it is necessary to inclose the spark gap in a cast-iron box, and to blow upon the spark with a jet of air to secure silence, absence of emission of electromagnetic waves direct from the spark balls, and constancy in the oscillatory circuit. I then set up, a few score or few hundred feet away, a similar tuned closed oscillatory circuit, and I connect the oscillation detector to be tested either in this circuit or as a shunt across the condenser. The closed receiving circuit is so constructed that it may be rotated around either of three axes. It is then generally possible to find some position of the receiving circuit such that no sounds are heard in a telephone connected to a highly sensitive detector associated with the circuit. This position is called the "zero position." If the receiving circuit is rotated around some axis, it begins at a certain displacement to receive signals, and the angle through which it has to be turned is a measure of the insensibility of the particular oscillation detector being used. I find, for instance, that it is quite easy to take one of my oscillation valves, a magnetic detector, an electrolytic detector, a crystal detector, or any other type, and arrange these in order of their sensibility by means of the device described. Sensibility is not, however, the only virtue which a wave detector should possess. It is important that it should be simple, easily adjusted, and not injured by the chance passage through it of any unusually large oscillatory currents. Another quality which is desirable is that it should be quantitative in its action, and that any change in the amplitude of the wave received should be accompanied by an equal change in the current which the detector allows to pass through the telephone. A quantitative oscillation detector then enables not merely signals but audible speech to be transmitted. In other words, it can effect wireless telephony. The difficulties, however, in connection with the achievement of wireless telephony are not so much in the receiver as in the transmitter. We have to obtain, first, the uniform production of persistent electromagnetic waves radiated from an antenna; and, next, we have to vary the amplitude of these electric waves proportionately to, and

by means of, the aerial vibrations created by the voice speaking to some form of microphone. We can not employ an intermittent spark generator because each spark would give rise to a sound in the telephone, and these sounds, if occurring at regular intervals, would produce a musical note in the telephone. If, however, we make the sparks run together into what is practically a high voltage arc taking a small current, then, in an oscillatory circuit shunted across this arc, we have set up persistent high frequency oscillations, as first achieved by Mr. Duddell. We can greatly increase the energy of the oscillations by immersing the arc in a strong transverse magnetic field and also in a hydrocarbon gas, as shown by Poulsen, or we may employ a number of arcs in series. E. Ruhmer has lately also employed a high-tension arc between aluminum electrodes (see fig. 21, pl. 2), shunted by a condenser and inductance as a means of generating persistent oscillations. As an alternative, it is possible to create them by a mechanical method, viz, by a high frequency alternator, subject, however, to certain limitations as to frequency. Both these types of generator have their advantages and practical objections. There is good evidence that radiotelephony has been accomplished over distances of 100 miles or more by each of these methods in the hands of experts, but what is now required is the reduction of the apparatus to such simple manageable and practical form that it can be applied in regular work. The wave-generating apparatus must be capable of producing uniform persistent oscillations of high voltage and frequency, not less than 30,000 or 40,000 per second, or at least above the limits of audition, and the amplitude of these oscillations must be capable of being varied by some form of speaking microphone placed in the oscillation circuit or in the radiating antenna, or in a secondary circuit coupled to it. No ordinary simple carbon microphone will safely pass sufficient current for this purpose. A type of multiple microphone has been used successfully and also a duplex microphone, the invention of Ernst Ruhmer.

It is not, however, possible to speak of radiotelephony at the present time as having reached the same level of practical perfection as radiotelegraphy. But the possibilities of it are of such a nature that it will continue to attract the serious attention of inventors. This is not the place to enter into a full discussion of the causes which limit submarine telephony through cables, but there are well-known reasons in the nature of submarine cables as at present made which impose very definite limits upon it, owing to what is called distortion of the wave form. Electric wave telephony is free at least from this disadvantage, and if (as has been asserted) arc generators can be made self-regulating and capable of being worked for hours automatically, or even for ten minutes without being touched, then the remaining difficulties with the microphone are not insuperable.

Time does not permit of the discussion of the many other points in connection with radiotelegraphy and telephony which have been the subject of recent work. Much attention has been paid lately to methods of cutting out atmospheric signals due to natural electrical discharges in the atmosphere, which are troublesome disturbers of the etherial calm necessary for radiotelegraphy. Considerable thought and expenditure have been necessary to discover means for overcoming the difficulties of long distance transmission by daylight, and also those arising from the cross talk of other stations. Much also has been done in training skilled wireless operators both in the navy and for the mercantile marine work. Radiotelegraphy, like aviation, is an art as well as a science, hence personal skill is a factor of importance in turning the flank of the difficulties of the moment. Nevertheless, the art and the science of radiotelegraphy are both progressing, and the splendid services already rendered by it in saving life at sea are at once a proof of present perfection and an evidence that the arduous labors of investigators and inventors have borne fruit in yet larger powers to command the great forces of nature for the use and benefit of mankind.

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RECENT PROGRESS IN PHYSICS.[a]

By Prof. Sir J. J. Thomson, M. A., LL. D., D. Sc., F. R. S.

It has usually been the practice of the president of this association to give some account of the progress made in the last few years in the branch of science which he has the honor to represent.

I propose this evening to follow that precedent and to attempt to give a very short account of some of the more recent developments of physics, and the new conceptions of physical processes to which they have led.

The period which has elapsed since the association last met in Canada has been one of almost unparalleled activity in many branches of physics, and many new and unsuspected properties of matter and electricity have been discovered. The history of this period affords a remarkable illustration of the effect which may be produced by a single discovery; for it is, I think, to the discovery of the Röntgen rays that we owe the rapidity of the progress which has recently been made in physics. A striking discovery like that of the Röntgen rays acts much like the discovery of gold in a sparsely populated country; it attracts workers who come in the first place for the gold, but who may find that the country has other products, other charms, perhaps even more valuable than the gold itself. The country in which the gold was discovered in the case of the Röntgen rays was the department of physics dealing with the discharge of electricity through gases, a subject which, almost from the beginning of electrical science, had attracted a few enthusiastic workers, who felt convinced that the key to unlock the secret of electricity was to be found in a vacuum tube. Röntgen, in 1895, showed that when electricity passed through such a tube, the tube emitted rays which could pass through bodies opaque to ordinary light; which could, for example, pass through the flesh of the body and throw a shadow of the bones on a suitable screen. The fascination of this discovery attracted many workers to the subject of the discharge of electricity

[a] Presidential address at British Association meeting, 1909. Reprinted by permission (omitting introduction) from Chemical News, London, vol. 100, No. 2596, August 27, 1909.

through gases, and led to great improvements in the instruments used in this type of research. It is not, however, to the power of probing dark places, important though this is, that the influence of Röntgen rays on the progress of science has mainly been due; it is rather because these rays make gases, and, indeed, solids and liquids, through which they pass conductors of electricity. It is true that before the discovery of these rays other methods of making gases conductors were known, but none of these was so convenient for the purposes of accurate measurement.

The study of gases exposed to Röntgen rays has revealed in such gases the presence of particles charged with electricity; some of these particles are charged with positive, others with negative electricity.

The properties of these particles have been investigated; we know the charge they carry, the speed with which they move under an electric force, the rate at which the oppositely charged ones recombine, and these investigations have thrown a new light, not only on electricity, but also on the structure of matter.

We know from these investigations that electricity, like matter, is molecular in structure, that just as a quantity of hydrogen is a collection of an immense number of small particles called molecules, so a charge of electricity is made up of a great number of small charges, each of a perfectly definite and known amount.

Helmholtz said in 1880 that in his opinion the evidence in favor of the molecular constitution of electricity was even stronger than that in favor of the molecular constitution of matter. How much stronger is that evidence now, when we have measured the charge on the unit and found it to be the same from whatever source the electricity is obtained. Nay, further, the molecular theory of matter is indebted to the molecular theory of electricity for the most accurate determination of its fundamental quantity, the number of molecules in any given quantity of an elementary substance.

The great advantage of the electrical methods for the study of the properties of matter is due to the fact that whenever a particle is electrified it is very easily identified, whereas an uncharged molecule is most elusive; and it is only when these are present in immense numbers that we are able to detect them. A very simple calculation will illustrate the difference in our power of detecting electrified and unelectrified molecules. The smallest quantity of unelectrified matter ever detected is probably that of neon, one of the inert gases of the atmosphere. Professor Strutt has shown that the amount of neon in one-twentieth of a cubic centimeter of the air at ordinary pressures can be detected by the spectroscope; Sir William Ramsay estimates that the neon in the air only amounts to one part of neon in 100,000 parts of air, so that the neon in one-twentieth of a cubic centimeter of air would only occupy at atmospheric pressure a vol-

ume of half a millionth of a cubic centimeter. When stated in this form the quantity seems exceedingly small, but in this small volume there are about ten million million molecules. Now the population of the earth is estimated at about fifteen hundred millions, so that the smallest number of molecules of neon we can identify is about 7,000 times the population of the earth. In other words, if we had no better test for the existence of a man than we have for that of an unelectrified molecule we should come to the conclusion that the earth is uninhabited. Contrast this with our power of detecting electrified molecules. We can by the electrical method, even better by the cloud method of C. T. R. Wilson, detect the presence of three or four charged particles in a cubic centimeter. Rutherford has shown that we can detect the presence of a single α-particle. Now the particle is a charged atom of helium; if this atom had been uncharged we should have required more than a million million of them, instead of one, before we should have been able to detect them.

We may, I think, conclude, since electrified particles can be studied with so much greater ease than unelectrified ones, that we shall obtain a knowledge of the ultimate structure of electricity before we arrive at a corresponding degree of certainty with regard to the structure of matter.

We have already made considerable progress in the task of discovering what the structure of electricity is. We have known for some time that of one kind of electricity—the negative—and a very interesting one it is. We know that negative electricity is made up of units all of which are of the same kind; that these units are exceedingly small compared with even the smallest atom, for the mass of the unit is only one seventeen-hundredth part of the mass of an atom of hydrogen; that its radius is only 10^{-13} centimeter, and that these units, "corpuscles" as they have been called, can be obtained from all substances. The size of these corpuscles is on an altogether different scale from that of atoms; the volume of a corpuscle bears to that of the atom about the same relation as that of a speck of dust to the volume of this room. Under suitable conditions they move at enormous speeds which approach in some instances the velocity of light.

The discovery of these corpuscles is an interesting example of the way nature responds to the demands made upon her by mathematicians. Some years before the discovery of corpuscles it had been shown by a mathematical investigation that the mass of a body must be increased by a charge of electricity. This increase, however, is greater for small bodies than for large ones, and even bodies as small as atoms are hopelessly too large to show any appreciable effect; thus the result seemed entirely academic. After a time corpuscles were discovered, and these are so much smaller than the atom that the

increase in mass due to the charge becomes not merely appreciable, but so great that, as the experiments of Kaufmann and Bucherer have shown, the whole of the mass of the corpuscle arises from its charge.

We know a great deal about negative electricity; what do we know about positive electricity? Is positive electricity molecular in structure? Is it made up into units, each unit carrying a charge equal in magnitude though opposite in sign to that carried by a corpuscle? Does, or does not, this unit differ, in size and physical properties, very widely from the corpuscles? We know that by suitable processes we can get corpuscles out of any kind of matter, and that the corpuscles will be the same from whatever source they may be derived. Is a similar thing true for positive electricity? Can we get, for example, a positive unit from oxygen of the same kind as that we get from hydrogen?

For my own part, I think the evidence is in favor of the view that we can, although the nature of the unit of positive electricity makes the proof much more difficult than for the negative unit.

In the first place we find that the positive particles—"canalstrahlen" is their technical name—discovered by our distinguished guest, Dr. Goldstein, which are found when an electric discharge passes through a highly rarefied gas, are, when the pressure is very low, the same, whatever may have been the gas in the vessel to begin with. If we pump out the gas until the pressure is too low to allow the discharge to pass, and then introduce a small quantity of gas and restart the discharge, the positive particles are the same whatever kind of gas may have been introduced.

I have, for example, put into the exhausted vessel oxygen, argon, helium, the vapor of carbon tetrachloride, none of which contain hydrogen, and found the positive particles to be the same as when hydrogen was introduced.

Some experiments made lately by Wellisch, in the Cavendish Laboratory, strongly support the view that there is a definite unit of positive electricity independent of the gas from which it is derived; these experiments were on the velocity with which positive particles move through mixed gases. If we have a mixture of methyliodide and hydrogen exposed to Röntgen rays, the effect of the rays on the methyliodide is so much greater than on the hydrogen that, even when the mixture contains only a small percentage of methyliodide, practically all the electricity comes from this gas, and not from the hydrogen.

Now, if the positive particles were merely the residue left when a corpuscle had been abstracted from the methyliodide, these particles would have the dimensions of a molecule of methyliodide; this is very large and heavy, and would therefore move more slowly

through the hydrogen molecules than the positive particles derived from hydrogen itself, which would, on this view, be of the size and weight of the light hydrogen molecules. Wellisch found that the velocities of both the positive and negatives particles through the mixture were the same as the velocities through pure hydrogen, although in the one case the ions had originated from methyliodide and in the other from hydrogen; a similar result was obtained when carbon tetrachloride, or mercury methyl, was used instead of methyliodide. These and similar results lead to the conclusion that the atom of the different chemical elements contain definite units of positive as well as of negative electricity, and that the positive electricity, like the negative, is molecular in structure.

The investigations made on the unit of positive electricity show that it is of quite a different kind from the unit of negative, the mass of the negative unit is exceedingly small compared with any atom, the only positive units that up to the present have been detected are quite comparable in mass with the mass of an atom of hydrogen; in fact, they seem equal to it. This makes it more difficult to be certain that the unit of positive electricity has been isolated, for we have to be on our guard against its being a much smaller body attached to the hydrogen atoms which happen to be present in the vessel. If the positive units have a much greater mass than the negative ones, they ought not to be so easily deflected by magnetic forces when moving at equal speeds; and, in general, the insensibility of the positive particles to the influence of a magnet is very marked; though there are cases when the positive particles are much more readily deflected, and these have been interpreted as proving the existence of positive units comparable in mass with the negative ones. I have found, however, that in these cases the positive particles are moving very slowly, and that the ease with which they are deflected is due to the smallness of the velocity and not to that of the mass. It should, however, be noted that M. Jean Becquerel has observed in the absorption spectra of some minerals and Professor Wood in the rotation of the plane of polarization by sodium vapor, effects which could be explained by the presence in the substances of positive units comparable in mass with corpuscles. This, however, is not the only explanation which can be given of these effects, and at present the smallest positive electrified particles of which we have direct experimental evidence have masses comparable with that of an atom of hydrogen.

A knowledge of the mass and size of the two units of electricity, the positive and the negative, would give us the material for constructing what may be called a molecular theory of electricity, and would be a starting point for a theory of the structure of matter; for the most natural view to take, as a provisional hypothesis, is that matter is just a collection of positive and negative units of electricity,

and that the forces which hold atoms and molecules together, the properties which differentiate one kind of matter from another, all have their origin in the electrical forces exerted by positive and negative units of electricity, grouped together in different ways in the atoms of the different elements.

As it would seem that the units of positive and negative electricity are of very different sizes, we must regard matter as a mixture containing systems of very different types, one type corresponding to the small corpuscle, the other to the large positive unit.

Since the energy associated with a given charge is greater the smaller the body on which the charge is concentrated, the energy stored up in the negative corpuscles will be far greater than that stored up by the positive. The amount of energy which is stored up in ordinary matter in the form of the electrostatic potential energy of its corpuscles is, I think, not generally realized. All substances give out corpuscles, so that we may assume that each atom of a substance contains at least one corpuscle. From the size and the charge on the corpuscle, both of which are known, we find that each corpuscle has 8×10^{-7} ergs of energy; this is on the supposition that the usual expressions for the energy of a charged body hold when, as in the case of a corpuscle, the charge is reduced to one unit. Now, in 1 gram of hydrogen there are about 6×10^{23} atoms, so if there is only one corpuscle in each atom the energy due to the corpuscles in a gram of hydrogen would be 48×10^{16} ergs, or 11×10^{9} calories. This is more than seven times the heat developed by 1 gram of radium, or than that developed by the burning of 5 tons of coal. Thus we see that even ordinary matter contains enormous stores of energy; this energy is fortunately kept fast bound by the corpuscles; if at any time an appreciable fraction were to get free the earth would explode and become a gaseous nebula.

The matter of which I have been speaking so far is the material which builds up the earth, the sun, and the stars, the matter studied by the chemist, and which he can represent by a formula; this matter occupies, however, but an insignificant fraction of the universe, it forms but minute islands in the great ocean of the ether, the substance with which the whole universe is filled.

The ether is not a fantastic creation of the speculative philosopher; it is as essential to us as the air we breathe. For we must remember that we on this earth are not living on our own resources; we are dependent from minute to minute upon what we are getting from the sun, and the gifts of the sun are conveyed to us by the ether. It is to the sun that we owe not merely night and day, spring time and harvest, but it is the energy of the sun, stored up in coal, in waterfalls, in food, that practically does all the work of the world.

How great is the supply the sun lavishes upon us becomes clear when we consider that the heat received by the earth under a high sun and a clear sky is equivalent, according to the measurements of Langley, to about 7,000 horsepower per acre. Though our engineers have not yet discovered how to utilize this enormous supply of power, they will, I have not the slightest doubt, ultimately succeed in doing so; and when coal is exhausted and our water power inadequate, it may be that this is the source from which we shall derive the energy necessary for the world's work. When that comes about, our centers of industrial activity may perhaps be transferred to the burning deserts of the Sahara, and the value of land determined by its suitability for the reception of traps to catch sunbeams.

This energy, in the interval between its departure from the sun and its arrival at the earth, must be in the space between them. Thus this space must contain something which, like ordinary matter, can store up energy, which can carry at an enormous pace the energy associated with light and heat, and which can, in addition, exert the enormous stresses necessary to keep the earth circling round the sun and the moon round the earth.

The study of this all-pervading substance is perhaps the most fascinating and important duty of the physicist.

On the electromagnetic theory of light, now universally accepted, the energy streaming to the earth travels through the ether in electric waves; thus practically the whole of the energy at our disposal has at one time or another been electrical energy. The ether must, then, be the seat of electrical and magnetic forces. We know, thanks to the genius of Clerk Maxwell, the founder and inspirer of modern electrical theory, the equations which express the relation between these forces, and although for some purposes these are all we require, yet they do not tell us very much about the nature of the ether.

The interest inspired by equations, too, in some minds is apt to be somewhat platonic; and something more grossly mechanical—a model, for example, is felt by many to be more suggestive and manageable, and for them a more powerful instrument of research, than a purely analytical theory.

Is the ether dense or rare? Has it a structure? Is it at rest or in motion? are some of the questions which force themselves upon us.

Let us consider some of the facts known about the ether. When light falls on a body and is absorbed by it, the body is pushed forward in the direction in which the light is traveling, and if the body is free to move it is set in motion by the light. Now, it is a fundamental principle of dynamics that when a body is set moving in a certain direction, or, to use the language of dynamics, acquires momentum in that direction, some other mass must lose the same amount of momentum; in other words, the amount of momentum in the uni-

verse is constant. Thus when the body is pushed forward by the light some other system must have lost the momentum the body acquires, and the only other system available is the wave of light falling on the body; hence we conclude that there must have been momentum in the wave in the direction in which it is traveling. Momentum, however, implies mass in motion. We conclude, then, that in the ether through which the wave is moving there is mass moving with the velocity of light. The experiments made on the pressure due to light enable us to calculate this mass, and we find that in a cubic kilometer of ether carrying light as intense as sunlight is at the surface of the earth, the mass moving is only about one fifty-millionth of a milligram. We must be careful not to confuse this with the mass of a cubic kilometer of ether; it is only the mass moved when the light passes through it; the vast majority of the ether is left undisturbed by the light. Now, on the electromagnetic theory of light, a wave of light may be regarded as made up of groups of lines of electric force moving with the velocity of light; and if we take this point of view we can prove that the mass of ether per cubic centimeter carried along is proportional to the energy possessed by these lines of electric force per cubic centimeter, divided by the square of the velocity of light. But though lines of electric force carry some of the ether along with them as they move, the amount so carried, even in the strongest electric fields we can produce, is but a minute fraction of the ether in their neighborhood.

This is proved by an experiment made by Sir Oliver Lodge in which light was made to travel through an electric field in rapid motion. If the electric field had carried the whole of the ether with it, the velocity of the light would have been increased by the velocity of the electric field. As a matter of fact no increase whatever could be detected, though it would have been registered if it had amounted to one-thousandth part of that of the field.

The ether carried along by a wave of light must be an exceedingly small part of the volume through which the wave is spread. Parts of this volume are in motion, but by far the greater part is at rest; thus in the wave front there can not be uniformity, at some parts the ether is moving, at others it is at rest—in other words, the wave front must be more analogous to bright specks on a dark ground than to a uniformly illuminated surface.

The place where the density of the ether carried along by an electric field rises to its highest value is close to a corpuscle, for round the corpuscles are by far the strongest electric fields of which we have any knowledge. We know the mass of the corpuscle, we know from Kaufmann's experiments that this arises entirely from the electric charge, and is therefore due to the ether carried along with the corpuscle by the lines of force attached to it.

A simple calculation shows that one-half of this mass is contained in a volume seven times that of a corpuscle. Since we know the volume of the corpuscle as well as the mass, we can calculate the density of the ether attached to the corpuscle; doing so, we find it amounts to the prodigious value of about 5×10^{10}, or about 2,000 million times that of lead. Sir Oliver Lodge, by somewhat different considerations, has arrived at a value of the same order of magnitude.

Thus around the corpuscle ether must have an extravagant density; whether the density is as great as this in other places depends upon whether the ether is compressible or not. If it is compressible, then it may be condensed round the corpuscles, and there have an abnormally great density; if it is not compressible, then the density in free space can not be less than the number I have just mentioned.

With respect to this point we must remember that the forces acting on the ether close to the corpuscle are prodigious. If the ether were, for example, an ideal gas whose density increased in proportion to the pressure, however great the pressure might be, then if, when exposed to the pressures which exist in some directions close to the corpuscle, it had the density stated above, its density under atmospheric pressure would only be about 8×10^{-16}, or a cubic kilometer would have a mass less than a gram; so that instead of being almost incomparably denser than lead, it would be almost incomparably rarer than the lightest gas.

I do not know at present of any effect which would enable us to determine whether ether is compressible or not. And although at first sight the idea that we are immersed in a medium almost infinitely denser than lead might seem inconceivable, it is not so if we remember that in all probability matter is composed mainly of holes. We may, in fact, regard matter as possessing a bird-cage kind of structure in which the volume of the ether disturbed by the wires when the structure is moved is infinitesimal in comparison with the volume inclosed by them. If we do this, no difficulty arises from the great density of the ether; all we have to do is to increase the distance between the wires in proportion as we increase the density of the ether.

Let us now consider how much ether is carried along by ordinary matter, and what effects this might be expected to produce.

The simplest electrical system we know, an electrified sphere, has attached to it a mass of ether proportional to its potential energy, and such that if the mass were to move with the velocity of light its kinetic energy would equal the electrostatic potential energy of the particle. This result can be extended to any electrified system, and it can be shown that such a system binds a mass of the ether proportional to its potential energy. Thus a part of the mass of any system is proportional to the potential energy of the system.

The question now arises, Does this part of the mass add anything to the weight of the body? If the ether were not subject to gravitational attraction it certainly would not; and even if the ether were ponderable, we might expect that as the mass is swimming in a sea of ether it would not increase the weight of the body to which it is attached. But if it does not, then a body with a large amount of potential energy may have an appreciable amount of its mass in a form which does not increase its weight, and thus the weight of a given mass of it may be less than that of an equal mass of some substance with a smaller amount of potential energy. Thus the weights of equal masses of these substances would be different. Now, experiments with pendulums, as Newton pointed out, enable us to determine with great accuracy the weights of equal masses of different substances. Newton himself made experiments of this kind, and found that the weights of equal masses were the same for all the materials he tried. Bessel, in 1830, made some experiments on this subject which are still the most accurate we possess, and he showed that the weights of equal masses of lead, silver, iron, or brass did not differ by as much as one part in 60,000.

The substances tried by Newton and Bessel did not, however, include any of those substances which possess the marvelous power of radioactivity; the discovery of these came much later, and is one of the most striking achievements of modern physics.

These radioactive substances are constantly giving out large quantities of heat, presumably at the expense of their potential energy; thus when these substances reach their final nonradioactive state their potential energy must be less than when they were radioactive. Professor Rutherford's measurements show that the energy emitted by 1 gram of radium in the course of its degradation to nonradioactive forms is equal to the kinetic energy of a mass of one-thirteenth of a milligram moving with the velocity of light.

This energy, according to the rule I have stated, corresponds to a mass of one-thirteenth of a milligram of the ether, and thus a gram of radium in its radioactive state must have at least one-thirteenth of a milligram more of ether attached to it than when it has been degraded into the nonradioactive forms. Thus if this ether does not increase the weight of the radium, the ratio of mass to weight for radium would be greater by about one part in 13,000 than for its nonradioactive products.

I attempted several years ago to find the ratio of mass to weight for radium by swinging a little pendulum, the bob of which was made of radium. I had only a small quantity of radium, and was not, therefore, able to attain any great accuracy. I found that the difference, if any, in the ratio of the mass to weight between radium and other substances was not more than one part in 2,000. Lately

we have been using at the Cavendish Laboratory a pendulum whose bob was filled with uranium oxide. We have got good reasons for supposing that uranium is a parent of radium, so that the great potential energy and large ethereal mass possessed by the radium will be also in the uranium; the experiments are not yet completed. It is, perhaps, expecting almost too much to hope that the radio-active substances may add to the great services they have already done to science by furnishing the first case in which there is some differentiation in the action of gravity.

The mass of ether bound by any system is such that if it were to move with the velocity of light its kinetic energy would be equal to the potential energy of the system. This result suggests a new view of the nature of potential energy. Potential energy is usually regarded as essentially different from kinetic energy. Potential energy depends on the configuration of the system, and can be calculated from it when we have the requisite data; kinetic energy, on the other hand, depends upon the velocity of the system. According to the principle of the conservation of energy the one form can be converted into the other at a fixed rate of exchange, so that when one unit of one kind disappears a unit of the other simultaneously appears.

Now, in many cases, this rule is all that we require to calculate the behavior of the system, and the conception of potential energy is of the utmost value in making the knowledge derived from experiment and observation available for mathematical calculation. It must, however, I think, be admitted that from the purely philosophical point of view it is open to serious objection. It violates, for example, the principle of continuity. When a thing changes from a state A to a different state B, the principle of continuity requires that it must pass through a number of states intermediate between A and B, so that the transition is made gradually, and not abruptly. Now, when kinetic energy changes into potential, although there is no discontinuity in the quantity of the energy, there is in its quality, for we do not recognize any kind of energy intermediate between that due to the motion and that due to the position of the system, and some portions of energy are supposed to change per saltum from the kinetic to the potential form. In the case of the transition of kinetic energy into heat energy in a gas, the discontinuity has disappeared with a fuller knowledge of what the heat energy in a gas is due to. When we were ignorant of the nature of this energy, the transition from kinetic into thermal energy seemed discontinuous; but now we know that this energy is the kinetic energy of the molecules of which the gas is composed, so that there is no change in the type of energy when the kinetic energy of visible motion is trans-

formed into the thermal energy of a gas—it is just the transference of kinetic energy from one body to another.

If we regard potential energy as the kinetic energy of portions of the ether attached to the system, then all energy is kinetic energy, due to the motion of matter or of portions of ether attached to the matter. I showed, many years ago, in my "Applications of Dynamics to Physics and Chemistry," that we could imitate the effects of the potential energy of a system by means of the kinetic energy of invisible systems connected in an appropriate manner with the main system, and that the potential energy of the visible universe may in reality be the kinetic energy of an invisible one connected up with it. We naturally suppose that this invisible universe is the luminiferous ether, that portions of the ether in rapid motion are connected with the visible systems, and that their kinetic energy is the potential energy of the systems.

We may thus regard the ether as a bank in which we may deposit energy and withdraw it at our convenience. The mass of the ether attached to the system will change as the potential energy changes, and thus the mass of a system whose potential energy is changing can not be constant; the fluctuations in mass under ordinary conditions are, however, so small that they can not be detected by any means at present at our disposal. Inasmuch as the various forms of potential energy are continually being changed into heat energy, which is the kinetic energy of the molecules of matter, there is a constant tendency for the mass of a system such as the earth or the sun to diminish, and thus as time goes on for the mass of ether gripped by the material universe to become smaller and smaller; the rate at which it would diminish would, however, get slower as time went on, and there is no reason to think that it would ever get below a very large value.

Radiation of light and heat from an incandescent body like the sun involves a constant loss of mass by the body. Each unit of energy radiated carries off its quota of mass, but as the mass ejected from the sun per year is only one part in 20 billionths (1 in 2×10^{13}) of the mass of the sun, and as this diminution in mass is not necessarily accompanied by any decrease in its gravitational attraction, we can not expect to be able to get any evidence of this effect.

As our knowledge of the properties of light has progressed, we have been driven to recognize that the ether, when transmitting light, possesses properties which, before the introduction of the electromagnetic theory, would have been thought to be peculiar to an emission theory of light and to be fatal to the theory that light consists of undulations.

Take, for example, the pressure exerted by light. This would follow as a matter of course if we supposed light to be small particles moving with great velocities, for these, if they struck against a body,

would manifestly tend to push it forward, while on the undulatory theory there seemed no reason why any effect of this kind should take place.

Indeed, in 1792, this very point was regarded as a test between the theories, and Bennet made experiments to see whether or not he could find any traces of this pressure. We now know that the pressure is there, and if Bennet's instrument had been more sensitive he must have observed it. It is perhaps fortunate that Bennet had not at his command more delicate apparatus. Had he discovered the pressure of light, it would have shaken confidence in the undulatory theory and checked that magnificent work at the beginning of the last century which so greatly increased our knowledge of optics.

As another example, take the question of the distribution of energy in a wave of light. On the emission theory the energy in the light is the kinetic energy of the light particles. Thus the energy of light is made up of distinct units, the unit being the energy of one of the particles.

The idea that the energy has a structure of this kind has lately received a good deal of support. Planck, in a very remarkable series of investigations on the thermodynamics of radiation, pointed out that the expressions for the energy and entropy of radiant energy were of such a form as to suggest that the energy of radiation, like that of a gas on the molecular theory, was made up of distinct units, the magnitude of the unit depending on the color of the light; and on this assumption he was able to calculate the value of the unit, and from this deduce incidentally the value of Avogadro's constant—the number of molecules in a cubic centimeter of gas at standard temperature and pressure.

This result is most interesting and important because if it were a legitimate deduction from the second law of thermodynamics, it would appear that only a particular type of mechanism for the vibrators which give out light and the absorbers which absorb it could be in accordance with that law.

If this were so, then, regarding the universe as a collection of machines all obeying the laws of dynamics, the second law of thermodynamics would only be true for a particular kind of machine.

There seems, however, grave objection to this view, which I may illustrate by the case of the first law of thermodynamics, the principle of the conservation of energy. This must be true whatever be the nature of the machines which make up the universe, provided they obey the laws of dynamics, any application of the principle of the conservation of energy could not discriminate between one type of machine and another.

Now, the second law of thermodynamics, though not a dynamical principle in as strict a sense as the law of the conservation of energy,

is one that we should expect to hold for a collection of a large number of machines of any type, provided that we could not directly affect the individual machines, but could only observe the average effects produced by an enormous number of them. On this view, the second law, as well as the first, should be incapable of saying that the machines were of any particular type; so that investigations founded on thermodynamics, though the expressions they lead to may suggest—can not, I think, be regarded as proving—the unit structure of light energy.

It would seem as if in the application of thermodynamics to radiation some additional assumption has been implicitly introduced, for these applications lead to definite relations between the energy of the light of any particular wave length and the temperature of the luminous body.

Now, a possible way of accounting for the light emitted by hot bodies is to suppose that it arises from the collisions of corpuscles with the molecules of the hot body, but it is only for one particular law of force between the corpuscles and the molecules that the distribution of energy would be the same as that deduced by the second law of thermodynamics, so that in this case, as in the other, the results obtained by the application of thermodynamics to radiation would require us to suppose that the second law of thermodynamics is only true for radiation when the radiation is produced by mechanism of a special type.

Quite apart, however, from considerations of thermodynamics, we should expect that the light from a luminous source should in many cases consist of parcels, possessing, at any rate to begin with, a definite amount of energy. Consider, for example, the case of a gas like sodium vapor, emitting light of a definite wave length; we may imagine that this light, consisting of electrical waves, is emitted by systems resembling Leyden jars. The energy originally possessed by such a system will be the electrostatic energy of the charged jar. When the vibrations are started this energy will be radiated away into space, the radiation forming a complex system, containing, if the jar has no electrical resistance, the energy stored up in the jar.

The amount of this energy will depend on the size of the jar and the quantity of electricity with which it is charged. With regard to the charge, we must remember that we are dealing with systems formed out of single molecules, so that the charge will only consist of one or two natural units of electricity, or, at all events, some small multiple of that unit, while for geometrically similar Leyden jars the energy for a given charge will be proportional to the frequency of the vibration; thus the energy in the bundle of radiation will be proportional to the frequency of the vibration.

We may picture to ourselves the radiation as consisting of the lines of electric force which, before the vibrations were started, were held, bound by the charges on the jar, and which, when the vibrations begin, are thrown into rhythmic undulations, liberated from the jar and travel through space with the velocity of light.

Now let us suppose that this system strikes against an uncharged condenser and gives it a charge of electricity, the charge on the plates of the condenser must be at least one unit of electricity, because fractions of this charge do not exist, and each unit charge will anchor a unit tube of force, which must come from the parcel of radiation falling upon it. Thus a tube in the incident light will be anchored by the condenser, and the parcel formed by this tube will be anchored and withdrawn as a whole from the pencil of light incident on the condenser. If the energy required to charge up the condenser with a unit of electricity is greater than the energy in the incident parcel the tube will not be anchored, and the light will pass over the condenser and escape from it. These principles that radiation is made up of units, and that it requires a unit possessing a definite amount of energy to excite radiation in a body on which it falls, perhaps receive their best illustration in the remarkable laws governing secondary Röntgen radiation, recently discovered by Professor Barkla. Professor Barkla has found that each of the different chemical elements, when exposed to Röntgen rays, emit a definite type of secondary radiation whatever may have been the type of primary, thus lead emits one type, copper another, and so on; but these radiations are not excited at all if the primary radiation is of a softer type than the specific radiation emitted by the substance; thus the secondary radiation from lead being harder than that from copper; if copper is exposed to the secondary radiation from lead the copper will radiate, but lead will not radiate when exposed to copper. Thus, if we suppose that the energy in a unit of hard Röntgen rays is greater than that in one of soft, Barkla's results are strikingly analogous to those which would follow on the unit theory of light.

Though we have, I think, strong reasons for thinking that the energy in the light waves of definite wave length is done up into bundles, and that these bundles, when emitted, all possess the same amount of energy, I do not think there is any reason for supposing that in any casual specimen of light of this wave length, which may subsequent to its emission have been many times refracted or reflected, the bundles possess any definite amount of energy. For consider what must happen when a bundle is incident on a surface such as glass, when part of it is reflected and part transmitted. The bundle is divided into two portions, in each of which the energy is less than the incident bundle, and since these portions diverge and may ultimately be many thousands of miles apart, it would seem meaningless

to still regard them as forming one unit. Thus the energy in the bundles of light, after they have suffered partial reflection, will not be the same as in the bundles when they were emitted. The study of the dimensions of these bundles, for example, the angle they subtend at the luminous source, is an interesting subject for investigation; experiments on interference between rays of light emerging in different directions from the luminous source would probably throw light on this point.

I now pass to a very brief consideration of one of the most important and interesting advances ever made in physics, and in which Canada, as the place of the labors of Professors Rutherford and Soddy, has taken a conspicuous part. I mean the discovery and investigation of radioactivity. Radioactivity was brought to light by the Röntgen rays. One of the many remarkable properties of these rays is to excite phosphorescence in certain substances, including the salts of uranium, when they fall upon them. Since Röntgen rays produce phosphorescence, it occurred to Becquerel to try whether phosphoresence would produce Röntgen rays. He took some uranium salts which had been made to phosphoresce by exposure not to Röntgen rays but to sunlight, tested them, and found that they gave out rays possessing properties similar to Röntgen rays. Further investigation showed, however, that to get these rays it was not necessary to make the uranium phosphoresce, that the salts were just as active if they had been kept in the dark. It thus appeared that the property was due to the metal and not to the phosphorescence, and that uranium and its compounds possessed the power of giving out rays which, like Röntgen rays, affect a photographic plate, make certain minerals phosphoresce, and make gases through which they pass conductors of electricity.

Niepce de Saint-Victor had observed some years before this discovery that paper soaked in a solution of uranium nitrate affected a photographic plate, but the observation excited but little interest. The ground had not been prepared, by the discovery of the Röntgen rays, for its reception, and it withered and was soon forgotten.

Shortly after Becquerel's discovery of uranium, Schmidt found that thorium possessed similar properties. Then Monsieur and Madame Curie, after a most difficult and laborious investigation, discovered two new substances, radium and polonium, possessing this property to an enormously greater extent than either thorium or uranium, and this was followed by the discovery of actinium by Debierne. Now the researches of Rutherford and others have led to the discovery of so many new radioactive substances that any attempt at christening seems to have been abandoned, and they are denoted, like policemen, by the letters of the alphabet.

Mr. Campbell has recently found that potassium, though far inferior in this respect to any of the substances I have named, emits an appreciable amount of radiation, the amount depending only on the quantity of potassium, and being the same whatever the source from which the potassium is obtained or whatever the elements with which it may be in combination.

The radiation emitted by these substances is of three types known as α-, β-, and γ-rays. The α-rays have been shown by Rutherford to be positively electrified atoms of helium, moving with speeds which reach up to about one-tenth of the velocity of light. The β-rays are negatively electrified corpuscles, moving in some cases with very nearly the velocity of light itself, while the γ-rays are unelectrified, and are analogous to the Röntgen rays.

The radioactivity of uranium was shown by Crookes to arise from something mixed with the uranium, and which differed sufficiently in properties from the uranium itself to enable it to be separated by chemical analysis. He took some uranium, and by chemical treatment separated it into two portions, one of which was radioactive and the other not.

Next, Becquerel found that if these two portions were kept for several months, the part which was not radioactive to begin with regained radioactivity, while the part which was radioactive to begin with had lost its radioactivity. These effects and many others receive a complete explanation by the theory of radioactive change which we owe to Rutherford and Soddy.

According to this theory, the radioactive elements are not permanent, but are gradually breaking up into elements of lower atomic weight; uranium, for example, is slowly breaking up, one of the products being radium, while radium breaks up into a radioactive gas called radium emanation, the emanation into another radioactive substance, and so on, and that the radiations are a kind of swan's song emitted by the atoms when they pass from one form to another; that, for example, it is when a radium atom breaks up and an atom of the emanation appears that the rays which constitute the radioactivity are produced.

Thus, on this view the atoms of the radioactive elements are not immortal; they perish after a life whose average value ranges from thousands of millions of years in the case of uranium to a second or so in the case of the gaseous emanation from actinium.

When the atoms pass from one state to another they give out large stores of energy, thus their descendants do not inherit the whole of their wealth of storedup energy; the estate becomes less and less wealthy with each generation; we find, in fact, that the politician, when he imposes death duties, is but imitating a process which has been going on for ages in the case of these radioactive substances.

Many points of interest arise when we consider the rate at which the atoms of radioactive substance disappear. Rutherford has shown that whatever be the age of these atoms, the percentage of atoms which disappear in one second is always the same; another way of putting it is that the expectation of life of an atom is independent of its age—that an atom of radium one thousand years old is just as likely to live for another thousand years as one just sprung into existence.

Now this would be the case if the death of the atom were due to something from outside which struck old and young indiscriminately; in a battle, for example, the chance of being shot is the same for old and young; so that we are inclined at first to look to something coming from outside as the cause why an atom of radium, for example, suddenly changes into an atom of the emanation. But here we are met with the difficulty that no changes in the external conditions that we have as yet been able to produce have had any effect on the life of the atom; as far as we know at present the life of a radium atom is the same at the temperature of a furnace as at that of liquid air—it is not altered by surrounding the radium by thick screens of lead or other dense materials to ward off radiation from outside, and what to my mind is especially significant, it is the same when the radium is in the most concentrated form, when its atoms are exposed to the vigorous bombardment from the rays given off by the neighboring atoms, as when it is in the most dilute solution, when the rays are absorbed by the water which separates one atom from another. This last result seems to me to make it somewhat improbable that we shall be able to split up the atoms of the nonradioactive elements by exposing them to the radiation from radium; if this radiation is unable to affect the unstable radioactive atoms, it is somewhat unlikely that it will be able to affect the much more stable nonradioactive elements.

The evidence we have at present is against a disturbance coming from outside breaking up of the radioactive atoms, and we must therefore look to some process of decay in the atom itself; but if this is the case, how are we to reconcile it with the fact that the expectation of life of an atom does not diminish as the atom gets older? We can do this if we suppose that the atoms when they are first produced have not all the same strength of constitution, that some are more robust than others, perhaps because they contain more intrinsic energy to begin with, and will therefore have a longer life. Now if when the atoms are first produced there are some which will live for one year, some for ten, some for a thousand, and so on; and if lives of all durations, from nothing to infinity, are present in such proportion that the number of atoms which will live longer than a certain number of years decrease in a constant proportion for each additional year of life, we can easily prove that the expectation of life of an

atom will be the same whatever its age may be. On this view the different atoms of a radioactive substance are not, in all respects, identical.

The energy developed by radioactive substances is exceedingly large, 1 gram of radium developing nearly as much energy as would be produced by burning a ton of coal. This energy is mainly in the α particles, the positively charged helium atoms which are emitted when the change in the atom takes place; if this energy were produced by electrical forces it would indicate that the helium atom had moved through a potential difference of about 2,000,000 volts on its way out of the atom of radium. The source of this energy is a problem of the deepest interest; if it arises from the repulsion of similarly electrified systems exerting forces varying inversely as the square of the distance, then to get the requisite amount of energy the systems, if their charges were comparable with the charge on the α particle, could not when they start be farther apart than the radius of a corpuscle, 10^{-13} cm. If we suppose that the particles do not acquire this energy at the explosion, but that before they are shot out of the radium atom they move in circles inside this atom with the speed with which they emerge, the forces required to prevent particles moving with this velocity from flying off at a tangent are so great that finite charges of electricity could only produce them at distances comparable with the radius of a corpuscle.

One method by which the requisite amount of energy could be obtained is suggested by the view to which I have already alluded—that in the atom we have electrified systems of very different types, one small, the other large; the radius of one type is comparable with 10^{-13} cm., that of the other is about 100,000 times greater. The electrostatic potential energy in the smaller bodies is enormously greater than that in the larger ones; if one of these small bodies were to explode and expand to the size of the larger ones, we should have a liberation of energy large enough to endow an α particle with the energy it possesses. Is it possible that the positive units of electricity were, to begin with, quite as small as the negative, but while in the course of ages most of these have passed from the smaller stage to the larger, there are some small ones still lingering in radioactive substances, and it is the explosion of these which liberates the energy set free during radioactive transformation?

The properties of radium have consequences of enormous importance to the geologist as well as to the physicist or chemist. In fact, the discovery of these properties has entirely altered the aspect of one of the most interesting geological problems, that of the age of the earth. Before the discovery of radium it was supposed that the supplies of heat furnished by chemical changes going on in the earth were quite insignificant, and that there was nothing to replace

the heat which flows from the hot interior of the earth to the colder crust. Now, when the earth first solidified it only possessed a certain amount of capital in the form of heat, and if it is continually spending this capital and not gaining any fresh heat it is evident that the process can not have been going on for more than a certain number of years, otherwise the earth would be colder than it is. Lord Kelvin in this way estimated the age of the earth to be less than 100,000,000 years. Though the quantity of radium in the earth is an exceedingly small fraction of the mass of the earth, only amounting, according to the determinations of Professors Strutt and Joly, to about 5 grams in a cube whose side is 100 miles, yet the amount of heat given out by this small quantity of radium is so great that it is more than enough to replace the heat which flows from the inside to the outside of the earth. This, as Rutherford has pointed out, entirely vitiates the previous method of determining the age of the earth. The fact is that the radium gives out so much heat that we do not quite know what to do with it, for if there was as much radium throughout the interior of the earth as there is in its crust, the temperature of the earth would increase much more rapidly than it does as we descend below the earth's surface. Professor Strutt has shown that if radium behaves in the interior of the earth as it does at the surface, rocks similar to those in the earth's crust can not extend to a depth of more than 45 miles below the surface.

It is remarkable that Professor Milne from the study of earthquake phenomena had previously come to the conclusion that rocks similar to those at the earth's surface only descend a short distance below the surface; he estimates this distance at about 30 miles, and concludes that at a depth greater than this the earth is fairly homogeneous.

Though the discovery of radioactivity has taken away one method of calculating the age of the earth it has supplied another.

The gas helium is given out by radioactive bodies, and since, except in beryls, it is not found in minerals which do not contain radioactive elements, it is probable that all the helium in these minerals has come from these elements. In the case of a mineral containing uranium, the parent of radium in radioactive equilibrium, with radium and its products, helium will be produced at a definite rate. Helium, however, unlike the radioactive elements, is permanent and accumulates in the mineral; hence if we measure the amount of helium in a sample of rock and the amount produced by the sample in one year we can find the length of time the helium has been accumulating, and hence the age of the rock. This method, which is due to Professor Strutt, may lead to determinations not merely of the average age of the crust of the earth, but of the ages of particular rocks and the date at which the various strata were deposited; he has, for example, shown in this

way that a specimen of the mineral thorianite must be more than 240,000,000 years old.

The physiological and medical properties of the rays emitted by radium is a field of research in which enough has already been done to justify the hope that it may lead to considerable alleviation of human suffering. It seems quite definitely established that for some diseases, notably rodent ulcer, treatment with these rays has produced remarkable cures; it is imperative, lest we should be passing over a means of saving life and health, that the subject should be investigated in a much more systematic and extensive manner than there has yet been either time or material for. Radium is, however, so costly that few hospitals could afford to undertake pioneering work of this kind; fortunately, however, through the generosity of Sir Ernest Cassel and Lord Iveagh, a radium institute, under the patronage of His Majesty the King, has been founded in London for the study of the medical properties of radium, and for the treatment of patients suffering from diseases for which radium is beneficial.

The new discoveries made in physics in the last few years, and the ideas and potentialities suggested by them, have had an effect upon the workers in that subject akin to that produced in literature by the renaissance. Enthusiasm has been quickened, and there is a hopeful, youthful, perhaps exuberant, spirit abroad which leads men to make, with confidence, experiments which would have been thought fantastic twenty years ago. It has quite dispelled the pessimistic feeling, not uncommon at that time, that all the interesting things had been discovered, and all that was left was to alter a decimal or two in some physical constant. There was never any justification for this feeling, there never were any signs of an approach to finality in science. The sum of knowledge is at present, at any rate, a diverging not a converging series. As we conquer peak after peak we see in front of us regions full of interest and beauty, but we do not see our goal, we do not see the horizon; in the distance tower still higher peaks, which will yield to those who ascend them still wider prospects, and deepen the feeling, whose truth is emphasized by every advance in science, that "Great are the Works of the Lord."

PRODUCTION OF LOW TEMPERATURES, AND REFRIGERATION.

By L. Marchis.

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The first International Congress of Refrigerative Industries, held at Paris October 5–12, 1908, was remarkable for the number and importance of the papers submitted by the men of science and engineers who responded to the call of the organization committee.

The congress was divided into six sections as follows:

First section. Low temperatures and their general effects.

Second section. Refrigerating media.

Third and fourth sections. Application of refrigeration to food and in various other industries.

Fifth section. Application of refrigeration in commerce and transportation.

Sixth section. Legislation.

In this article we do not intend to summarize the memoirs and communications presented, but rather to give a general view of the congress that brought together men of science, engineers, biologists, legislators, and men from the business world.

I. LIQUID AIR AND THE PROPERTIES OF BODIES AT LOW TEMPERATURES.

The first section considered principally the production of liquid air and the preparation, with this as a starting point, of oxygen and nitrogen in a commercial way.

It is well known that air, like all gases, is brought into a liquid condition by the combined effect of lowering its temperature and expanding it sufficiently. In carrying out this process, gaseous air cooled to a low temperature is expanded suddenly from a pressure p_0 to a lower pressure p_1. Part of it goes over into a liquid state, and the other part, gaseous and very cold, is led into an economizer, where it cools down the air that is being compressed to the pressure p_0 for the first time.

The essentially adiabatic expansion of air can be effected in two different ways.

(*a*) Air compressed to the pressure p_0 may be expanded without doing available exterior work. It passes from the compression tank to the liquefaction tank by the way of a narrow orifice. This is the manner of expansion adopted by Linde in his liquid-air machines. The lowering of temperature obtained under such conditions is only appreciable if the difference between the pressures p_0 and p_1 is considerable. In Linde's apparatus [a] gaseous air cooled to about —100° C. is expanded from a pressure of 200 to 40 atmospheres; the liquefied part of the gas at about —140° C. passes into a regenerator where it cools the air compressed at 200 atmospheres; it is then led into a pump which brings it up to this latter pressure. A second auxiliary pump draws air from the atmosphere to take the place of that part which has been liquefied. In the industrial machines the gases compressed to 200 atmospheres, before passing into the economizer where the gas at —140° circulates, are cooled by liquid ammonia.

Under such conditions, in machines which produce 50 liters per hour the yield of liquid air is about half a liter per horsepower-hour.

(*b*) The second method of air expansion consists in utilizing the exterior work which the gas is capable of doing when it passes from pressure p_0 to p_1. This mode of expansion with utilizable exterior work is the basis of the processes of G. Claude for the production of liquid air.[b] Air compressed to a maximum pressure of 30 or 40 atmospheres passes first to an economizer, where it is cooled down as in Linde's apparatus by unliquefied gas. It is then expanded in the cylinder of a motor whose energy can be utilized in the original compression of the air. In course of time a partial liquefaction of the air occurs in the cylinder of the auxiliary motor. The lubrication of this cylinder is accomplished by means of a petroleum distillate having a specific gravity of 0.675 (automobile gasoline), which, at the low temperature at which the motor operates, attains a sirupy consistency comparable to industrial lubricants.

Applied in this form the process of G. Claude gives only unsatisfactory results. The expansion of the air, occurring at temperatures of —175° to —180° by the gas expanding in the auxiliary motor, takes place under unfavorable conditions. The appearance of liquid air in this auxiliary cylinder is likely to produce a peculiar water-hammer effect and is accompanied by a large increase in friction, that

[a] For a description of Linde's machine, see E. Mathias: "La préparation industrielle et les principales applications des gaz liquéfiés." Revue générale des Sciences, vol. 12, 1901.

[b] Readers desirous of obtaining the details of Claude's processes will find an account of them in the following: G. Claude: Air liquide, Oxygène, Azote. Paris, H. Dunod and E. Pinat, 1909.

is to say, by a correlative destruction of the liquid air produced. Moreover, under the most favorable conditions the yield of this machine is hardly more than 0.2 liter of liquid air per horsepower-hour.

For this reason M. Claude has been led to modify the process in the following way, which I shall endeavor to explain: A part of the cooled current of air compressed to 40 atmospheres is deflected before it arrives at the expansion cylinder. This air under a pressure of 40 atmospheres is led into a chamber (liquefier) cooled by the gas of the original current which has been expanded in the auxiliary motor. Thanks to a pressure of 40 atmospheres the deflected gas is liquefied in this latter chamber at a temperature no longer of —190°, as was the case in the original process, where liquefaction occurred at the limit of its expansion, but at —140°. Furthermore, the expanded air which circulated in the liquefier is heated up and arrives in the economizer no longer at —190°, but at about —130°. It cools the gas in the feed conduit less, so that this gas arrives in the auxiliary motor at a temperature of about —100°. Its expansion takes place, therefore, under more favorable conditions, and liquefaction by expansion is less to be feared.

By thus substituting liquefaction under pressure for spontaneous liquefaction by expansion M. Claude had brought his process of recovering the energy of expansion down to a practical basis. With machines utilizing an exterior air compression capacity of 75 horsepower the yield of this process becomes as high as 0.7 liter of liquid air per horsepower-hour.

This idea can be carried still further, however. The air which arrives at the auxiliary motor at a pressure of 40 atmospheres and a temperature of about —100° C. can be subjected in expansion to a too great drop in temperature. To avoid the recurrence here of the difficulties encountered in the original process all that has to be done is to carry out the expansion by degrees in several auxiliary cylinders. The air of the first expansion can circulate about a first liquefier, into which is led a deflected portion of air from the feed circuit in a cold and compressed condition. The circulating air is warmed up and goes on to be expanded in a second auxiliary cylinder. This air from the second expansion is sent into a second liquefier similar to the first, and is finally led into the economizer. In practice the two liquefiers are not distinct; the two currents of air after expansion merely circulate about different sections of the same liquefaction apparatus. M. Claude has given the name of "compound liquefaction" to this last process. It marks a new and important step in the technique of the liquefaction of air. In machines of the type described above the yield of liquid air, by the application of compound liquefaction, is as high as 0.85 liter per horsepower-hour.

Liquid air promises to be the sole industrial source of oxygen and nitrogen. The manufacture of these two gases at a very low price is a problem the solution of which has a very great importance in metallurgy and in the fertilizing industry. How we can derive these gases from liquid air is a problem that I am now going to consider.

Oxygen and nitrogen are two bodies whose critical points are slightly different (—118° and 13 atmospheres for oxygen; —146° and 33 atmospheres for nitrogen). The vapor tension curve of nitrogen is below that of oxygen. At a like temperature, below the lower of their critical temperatures, the two gases, considered separately, liquefy at very different pressures. The liquefaction of air—that is to say, a mixture of these two gases—presents, however, some peculiarities which are worth mentioning.

If at a sufficiently low constant temperature, T, air is compressed in a closed chamber, the following phenomena may be observed:

(1) At a predetermined point of pressure, P_0, a first drop of liquid appears. This is what, after Duhem,[a] we call the dew-point."

(2) If at the constant temperature T the volume of the air is diminished the pressure increases; at the same time the quantity of the liquid phase grows larger. If this increase of the pressure is continued all the air will pass into the liquid state, the values for P_1 and T, for pressure and temperature at that instant, characterizing what Duhem has denoted the boiling point.

(3) The dew and boiling points obtained at different temperatures trace in the system P O T, on one hand the dew line and on the other the line of boiling of the gaseous mixture considered.

(4) For each system of values (T, P) of temperature and pressure the two phases, liquid and gas, are in a state of equilibrium; in this state the composition of the two phases is different.

(5) The percentage of oxygen (the more easily liquefied element) in either liquid or gaseous phase, we will term the content of this phase.

The content of the liquid phase in a state of equilibrium is always greater than the content of the gaseous phase. At a constant temperature, when the pressure is increased, the contents of the two phases, liquid and gaseous, continue to diminish till the mixture is completely liquefied. Thus, when air is liquefied (volumetric content 21 per cent oxygen) the first drop of liquid contains oxygen and nitrogen and its content is 47 per cent. This content continues to diminish as the volume of the liquid phase increases. A liquid with 34 per cent oxygen can only be in equilibrium with gas of 12.5 per cent oxygen. But as long as there is a gas phase its content is considerably above zero. It remains above 7 per cent.

[a] Duhem: Traité de Mecanique chimique, vol. 4, chap. 3. Paris, Hermann.

It can be readily seen, therefore, that if the two phases, liquid and gaseous, formed by the progressive liquefaction of air are maintained in contact, it is impossible to prepare gaseous nitrogen of a sufficient degree of purity.

It is a different matter, however, when, under constant pressure conditions, the liquid phase is eliminated as fast as it is produced. We find ourselves here in the presence of a phenomenon inverse to that observed when liquid air is distilled under constant pressure. In such a case the contents of gaseous and liquid phases increase continuously. The phases both tend toward a composition of pure oxygen. At the same time the temperature of boiling rises from a value in the neighborhood of that of pure nitrogen to the boiling point of pure oxygen. Inversely, if we progressively condense air under constant pressure, eliminating the liquid phase as fast as it is formed, there are obtained gaseous residues less and less rich in oxygen; at the same time the temperature of condensation becomes lower and tends toward the boiling point of pure nitrogen at the pressure employed. We obtain, therefore, much more rapidly than in the process considered above a gaseous mixture richer in nitrogen. To obtain a gaseous residue practically free from oxygen, however, it is necessary, if this method is used, to almost completely liquefy the air.

A much better result is obtained by the use of a device designed by M. Claude which he calls a retour en arrière (reflux apparatus).

Let us imagine that the liquid after separating from the gas encounters a gaseous mass richer in oxygen. The liquid is colder on account of the large proportion of nitrogen it contains. A part of the more condensable oxygen of the mixture will therefore be liquefied and take the place of nitrogen which will vaporize. Thus by circulating in opposite directions a liquid and a gas having different contents, there is obtained on one hand a liquid very rich in oxygen and on the other practically pure gaseous nitrogen. This process utilizes, moreover, a large amount of air which never needs to be liquefied.

M. Claude has utilized this principle of reflux in the following way: A sort of small tubular boiler is arranged so that its axis is vertical. The tubes are surrounded on the outside with liquid air and into the lower ends of these tubes is led a current of cold compressed air. This liquefies progressively, giving liquids poorer and poorer in oxygen; these liquids, in falling into a receptacle below, encounter gases rich in oxygen and produce the gradual dilution, the principle of which we have described. There finally separates out at the top of the group of tubes practically pure nitrogen, while liquid with a high percentage of oxygen is continually drawn out of the lower part.

A second obstacle remains still to be overcome. Instead of air supercharged with a volumetric content of 47 per cent oxygen, it is necessary to obtain practically pure oxygen. This can be attained, thanks to processes of rectification based on those employed in the alcohol industry. In such a process there are two circulating streams inside of a column, one from the bottom to the top, of practically pure oxygen gas, and the other from the top to the bottom, of liquid containing a large proportion of nitrogen. The latter, being colder, condenses the oxygen and allows its nitrogen to escape in a gaseous form according to the process which we have seen developed in connection with the reflux apparatus.

The apparatus for this purpose is again composed of a sort of tubular boiler with its axis vertical. At the upper end it continues into a column with condensing shelves, such as is used in the alcohol industry. The vertical tubes of the boiler are surrounded by practically pure oxygen, and into the interior of these tubes cold air is introduced at a pressure of about 5 atmospheres. As we have explained above, this air becomes liquefied, giving in the lower part of the boiler liquid air surcharged with oxygen and in the upper part practically pure gaseous nitrogen. This is carried through the liquefied oxygen and in turn becomes liquefied. The superoxygenated liquid is carried up (through a tube) by its vapor pressure and flows continuously into the central part of the rectification column. The liquid nitrogen is conveyed to the summit of the column. The oxygen vaporized in the tubular chamber on account of the condensation of the air in the interior of the tubes, encounters, in the rectifying column, liquids richer and richer in nitrogen; there falls back in the still, consequently, liquid oxygen in a practically pure state, while pure nitrogen separates out at the top of the column. The quantity of liquid oxygen which falls back into the still is greater than the amount which vaporizes and ascends into the rectifying column. This excess of oxygen is drawn off and led by way of an economizer to meters and to apparatus where it is used.

Such is the principle of the Claude method for the production of practically pure oxygen and nitrogen. The Linde method differs only in certain of its details. The Bardot factory, which works the Linde process at Aubervilliers, at present produces about 50 cubic meters of oxygen per hour. The Société de l'Air Liquide, which uses the Claude process, has placed in operation apparatus capable of producing 100 cubic meters of oxygen per hour. The yield is about 1 cubic meter of pure oxygen per each horsepower effective on the shaft of the compressor, in apparatus of 50 cubic meters, and about 1.19 cubic meters for those of 100 cubic meters capacity.

This method of reflux has also made it possible for M. Claude to extract pure gases, such as neon and helium, from the air. The

apparatus enables him to extract as a by-product of the industrial manufacture of oxygen and nitrogen, a mixture of nitrogen with at least 50 per cent of neon, helium, and hydrogen. To accomplish this the gaseous residues which are strongly resistant to liquefaction are drawn out, in the proportion of 6,000 liters per hour for an influx of air of 3,500 cubic meters, from the lower parts of a tubular system cooled by liquid nitrogen. By the conjunction of a pressure of 4 atmospheres and a very low temperature, all the liquefiable parts are condensed and the gaseous residue, if the quantity is well regulated, consists of an almost pure mixture of neon and helium.

The liquefaction of air is not the last obstacle which men of science have overcome in the field of gas condensation. Helium, which long resisted the efforts of all physicists, has finally been liquefied by M. Kammerlingh Onnes in the cryogenic laboratory at Leyden[a] whose installation admits of the attainment of a range of temperatures from 0° down to −253°. By cooling down helium by hydrogen boiling in a vacuum and suddenly expanding the gas compressed to 100 atmospheres, the Dutch scientist has obtained a transparent colorless liquid boiling at −269° with a density of 0.154. The critical constants of helium appear to be in the neighborhood of −268° and 3 atmospheres.

Thanks to the admirable scientific equipment of the laboratory at Leyden, M. Jean Becquerel has been able to study at very low temperatures the phenomena of liquid absorption and emission, such as the magneto-optic phenomena in crystals and solidified solutions. This work of Becquerel, so important in its significance, bears on the following points:

(1) Observation of the influence of variations of temperature on the abnormal phenomena of absorption and dispersion. Laws of the variation of the width of bands, and the existence for each band of a maximum absorption. Calculation of the number of corpuscles producing absorption. Spectral analysis at low temperatures.

(2) Study, in crystals and solutions of a phenomenon of the same nature as the Zeeman effect. Invariability at varying temperatures, of period changes produced by magnetism. Observations at low temperatures of phenomena showing the variation in stability of vibrating systems, where their period is modified.

(3) Rotary magnetic polarization at low temperatures. Explanation of rotation in the vicinity of the bands of absorption. Generalization of the phenomenon of rotary magnetic polarization. Extension of the phenomenon to biaxial crystals. Joinder produced by a magnetic field, of two principal vibrations, normal to the lines of

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[a] Mathias: Le Laboratoire cryogene de Leyde. Revue générale des Sciences, Paris, vol. 7, 1896, p. 381.

force. Experimental proof of the existence in a body submitted to a field normal to a luminous ray, of a longitudinal component of electric force.

As M. d'Arsonval has so aptly pointed out in his paper at the close of the conference, the study of these phenomena gives new results on the nature, the movements, and the number of the electrons which produce absorption. It contributes to the extension of our knowledge as to the ultimate constitution of matter.

The study of the phenomenon of magnetic saturation at low temperatures permits, as M. Pierre Weiss has remarked, of the determination of the magnetic moment of the molecule.[a] This quantity is fundamental in the expression of the law of corresponding magnetic states, a law analogous to that of the same name which governs the compression and dilation of bodies.

A study of such importance as the molecular modification of bodies is rendered possible by the well-known fact that electric conductibility increases as the temperature is lowered. The creation of powerful magnetic fields by simple coils cooled down and traversed by very intense currents, permits the realization of the atom, and allows it to be transformed and its movements modified.

For this reason the first section of the congress adopted the following resolutions presented by Messrs. Jean Perrin, Mathias, and Kammerlingh Onnes:

"(*a*) In view of the extreme importance which is attached to the modification of atoms and the possibility of attaining this result by means of an intense magnetic field (a possibility which the Zeeman phenomenon has already demonstrated), the congress offers the resolution that the nations should unite for the construction of a great electro magnet without iron, the efficiency of which shall be increased by an intense refrigeration.

"(*b*) In view of the admirable scientific equipment of the cryogenic laboratory at Leyden and the hospitable offer of welcome made by Prof. K. Onnes to the investigators of all nations, the physicists present at the first section of the Congress of Refrigeration, express the following resolution: That the governments of the nations represented at the congress should furnish necessary assistance to permit physicists to carry out at the cryogenic laboratory at Leyden researches with regard to physical properties at very low temperatures.

"(*c*) The congress resolves that an international association shall be founded to further such study, scientific or otherwise, an association with its headquarters at Paris, which while aiding the already specialized fields of research shall undertake the study of the whole domain of low temperature.

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[a] P. Weiss: L'hypothèse du champ moléculaire et la propriété ferro-magnétique. Revue générale des Sciences, February 15, 1908.

"In view of the high degree of interest which attaches to the carrying out and coordinating of scientific research in the field of low temperatures, the congress resolves, that the bureau of section A shall be charged with the organization of a permanent international association for the study of all scientific questions relating to low temperatures."

II. REFRIGERATING MEDIA.

In the storehouses where at the present day foodstuffs are preserved by refrigeration, low temperatures are obtained by the vaporization of the following liquefied gases: Ammonia, sulphurous anhydride, carbon dioxide, and methyl chloride.

The liquefaction of these refrigerating agents may be attained (1) by means of a compression pump (compression machines); (2) by means of a solvent such as water (absorption machines). In the compression machines, which are at present the most widely used in the refrigerating industry, the gas liquefied in the condenser or liquefier, passes by way of a regulating cock into the refrigerating chamber or evaporator; there it is vaporized by a pump which draws out the vapor, compresses it, and sends it to be liquefied again in the condenser. In the absorption machines there is also a liquefier connected with a refrigerating chamber by a stopcock. The compressor—the aspirating and force pump—is replaced (*a*) partly by an absorber in which the vapors from the refrigerator (in these machines as a matter of fact ammonia gas is used) are dissolved in water; (*b*) partly by a boiler where the heated ammonia solution gives off ammonia gas. This is again condensed in the liquefier.

The utilizable effect of such a machine, or its refrigerating power, is measured by the quantity of heat absorbed in the refrigerator during a certain period, or as is sometimes said, the quantity of cold developed in the refrigerator during the same period.

As M. Barrier has remarked, this power varies widely with the temperature of the refrigerating agent at the condenser and at the refrigerator. The specification of these temperatures affords the only means of comparing with any exactitude the claims of machines made by different constructors, and the only means of avoiding difficulties in commercial contracts and exchanges.

Furthermore, different countries adopt different units to express this refrigerating power. In France and Germany they express the refrigerating capacity by the number of kilogram-calories absorbed, or kilogram-frigories (negative calories freed per hour). In England and in the United States they prefer to measure the refrigerating capacity for a day of 24 hours and express it in tons of refrigeration, but in England the refrigeration ton is equal to 81,300 kilogram-frigories while the refrigeration ton in the United States

only amounts to 72,600 kilogram-frigories. Lastly, moreover, in the United States the constructors and consulting engineers often express the cooling capacity of the machines in gallon degrees per minute, the temperature of the refrigerator being kept at −10 F. (−23°.3 C). Such a unit is equal to 110.26 hour-frigories.

It would be very useful to adopt for the refrigeration capacity, and for the different quantities which have to be considered in the refrigeration industry, a perfectly coordinate system of units like that used in the electricity.

M. Maurice Leblanc has submitted a very carefully studied out report on this subject. But in view of the opposition of the English-speaking delegates the question does not seem to be fully settled, and Section II has passed the following resolution:

"That an international scientific commission, composed of theoretical and practical specialists in the subject of low temperatures, shall be appointed to consider values, units, and notation suitable to the refrigerating industry, and shall report at the next Congress." It is to this commission that the proposition of M. Kammerlingh Onnes to give the name of Carnot to the unit of entropy has been referred.

This same commission has been likewise charged with the duty of fixing the temperatures of condenser and refrigerator, which shall be adopted so that the refrigeration capacity of a machine may be defined. Section II has only been able to take the following resolution on that subject: That the normal capacity of a refrigerating machine shall be defined by the number of thermal units it can produce in an hour at the given temperatures of the gas at condenser and refrigerator, the choice of these temperatures and thermal units to be left to the determination of the international commission charged with the selection of units.

As a corollary to these resolutions it is likewise desirable to unify the methods of testing refrigerating machines. For this reason the following resolution has also been adopted by Section II: That the question of simple, practical, and uniform methods of testing refrigerating machines, based on the units defined by the international commission and applicable to the different types of machines and to different circumstances of installation, shall be made a subject of study, with a view to international agreement.

Cold-storage rooms can be cooled by different methods. In the abattoirs one of the most common methods is to direct dry cold air into the preserving rooms. This air is brought down to a low temperature and sufficiently dried out either by passing over a cold saline solution (spray refrigerator) or by circulation in contact with a coil acting as refrigerant (dry refrigerator). The choice of the type of refrigerator, as M. Barrier has said, is a question of cir-

cumstances. Even in the case of meat preservation it makes a difference whether the meat is frozen, that is to say, immunized, or whether it is merely refrigerated (brought to a temperature between zero and 4° C.), where it is more particularly subject to the action of harmful germs. It also makes a difference whether it is a military storehouse, where the meat is only taken out for immediate consumption and the refrigerating chambers are closed up to the time the food is removed, or whether it is a commercial storehouse, where the meat is taken in or brought out daily and is more or less exposed to the air, and where the frequent entries of the workmen carry in noxious gases and impurities. In this latter case the spray evaporator appears preferable on account of the purification and asepsis of the air of the chambers. In the first case, however, the dry evaporator, on account of its greater simplicity and the lowering of the concentration of the brine, presents some real advantages.

It is not sufficient only to produce cold; the cold must be conservated. For this reason the insulation from heat should be considered a question of the first importance in the construction of a cold store. The proper conservation of the contents demands that the temperature of the storage chambers should be as constant as possible. The question of insulating materials, therefore, has been a subject of particular attention by the congress.

A good heat insulator should fulfill the following conditions:

(1) It should be a very poor conductor of heat. If a very thin layer of the insulator is sufficient to obtain proper insulation, the result is both economy of space and economy of the insulating material.

(2) It should have a low specific gravity. This condition is important in insulation installment aboard ship. Its importance is not less, however, in cold-storage warehouses, because of the reduction of cost in transporting it to the work and the possibility of economy in the cost of construction by making possible the construction of very lightly built buildings.

(3) The insulator should be free from odor, and not subject to decomposition, even when moist. This condition is all important in the construction of cold-storage houses designed for the preservation of foodstuffs. These absorb very easily bad odors arising from the fermentation of insulating material and become unfit for consumption. For this reason such substances as rice husks, cut straw, oat husks, or cork mixtures made with fermentable substances, such as casein, should be rejected.

(4) The insulating material should absorb to as great a degree as possible the bad odors which are set free in refrigerating chambers and render them less harmful. From this point of view peat or turf sometimes is of great service.

(5) The insulating material should not be hygroscopic. It should not absorb and retain moisture, which is capable of causing it to lose

its poor conducting qualities. This is the case with mineral wool, a sort of fibrous glass made out of the slag of blast furnaces.

(6) When by reason of circumstances, such as the breaking of a water tube, etc., an insulating material is wet it should be able to dry out easily and regain its property of poor conduction.

(7) The insulating substances should not be attractive to parasites, mice, rats, etc., nor afford a good culture ground for microbes.

(8) The insulation material should be incombustible, or at least should not propagate combustion started at any point of the mass. A certain number of cork mixtures possess this property; for example, the mixture of cork and pitch. M. Brüll has shown to the congress several different types of entirely fireproof cork mixtures.

(9) When once placed in the packing which makes up the insulating mat, either inside or outside of the wall, the insulating material should not settle and thus produce continuous voids in the insulation. The different wood carbons included under the term charcoal are liable to this disadvantage, when they are used without special precautions.

(10) The insulating materials should not attack the wood, iron, or masonry which comes in contact with them.

(11) The insulating materials should be very easy to work and to apply to the walls of the storage chambers and should possess a certain resistance to bending or crushing.

(12) The insulation should not lose its qualities with time.

It is difficult enough to find an insulation that combines all these qualities. Cork either in granular form or agglomerated, however, is at present the most employed. M. Pasquay has informed the congress that silk waste protected by an impermeable envelope forms an excellent insulation.

The knowledge of the coefficient of conduction of insulators is of great importance with regard to the thickness which the protecting linings must be to bring down the loss of cold within a certain limit. Different methods have been proposed for determining this. In one of these, the two faces of a plate of the substance are maintained constantly at different temperatures and the quantity of heat passing through the plate in a certain time determined. This may be accurately measured by weighing the amount of ice melted. This is the principle of the well-known physical method called the wall method. It may perhaps be remarked that those who have used this method have not taken precautions against the loss of heat at the edges of the experimental plates. They have not made use of the method of using a guard ring in the form originated by M. Berget.

The other methods for measuring the conductibility are based on Forbes' method. This consists of heating one of the extremities of a long slender bar of the material to be tested. When the system has

attained an equilibrium the temperature is taken at different points along the bar, and by the formulæ of Fourrier the coefficient of conductibility can be calculated, if that of emission is known. This latter may be that of a coating or a very thin layer of metal, with which the bar has been previously provided.

A variation of the Forbes method is that of the sectional bar of Lodge. This bar is composed of three sections; the first and the third are of a metal the conductibility of which is known. The second is made up of the material to be tested. The end of the first section is heated and the progression of temperature when equilibrium is established is measured. The general formula for uniform movement of heat in an elongated bar makes possible the calculation of the conductibility of the material composing the second section.

It is this method that M. Desvignes has used in determining the conductibility of several insulating substances. He has worked out the technique so that it can be easily employed in the refrigerating industry.

Some of the results obtained by this method are as follows:

Coefficient of conductibility.

	Calories for meter-degree-hour.
Cork	0.05 to 0.014
Granular cork	.068
Cork with casein binder	.069
Cork with odorless pitch binder	.087
Cork with sodium silicate binder	.067
Cork mixed with infusorial earth and calcined	.089

As M. Desvignes has remarked, it would perhaps be imprudent to take these figures as a basis for the calculation of loss in a cold-storage plant. The specimens which were used in the tests were picked and were perfectly dry. The given coefficients should be increased not less than 20 per cent. In the application to certain materials some account should be taken to the method of joining. Thus in a partition of cork bricks pointed by cement mortar, where the joints represent in very careful work about 15 per cent of the total volume, the coefficient of conductibility of the brick itself, referred to the total surface of the partition, should be almost doubled. These considerations will show what a difficult question even the approximate calculation of the heating effect due to the walls of the refrigerator may be. The second section has withheld opinion on this question, therefore, and taken the following resolutions:

(1) That study and research shall be undertaken in the technical schools and laboratories to determine, either by known apparatus or that which shall be subsequently devised, the specific constants of the different insulators which are practically utilizable in the refrigerating industry.

(2) That the characteristic properties and constants to be determined, account being taken in each case of the degree of humidity, shall be the following:

The density to be employed.

The coefficient of conductibility.

The resistance to flexure.

The resistance to crushing.

The power of expelling water.

The power of absorbing odors.

The incombustibility.

These constants should be determined under conditions of temperature and thickness of material applicable to the refrigerating industry.

(3) That the second section shall call especial attention to the study of the conductibility as a function of temperature, thickness, degree of humidity, and of other causes capable of influencing the conductibility; for example, the state of division of the material necessary to assure a certain insulation.

(4) That the section requests that the International Bureau of the Refrigeration Congresses, the organization of which has been planned, shall constitute an international commission charged with taking up the study of methods of testing, and cordinating, with a view to establishing methods and obtaining comparable results, any researches which are made, in which otherwise the investigators would have their usual latitude.

(5) That it shall be of interest to submit the question of the uniformization of such methods to the next congress if the researches concerned are sufficiently advanced.

Official instruction up to the present time has been somewhat neglectful of the refrigerating industry. The present-day developments of this industry renders more and more necessary the education of engineers who are specialists in this line. For this reason the second section has also taken the following resolutions:

(1) That theoretical and professional instruction, applied to different present-day phases of the industry of refrigeration and with a view to new applications, shall be inaugurated in the laboratories and higher technical schools of all countries, this course of instruction to be followed by detailed practical study of important refrigerating establishments and rational experimentation with the machinery there used, under the direction of specialists.

(2) That in order that the necessary scientific equipment and experimental material and the cost of the experiments may be provided for, this instruction should be subsidized by the governments, municipalities, chambers of commerce, industrial societies, agricul-

tural syndicates, and all others individually or collectively interested in the refrigeration industry.

(3) That the general work and the results of researches carried out in these laboratories and schools, as well as those of associations of engineers and manufacturers who are working in refrigeration, should be submitted to the permanent International Bureau and coordinated by it, in order that it may publish periodically a bibliographical index, and may compare the results and derive all the useful indications and conclusions possible from them for presentation to the next Congress of Refrigeration for its examination.

III. THE CONSERVATION OF PERISHABLE ARTICLES.

We have now found out how to produce and maintain a low temperature in cold stores. It remains now to study the methods of construction and use of the cold storage rooms, and the rules permitting of the conservation of different sorts of articles. These questions have been the subject of numerous reports and discussions which it would take too much time to digest here. I will, therefore, only indicate some of the most important conclusions on these questions.

The cold air of rooms in a cold storage house should circulate as little as possible from one chamber to another, in order that the odors of certain preserved products may not affect others. In particular, if the refrigeration of the cold store is accomplished by means of air coolers it is absolutely necessary to have a special air cooler for each series of chambers designed to contain a particular product.

The articles to be preserved should not pass suddenly from the ordinary temperature to the temperature of the storage rooms, or vice versa; in other words, the refrigeration should be progressive. Thus, in abattoirs the warm meat coming from the slaughter rooms is transported by means of an overhead rail into a cold anteroom kept at a temperature of 7° to 8° C. There it undergoes for about twenty-four hours a preliminary cooling, at the termination of which it is carried into the rooms where the air is maintained at a temperature of 0° to 4° C. and a humidity lower than 75 per cent. Salting and treatment of the intestines, the hides, etc., should be carried on in rooms entirely separate from those mentioned above, which should be confined solely to the preservation of fresh meat.

The question of the preservation of horticultural products is one of the most difficult in the application of cold to food stuffs. The preservation of apples and pears has been studied in detail in the United States by Mr. G. H. Powell. He has placed results before the congress which demonstrate with the greatest clearness the effect

of placing in the refrigerating chamber freshly picked fruits in comparison with those that have been exposed to the air several days after picking. It is necessary to place the sound fruit in the cold fruit chamber soon after it is gathered. Other circumstances also influence its keeping qualities. It is much better if the fruit comes from older trees; it also appears that sandy soils are not favorable to preservation.

Fruits with a thick skin keep much better than those with an easily ruptured covering. The peach, in particular, is one of the most difficult of fruits to preserve. M. Loiseau, horticulturalist at Montreuil, however, has succeeded in keeping this delicate fruit more than a month. According to him, it is especially necessary to maintain the temperature as constant as possible, varying not more than from 0° to 1° C.

Among the recent applications of low temperatures which have been pointed out may be mentioned the use of artificial cold in the manufacture of paraffin and viscose.

Crude petroleum generally contains from 5 to 6 per cent of paraffin in solution. To obtain this paraffin, the petroleum is distilled until it contains from 10 to 25 per cent of paraffin. Then by lowering the temperature of this liquid (paraffin oil) to a degree which varies according to the quality from +16° to −18° C., paraffin is obtained which separates from the oil in the form of crystals which can be separated from the oil by filtration under pressure. The application of refrigerating machines to this purpose makes possible the treatment at one time of large quantities of petroleum. As an example the works of Pardubitz in Bohemia are equipped with machines of a capacity of a million frigories, and produce annually about four million (kilograms) of paraffin.

The artificial silk called viscose is made by drawing through very fine openings a thick solution of cellulose obtained with alkaline or sulpho-alkaline solvents (caustic soda and carbon disulphide). To accomplish this successfully the solution must be allowed to stand in vessels cooled artificially to +2° C. for a month or two before spinning. The solution is then sufficiently pure to be decanted and spun with success.

IV. TRANSPORTATION WITH REFRIGERATION.

The question of transportation of products under refrigerating conditions is one which has justly been a subject of careful consideration by transportation companies both on land and sea.

The refrigerator cars or trains are of several types.

(1) The refrigerator train, consisting of a group of cars, one of which has no capacity for storage, but contains a complete refrigera-

tion plant which feeds the other cars, with which it is connected by suitable piping.

The impossibility of breaking up such a train by uncoupling the cars from each other limits the practical application of these trains, however, except in a few instances. This system was experimented with in 1905 in the transportation of Russian butter from Siberia (from Kourgane to Riga at a mean speed of 15 to 16 kilometers per hour). The cost of the refrigeration, the temperature of the butter being maintained at a mean of 5.5° C., was as high as 0.117 franc per kilogram of butter per day, exclusive of the cost of the refrigerator plant.

In this category must be classified the Russian refrigerator car of the Silitch system. It is mounted on four sets of wheels on bogy trucks and is of the following dimensions: Length, 8 meters; width, 3 meters; height, 2.65 meters; capacity, 120 cubic meters. It is divided into six compartments. Two in the center contain the refrigerating apparatus while the other four may be charged with goods to be refrigerated.

(2) The lack of elasticity of the refrigerator trains has been remedied by the use of refrigerator or insulated cars. The operation of these cars necessitates, at the starting point, an insulation composed of a refrigerating machine and an apparatus which forces a blast of cold air into the body of the car before and after charging. When the interior temperature of the car has been reduced to the requisite degree, the cold air is shut off and the car hermetically sealed. In Springfield, Mo., there is an installation of this kind capable of cooling 40 cars of bananas at once time to 15° C.

To this type of cars may be compared those where the low temperature is obtained by the previous cooling of brine contained in coils about the roof or walls of the car. The thermo-regulator car of the Maksoutoff system belongs to this type. The saline solution, which cools the air to about 5° C., must be cooled every two days, necessitating refrigerating stations every five or six hundred kilometers.

(3) Besides the tributary cars of the refrigerator trains and those depending on an installation at the point of departure, there are the self-cooling cars; that is to say, cars themselves containing cold-producing agents. These are the most universally used, both in Europe and America.

These may be divided into two great classes: Cars cooled by ice and cars cooled by evaporation of a liquefied gas.

In the ice-cooled cars the low temperature is obtained by means of ice disposed in compartments along the roof, as exemplified in the cars of the Société des Magasins et Transports frigorifiques de France, or along the walls of the car, as exemplified in the American cars and cars of the Moscow-Kazan Railroad. The plan of closing the body

of the car completely from the outside air has been generally abandoned. The ice-cooled cars now in use are usually provided with an arrangement which draws in air from the outside and sends it, after cooling it by contact with the ice, to renew the air in the car. The free space remaining for the disposition of the merchandise is about 30 to 40 cubic feet, allowing the introduction of a load of from 6 to 10 tons, according to the nature of the products. By an ice consumption of an average of 400 kilograms per day a temperature varying between 8° and 4° C. is obtained. The degree of humidity is high, however.

The cars cooled by evaporation of a liquid gas (in this case ammonia) carry on the outside two cylindrical tanks of liquid ammonia. This fluid is sent by regulating cocks into coils placed at the two ends of the car on the inside. The ammonia evaporates and absorbs heat, the ammonia gas produced dissolving in water in a tank placed under the car. One car of this variety was experimented with in 1905 in the transportation of butter from Siberia. The cost of refrigeration for butter maintained at a temperature of from 4° to 5° C. was as high as 0.068 franc per kilogram of butter per day.

In the ice-cooled cars of various types experimented with by the same Russian commission the total cost of refrigeration, including all expenses (ice consumption and charging, installation of ice houses, and operation of cars), amounted to 0.009 francs per kilogram of butter.

As the short summary I have just made shows, the First International Congress of Refrigeration has examined with care most of the scientific and technical problems which exist in the refrigerating industry. If it has solved any of these problems it has indicated in the form of resolutions a very great number of others which up to the present have been only incompletely worked out. The next international congress, which will be held in Vienna in 1910, will not be inferior to that at Paris, and will bring us, let it be hoped, in the scientific phase, to some accurate knowledge of the properties of bodies at low temperatures, and in the industrial phase to a uniformity of units of measure and methods of testing machines and insulating material.

THE NITROGEN QUESTION FROM THE MILITARY STANDPOINT.[a]

By Charles E. Munroe,
Professor of Chemistry, The George Washington University.

The invention of gunpowder afforded man a means of utilizing the energy of chemical separation in effecting propulsion and of more efficiently applying this form of energy in mining and quarrying. Through the discovery or invention of mercuric fulminate, the cellulose nitrates, the glyceryl nitrates, the nitro-substitution compounds, and the various explosive compositions made from these nitrates and nitro-compounds, man was enabled also to utilize the energy stored up in unstable molecules. History indicates that the invention of gunpowder was made where saltpeter, which is its chief ingredient, was naturally most abundant and most easily obtained, but that, owing to the great value of gunpowder to man, its use and manufacture spread to the cooler and more humid countries, and it is in these countries that it and the other explosives enumerated have come to be most extensively used. Statistics are not at hand by which to show the increase in the use of powder throughout the world, but some relative idea of this growth in recent years may be gained from Table 1, which sets forth the quantity, or value, or both, of the gunpowder, including, since 1860, blasting powder also, produced in the United States in each census year beginning with 1840.

The statistics for the world's production of the modern explosives are also not accessible, but an item contributing toward the assembling of this valuable information regarding the world's progress was given for dynamite as sold from the several factories with which Alfred Nobel, the inventor of dynamite, was associated, though as there were, during the period covered, independent factories in Germany, in America, and probably in other countries, these figures, as set forth in Table 2, give only a relative idea of the growth of this industry.

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[a] Reprinted by permission from United States Naval Institute Proceedings, vol. 35, No. 3.

TABLE 1.—*Powder produced in the United States.*[a]

Census.	Quantity (pounds).	Value.
1840	8,977,348	....
1850	([b])	$1,590,332
1860	([b])	3,223,090
1870	([b])	4,011,839
1880	([b])	3,348,941
1890	95,019,174	6,740,099
1900	124,824,473	5,395,193
1905	215,820,144	8,919,460

[a] Chemicals and Allied Products, Bulletin 92, Census of Manufactures for 1905, by Charles E. Munroe, p. 82.

[b] Not reported.

TABLE 2.—*Annual sales of dynamite from Nobel factories.*[a]

Year.	Tons.	Year.	Tons.
1867	11	1875	3,500
1868	78	1876	4,300
1869	184	1877	5,500
1870	424	1878	6,200
1871	785	1879	7,000
1872	1,350	1880	7,500
1873	2,050	1881	8,500
1874	3,120	1882	9,500

[a] Notes on Nitroglycerin, Dynamite, and Blasting Gelatine, by George McRoberts, Phil. Soc. Glasgow April 25, 1883.

TABLE 3.—*Quantities and values of explosives produced in the United States in the census years 1900 and 1905.*[a]

	1900.		1905.	
	Quantity.	Value.	Quantity.	Value.
Gunpowder ... pounds	5,450,773	$614,290	10,383,944	$1,541,483
Blasting powder ... kegs[b]	4,774,948	4,780,903	8,217,448	7,377,977
Nitroglycerin ... pounds	[c]35,280,498	5,532,570	[d]51,579,270	7,730,175
Dynamite ... do	85,846,456	8,247,223	130,920,829	12,900,193
Guncotton ... do	[e]2,988,176	1,473,619	[f]5,905,958	2,435,805
Smokeless powder ... do	3,053,126	1,716,101	7,009,720	4,406,477
All other explosives	....	6,493	....	190,948

[a] Chemicals and Allied Products, Bulletin 92, Census of Manufactures for 1905, by Charles E. Munroe, p. 80.

[b] A keg contains 25 pounds of blasting powder.

[c] Including 31,661,806 pounds, produced and consumed, valued at $4,749,271.

[d] Including 43,643,270 pounds, produced and consumed, valued at $6,110,058.

[e] Including 2,139,834 pounds, produced and consumed, valued at $1,069,917.

[f] Including 5,522,796 pounds, produced and consumed, valued at $2,209,118.

The most complete and detailed figures relative to the production of explosives to be found anywhere are those presented in the reports on the census of manufactures of the United States for 1900 and 1905, which are as follows, the gunpowder and blasting powder, which were combined in Table 1, being presented separately in Table 3.

It is an interesting and important fact that, as with gunpowder so with all of the other explosives enumerated, a nitrogen-containing compound is employed in the manufacture of each and nitrogen remains as a component or constituent of each product. The quantity of nitrogen in one hundred parts of these explosives, together with its equivalent in real nitric acid and in sodium nitrate, is shown, together with other data relative to these explosives, in the following table:

TABLE 4.—*Per cent of nitrogen in certain of the more important explosives.*

Explosive.	Acid components of nitrating mixture.		(3) Weight of acid per 100 of raw material.	(4)[a] Weight of product per 100 of raw material.	(5) Per cent of contained nitrogen.	(6) Equivalent of HNO_3 in 100 parts of product.	(7) Equivalent of $NaNO_3$ in 100 parts of product.
	(1) H_2SO_4	(2) HNO_3					
Blasting powder				100	12.20	54.85	74.00
Gunpowder				100	10.40	46.74	63.00
Guncotton	78.6	21.0	1,200.0	150	13.40	60.30	81.34
Mercuric fulminate		65.0	1,200.0	130	9.85	44.33	59.79
Nitroglycerol	61.5	34.5	[b] 689.7	[b] 228	18.50	83.25	112.30
Picric acid	26.6	55.8	400.0	230	18.30	82.35	111.08
Pyroxylin for S. P.	56.0	29.0	[c]1,900.0 / [d]5,000.0	145	12.50	56.25	75.88

[a] Factory yields.
[b] Using artificial refrigeration, vide Census Bulletin No. 92 of 1905.
[c] Nitrating in pots.
[d] Nitrating in centrifugals.

In calculating the data for Table 4 the gunpowder is assumed to be composed of KNO_3, 75 per cent; C, 15 per cent; S, 10 per cent; and the blasting powder of $NaNO_3$, 74 per cent; C, 16 per cent; S, 10 per cent; but variations from these compositions will be found in practice. However, it is believed that they represent very closely the averages of all commercial compositions so styled. Although a most important explosive, dynamite is omitted from the table because the wide variations in the character and quantities of the components of this mixture as it occurs in commerce render it impossible to properly represent it by an average formula, though it is usually admitted that on the average dynamite contains 40 per cent of nitroglycerol. The wide variation in nitrogen contents occurs in the dope or absorbent, which may contain from no nitrogen-containing com-

ponent whatever, as in the kieselguhr dynamites, to 60 per cent of sodium nitrate in straight wood-pulp dynamites; and this last material may be partly or wholly replaced by ammonium or potassium or cellulose nitrates in other dopes and compositions. Because of a similar wide variation in their components the compositions made from picric acid, its salts, and other nitro-substitution compounds are also omitted. Notwithstanding these omissions, it is believed that the data set forth in the table may prove useful in the development and checking of the statistics of manufacture. But, unfortunately, owing to the different manners in which the nitrogen atoms are grouped, as regards the other atoms, in the molecules of the different kinds of explosives, no direct relation is to be observed between the properties and behavior of these different bodies and the percentages of nitrogen they contain, and this want of relation becomes the more marked the larger the number of different nitrogen-containing substances that we consider. What, however, is emphasized by this presentation of data, is that the element nitrogen is a characteristic and important component of all explosives that have been accepted and used for military purposes.

From the time of the invention of gunpowder until the middle of the last century the only recognized available source of this nitrogen was India saltpeter, which is the potassium nitrate, and which was obtained from the niter found or formed in soil or rocks. The production of nitrates in the soil or rocks is brought about usually through the agency of nitrifying bacteria. In order that the process of nitrification may go on there is required a supply of nitrogenous organic matter, a slightly alkaline medium, a temperature range between definite limits, a limited amount of moisture, a supply of oxygen or air, complete or semi darkness, and the presence of the nitrifying organisms. The nitrification proceeds most rapidly at 100° F. and within a few inches of the surface of soil or rock which is well aerated and moderately moist. When potash salts are present in sufficient quantity the potassium nitrate is produced, but the native niter usually consists largely of calcium nitrate with some magnesium nitrate and other salts. All of these nitrates are readily soluble in water and may therefore, after formation, be to a great extent washed away by frequent rainfalls, but where there is only a moderate amount of water present the solution may be brought to the surface by capillarity, and as the water evaporates the nitrates will be left as an efflorescence on the surface of the soil or rock. It is evident, therefore, that accumulations of niter will be largest in those localities where not only the best conditions for its production obtain, but where also it is least likely to be washed away after being formed. The native sources of supply are therefore found as efflorescences on the soil in semiarid countries, in limestone caverns, where the remains

and excreta of bats are the chief source of the organic matter, and about stables.

Since the amount of niter procurable from these sources was limited it became necessary, as the demand for saltpeter increased, to resort to other sources of supply, and consequently niter plantations were established in many countries where, following the principles set forth above, the niter was formed and protected from the weather. Desortiaux[a] describes in detail the saltpeter plantations of Hungary, Switzerland, France, and Sweden. Such farms have been carried on in this country, especially in the Southern States during the civil war, and the means resorted to by John Harrolson, of Selma, Alabama, to secure the necessary nitrogenous organic matter for these farms became particularly widely known. In emergencies, as in Sweden in 1520, the earth of cemeteries has been lixiviated to obtain niter, and in this last-mentioned country a tax was imposed in 1642 which had to be paid in saltpeter.[b]

About 1821 the naturalist Mariano de Rivero found on the Pacific coast of South America, in the province of Tarapaca, immense deposits of sodium nitrate.[c] As this salt had prior to this been known only as a laboratory product, the discovery was of marked scientific interest, which became an economic one when, in 1830, the material was mined for exportation and 8,348 tons were shipped in that year. Investigation has shown that this deposit extends for some 450 miles north and south in the arid plains which lie between the western slope of the Andes Mountains and the coastal range on the Pacific, at altitudes of from 3,600 to 13,000 feet and at distances of from 15 to 93 miles from the sea. The exploitation of this deposit has been pushed to such an extent that in the year ending December 31, 1908, there were shipped from the various South American ports contiguous to this field 1,993,000 tons of the nitrate of soda, and because of the export taxes levied upon this material and the payments required for concessions to operate in this desert tract, this industry has been and still is a rich source of revenue to the Chilean Government. The extent to which this industry has grown and its rate of growth are clearly set forth in the following table prepared by F. V. Vergara,[d] collector of customs at the port of Valparaiso:

[a] Traité sur la poudre, les corps explosifs et la pyrotechnie, vol. 1, pp. 15–117, 1878.

[b] The Manufacture of Explosives, O. Guttmann, vol. 1, p. 24, 1895.

[c] Principles and Practice of Agricultural Analysis, H. W. Wiley, vol. 1, p. 16, 1894.

[d] Monthly Bulletin International Bureau of American Republics, November, 1903, p. 1290.

TABLE 5.—*Sodium nitrate exported from Chile, 1840–1903.*

Period.	Exports.	Annual average.	Period.	Exports.	An average.
	Tons.[a]	*Tons.*[a]		*Tons.*[a]	*Tons.*[a]
1840–1844	73,232	14,646	1875–1879	1,365,418	273,083
1845–1849	94,806	18,961	1880–1884	2,220,926	444,185
1850–1854	149,960	29,922	1885–1889	3,318,520	663,704
1855–1859	259,394	51,879	1890–1894	4,813,670	962,734
1860–1864	327,034	65,407	1895–1899	6,204,636	1,240,927
1865–1869	487,324	97,465	1900–1903	5,537,396	1,384,349
1870–1874	1,095,628	219,125			

[a] Metric tons of 2,204 pounds.

This material was not only cheap and relatively abundant, but, as previously shown,[a] the richest known source of oxygen for use in explosives. It is not surprising, therefore, that its use for this purpose has rapidly grown. Nitrate of soda was first used in blasting powder in 1856, and a patent for such a powder was issued to La Motte Dupont in 1857. During the census year 1905 there was produced in the United States 205,436,200 pounds of blasting powder, most of which was nitrate of soda powder, and large quantities of this powder were manufactured and consumed in Chile and other countries.

As nitrate of soda is quite deliquescent it is not suitable for direct use in the compounding of gunpowder, but early after becoming available in commerce it was made a source of manufacture of saltpeter. It was during the Crimean war (1854–55) that this industry was established in Germany, the sodium nitrate being converted into potassium nitrate by means of potassium carbonate obtained from the residues of sugar beets, and this assisted in the promotion of the beet-root sugar industry which Germany was seeking to foster.

Singularly, about this time the now famous deposit of potassium salts was discovered at Stassfurt, Germany. This town was noted for its salt works in the beginning of the nineteenth century, the source of supply being the natural brine from driven salt wells. With the utilization of rock-salt deposits in various localities, the price of salt was reduced to such a point that the Stassfurt works ceased to yield their former large revenue to the Prussian Government, and, with a view of making them again valuable, the Government began boring for rock salt in this locality in 1839. In 1857 a shaft, which began in 1852, reached, at a depth of 1,080 feet, a stratum of rock salt, but in doing so it passed through a heavy deposit of so-called "Abraum-salze" or refuse salts, which were then considered worthless. The "Abraum-salze" were found to consist largely of the minerals carnallite, which is a magnesium-potassium chloride; sylvite, which is potasssium chloride; and kainite,

[a] Lectures on Chemistry and Explosives, p. 2, 1888, by Charles E. Munroe.

which is a mixture of carnallite and magnesium chloride, and these refuse salts are to-day the chief source of the world's supply of potashes and potassium salts. Numerous uses have been found for them, not the least interesting of which is the production of saltpeter from the metathesis of the Chile nitrate with the Stassfurt sylvite or carnallite. In the United States alone there were produced 14,468,000 pounds of potassium nitrate by this means during the census year 1905, and this operation has been conducted here for many years. It is by such means that the Chile deposits have been made to render the saltpeter essential for use in sporting and military powders.

It has already been shown that the manufacture of dynamite consumes large quantities of nitrate of soda, and it has been also shown that the modern explosives, pyroxylin, guncotton, picric acid, and nitroglycerol, require for their maunfacture a larger quantity of sodium nitrate, or of any other nitrate, as a source of the required nitrogen, than gunpowder does, while mercuric fulminate requires nearly as much. It may, therefore, be safely asserted that but for the discovery and exploitation of the nitrate fields of Chile the explosives industry, as it is known to-day, would have been impossible, and the developments in mining and transportation which have characterized the last half century could not have been made. That is, the condition of civilization amid which we now live could not have been attained.

Yet the explosives industry is but one of several in which nitrate of soda is used. The relative quantities used in various countries differ. Unfortunately no detailed and accurate statistics can be had except for the United States. Omitting the minor industries of enameling, fluxing in metallurgy, pickling of meats and fish, and the manufacture of subordinate chemicals in which approximately 23,926 short tons were used during the census year 1900, and 67,937 short tons in 1905, the quantities consumed in various industries were as follows:[a]

TABLE 6.—*Nitrate of soda consumed in the United States by establishments classed as follows:*

Class.	1900.	1905.
	Short tons.	*Short tons.*
Fertilizer industry	19,518	42,213
Dyestuffs industry	223	261
General chemicals industry	35,990	38,048
Glass industry	10,770	11,915
Explosives industry	88,524	133,034
Sulphuric, nitric, and mixed acids industry	27,406	29,301
Total	182,431	254,772

[a] Journal of Industrial and Chemical Engineering, I, 298, 1909, by Charles E. Munroe.

It thus appears that of the total available supply of nitrate of soda in the United States but 42.90 per cent was used at the census of 1900, and 41.22 per cent at the census of 1905, in explosives factories, and of this a notable portion was used in the manufacture of saltpeter which was sold for other uses in the arts. While all the industries enumerated show a growing demand, the largest increase in any single industry is found in the fertilizer industry, where 22,695 tons, or 116.2 per cent, more of nitrate were used at the census of 1905 than were used at that of 1900.

While no detailed statement of the consumption of nitrate of soda elsewhere is available, there is issued semiannually by W. Montgomery & Co. (Limited), of 63 Mark Lane, London, a statement of the total shipments, consumption, stocks, and prices of this article during a considerable period, and the following data are derived from their circular statement for December 31, 1908:

TABLE 7.—*Consumption of nitrate of soda in 1908.*[a]

Locality.	Tons.
United Kingdom	104,000
Continent of Europe	1,272,000
United States	309,000
Other countries	45,000
Total	1,730,000

[a] The circular of Montgomery & Co. for June 30, 1910, gives the revised figures for 1908 as follows: United Kingdom, 99,000; Continent of Europe, 1,233,000; United States, 315,000; other countries, 55,000; total, 1,702,000 tons. From this data the percentage of the total consumption for the United States is 18.51.

From this it appears that of the total consumption of the year but 17.8 per cent was consumed in the United States. Analyzing the statement for the previous eight years, it appears that of the total that consumed in the United States was, in 1900, 12.6 per cent; 1901, 14.1 per cent; 1902, 16.9 per cent; 1903, 18.76 per cent; 1904, 19 per cent; 1905, 19.9 per cent; 1906, 21.7 per cent; 1907, 21.1 per cent; so that there was a steady increase in the proportion of the total consumed in the United States up to 1906, but that for the next two years there was a drop such that in 1908 our proportionate consumption was less than for any year since 1902.

It is commonly understood that a much larger percentage of the Chilean nitrate is used in agriculture in Europe than is used in this industry in the United States, and that the proportion is steadily increasing. This use of nitrogenous fertilizers is in conformity with the teaching of Baron von Liebig, whose views have become gradually disseminated among the farmers. A marked impetus was given to this use of the Chilean nitrate by the remarkable

address made by Sir William Crookes before the British Association for the Advancement of Science in 1898, when, in dealing with the problem of meeting the rapidly increasing demand for food, he pointed out that while the average yield of wheat was but 12.7 bushels per acre it had been demonstrated that the yield could be increased to 20 bushels by the use of 1½ hundredweight of nitrate of soda on each acre annually.

This increasing use, however, tends to exhaust the supply. Crookes estimated that if the nitrate were used over the whole area under cultivation at the rate he proposed, the Chilean deposits would be exhausted in four years. Vergara[a] estimated that at the rate that the nitrate had been mined and exported between 1840 and 1903, as shown in Table 5, the Chilean deposits would be exhausted by 1938. Albert Hale, however, in a more recent review of the situation,[b] points out that these estimates were based on the contents of the deposits then known in the province of Tarapaca, and the extent to which they could be profitably worked, and states that deposits of such magnitude have since been discovered in the provinces of Antofogasta and Atacama, and the processes of recovery of the nitrate from low-grade ore (caliche) have been so improved that, at a rate of consumption of 5,000,000 tons annually, which he expects will be the normal demand in a few years, there is enough nitrate in these deposits to last three hundred years.

This is a more encouraging outlook, but, nevertheless, from what has been said it is evident that the world has for long been largely dependent on these Chilean deposits for the greater part of its supply of nitrate and the substances derived from it. In time of prolonged war, in case nitrate has become contraband, most countries have been obliged to resort to the vicious policy of niter farming, or, as our Navy Department has done since 1863, have accumulated in advance considerable stores of niter, and this condition would have continued to hold but for important advances recently made in the production of nitrate from atmospheric nitrogen, and through other developments in chemistry.

We have in our atmosphere an abundant supply of this element. It is estimated that the air over each acre of ground contains 33,880 gross tons of nitrogen. It is, however, free, and to be available for use it must be combined. The methods for effecting the fixation of this nitrogen have proceeded along three lines: (1) The production of nitric acid and nitrates; (2) the production of cyanides; and (3) the production of amids, and the first and last have now been brought to commercial success.

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[a] Loc. cit.

[b] Bull. International Bureau of American Republics, p. 27, July, 1908.

As early as 1755 Priestly had noted that nitrogen compounds were formed when electric sparks were passed through air, and not long after Cavendish produced saltpeter by absorbing air, so treated, in caustic potash solution. Repeated attempts have been made since high potential currents have become readily available to utilize this method and an establishment was erected at Niagara Falls, by the Atmospheric Products Company, to operate the Bradley and Lovejoy process. This method, for which a United States patent was granted September 30, 1902, consisted in producing in the air a flaming electric arc of minimum volume by the rapid rotation of electrodes carrying high tension currents, but while it yielded nitric acid the method proved too costly.

A more successful device was shortly after put into operation by Birkeland and Eyde[a] at Nottoden, Norway, and it has been in operation ever since. In this the flaming arcs produced by high tension currents were made to move to and fro through the air within the apparatus by exposure to powerful magnets. This apparatus was characterized by a narrow chamber through which the air was passed and within which the electrodes, placed near together, were arranged between the poles of a strong magnet and at right angles to these poles. A disk-shaped or deflected electric arc was thus obtained perpendicular to the lines of force of the magnetic field. Three such furnaces at Nottoden, using 500 kilowatts and 5,000 volts, gave deflected arcs about 3 feet in diameter. The nitrogen oxides formed were quite dilute and they were carried to absorption towers where, by contact with milk of lime, calcium nitrate was formed, the product being eventually converted into basic calcium nitrate for use as a fertilizer. According to O. N. Witt,[b] with this apparatus an output of 500 to 600 kilos of nitric acid per kilowatt year can be regularly maintained.

A still more efficient form of furnace is that devised by Dr. Otto Schoenherr for the Badische Anilin and Soda Fabrik. From his lecture, delivered June 11, 1908, before the Verein Deutscher Chemiker at Jena, it appears that what is sought in these processes is to burn the nitrogen with the oxygen of the air. To accomplish this to any satisfactory degree the gases must be exposed to a temperature of 3,000° C. and upward. To prevent the decomposition of the product formed it must be immediately removed to a cooler region. This Birkeland and Eyde accomplish through moving the arc to and fro by the aid of magnets, while Shoenherr effects it by imparting to his air a gyratory motion about his elongated arc. His apparatus consists of a long iron tube in which an arc 5 meters

[a] The Electrochemical Problem of the Fixation of Nitrogen, Phillippe A. Guye, J. Soc. Chem. Ind., 25, 567, 1906.

[b] Chemiker Industrie, 28, 699, 1905.

in length, produced by an alternating current, is maintained constantly, the energy required being about 600 horsepower and the alternations being 50 per second. Air, which has been heated to 500° C. by the hot discharge of gases, is blown tangentially into this tube so that it surrounds the arc spirally in its passage through the tube. This prevents the deflection of the arc, permits of the maximum exposure of the air to the heat from the arc, and promptly sweeps the heated and reacting air to the cooler portion of the tube and beyond. A 2,000 horsepower plant of this character has been in operation at Christiansand, Norway, since the autumn of 1907, and its success has been such that the building of a 120,000 horsepower plant of this character has been undertaken at Rukwan Falls, Norway. The advantage claimed for this process is that it gives a good yield of concentrated gas.

The third method for the fixation of atmospheric nitrogen referred to above has been brought to a successful realization by Frank and Caro in their production of calcium cyanamid mixed with carbon or "lime nitrogen," or "nitrolim," as it is more recently called. This is produced [a] by heating calcium carbide in vertical iron retorts in an atmosphere of nitrogen, when the calcium cyanamid, mixed with carbon, is formed according to the following equation:

$$CaC_2+N_2 \rightarrow CaCN_2+C.$$

The nitrogen is obtained by liquefying the air and separating its constituents by fractional distillation, or by passing the air over heated copper, by which the oxygen is removed from it and the nitrogen separated. A plant with a capacity of nearly 4,000 tons per year was started at Piano d' Orta, Italy, in 1906, and with such success that the production was carried in 1908 to over 40,000 tons per annum in five plants, with others building. The material as produced is used directly as a fertilizer, but it is a simple matter to obtain ammonia from it and by a contact process this may be directly converted into nitric acid.

Yet another indirect source of supply of nitric acid and, therefore, of saltpeter is found in the manufacture of coke, for an important product of the by-product coke industry is ammonia, which is obtained usually nowadays as ammonium sulphate. I have elsewhere shown [b] that 15,773 tons of ammonium sulphate were produced in this country in 1905. But as only 3,317,585 tons of the 37,376,251 tons of coal coked in the census year were coked in by-product ovens it was possible, had all been so treated, to have ob-

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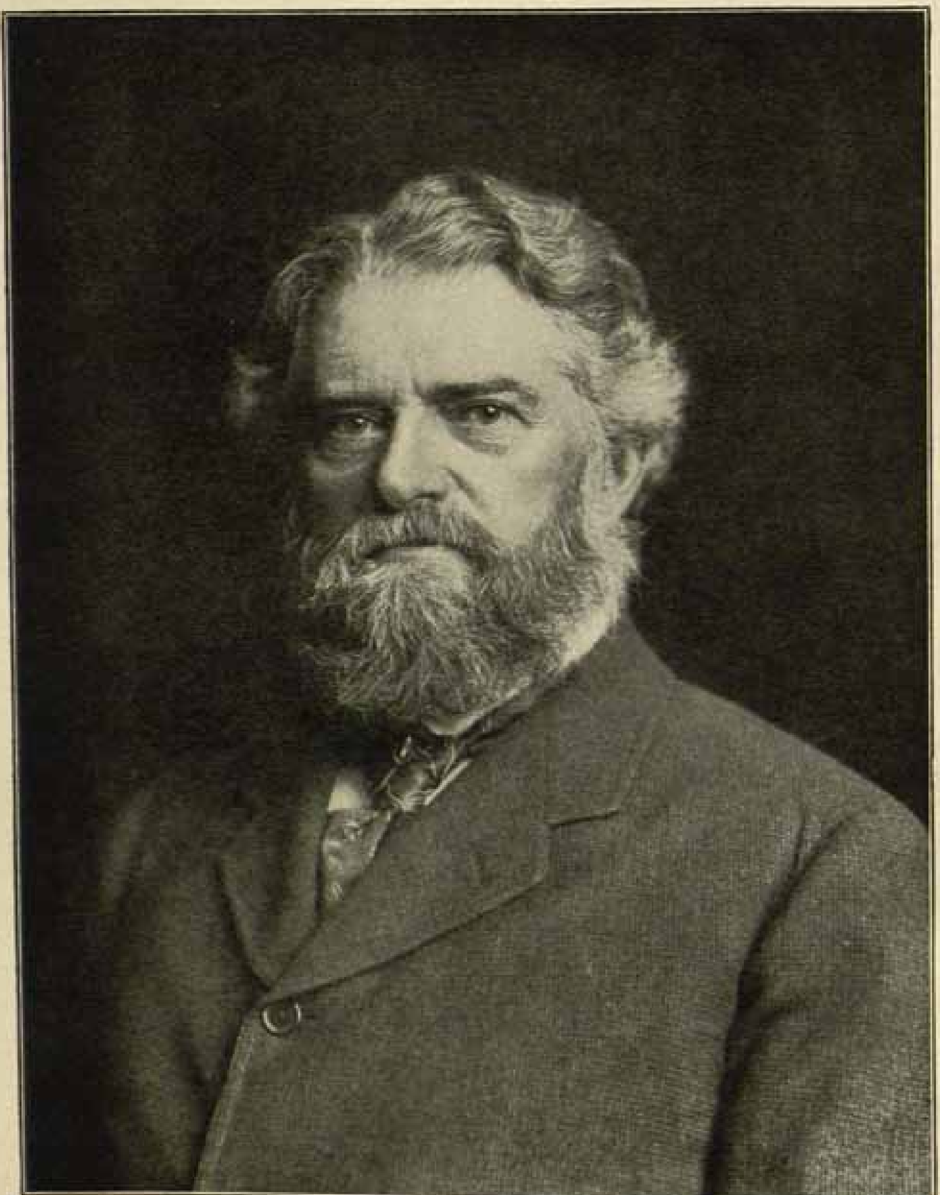
[a] Report on Calcium Cyanamid, Charles E. Munroe, Washington, April 27, 1907.

[b] Bulletin No. 65, Census of Manufactures, 1905, Coke, p. 18, by Charles E. Munroe.

tained 359,560 tons of ammonium sulphate, all of which if desired could have been converted into nitric acid for use in the manufacture of saltpeter or of any desired variety of explosive.

From this account of recent chemical progress it is evident that it is possible to conduct a prolonged war without robbing the soil on which the people depend for food of its fertility, and further, that, notwithstanding the enormous and constantly increasing demand for nitrogen compounds in agriculture and manufacture, this country has reached a potential degree of independence, as regards its supply of nitrogen compounds for military uses, such as it never before enjoyed, so that it needs hereafter to consider foreign sources of supply only from the economic standpoint. However, I desire to say regarding the plants for the fixation of nitrogen what I have repeatedly advised regarding plants for the manufacture of explosives, viz, that it is a wise policy for our Government to foster, and in a measure supervise, these manufacturing operations, and to look to it that plants for these purposes are so strategically located throughout the country as to be reasonably well protected from attack, so that they may serve the military establishment in case of foreign invasion from any quarter or of internal uprisings in any locality.



SIMON NEWCOMB.

SIMON NEWCOMB.[a]

[With 1 plate.]

By Ormond Stone.

Simon Newcomb was a unique figure in American science.[b] Perhaps no other great American scientist was so many sided, no other, who approached him in versatility, stood at or so near the head in various departments of science. He was mathematician; celestial mechanician; astronomical observer, computer, and statistician; fundamental star cataloguer; author of memoirs on the lunar theory, of planetary tables, of books on popular astronomy, of mathematical school and college texts, of books on economics; novelist; president of a society for psychical research!

Simon Newcomb was born March 12, 1835, in Wallace, a village of Nova Scotia, but he was of New England descent. At the age of 17 he went to Salem, Massachusetts, and later to Maryland, where he taught school for several years. When 22 he became assistant in the Nautical Almanac office, then located at Cambridge, Massachusetts, and also a student in the Lawrence Scientific School, where he later graduated as bachelor of science. At the age of 25 he received an appointment as professor of mathematics, United States Navy, and was assigned to duty in the Naval Observatory in Washington. Sixteen years later he was placed in charge of the Nautical Almanac office, which had been removed to Washington, and of which he remained director from 1877 until 1897, when, having reached the age of 62, he was placed on the retired list. He continued to reside in Washington until he died, July 12, 1909. Upon the death of Professor Winlock, in 1875, he was offered but declined the directorship of the Harvard Observatory. From 1884 to 1894 to his duties in the

[a] Reprinted by permission from Astrophysical Journal, vol. 30, No. 3, October, 1909.

[b] The portrait of Professor Newcomb, reproduced herewith, is from a photograph made in 1897 by Mr. A. D. Wyatt, of Brattleboro, Vermont. It therefore represents Professor Newcomb at the age of 62, in the year of his retirement from active service in the Navy Department.—Eds.

Nautical Almanac office he added those of professor of mathematics and astronomy at the Johns Hopkins University and editor of the American Journal of Mathematics. In what follows no attempt will be made to give more than the briefest outline of the more important of his astronomical activities.

The first work that called attention to his genius for research was carried out in Cambridge while he was an assistant in the Nautical Almanac office there. The final results were communicated in 1860 to the American Academy of Arts and Sciences in a paper showing, among other things, that so far as present theory could determine, the orbits of the asteroids had never passed through any common point of intersection. There was thus no evidence that these little planets were fragments of a larger planet which had suffered a cataclysm at some epoch in the distant past, as suggested by Olbers.

In 1862 the 8-inch transit circle of the Naval Observatory was received and placed in charge of Professor Newcomb, who proceeded to observe the stars of the American Ephemeris and other miscellaneous stars. During 1866 and 1867 the observing programme was so arranged that as far as possible groups of stars were observed about twelve hours apart in order to determine the systematic errors of the star places given in the Ephemeris, and thus obtain results independent of previous observers. In the volume of Washington observations for 1870 Professor Newcomb published a memoir on the right ascensions of the equatorial fundamental stars and the corrections necessary to reduce the right ascensions of different star catalogues to a mean homogeneous system. In the first volume of the Astronomical Papers of the American Ephemeris, a magnificent series of volumes founded by Professor Newcomb and continued by him during his directorship of the Nautical Almanac office, he published another fundamental catalogue, this time giving both right ascensions and declinations, derived from all the data then available, as had been the catalogue previously mentioned. And finally, in the eighth volume, is given a new determination of the precessional constant and a catalogue of fundamental stars for the epochs 1875 and 1900, reduced to an absolute system. This catalogue contains no less than 1,596 stars and is a masterpiece of exhaustive research. The positions given are likely to remain the standard for some time to come, probably at least until the observations of Piazzi, Maskelyne, Bessel, and Pond have been re-reduced. They have already been introduced into the principal national ephemerides of the world.

Professor Newcomb at an early date became interested in the question of the sun's parallax, and in 1869 published an investigation based upon all the data then available. The result at once became the standard and so remained for many years. Later, as a member of the Transit of Venus Commission, he took an active part in pre-

paring for and directing the expeditions sent by the United States to various parts of the world to observe the transits of Venus that occurred in 1874 and 1882. Still later he made a careful study of the transits of 1761 and 1769, obtaining results agreeing well with those obtained from more modern observations. In connection with this investigation, after examining the original records, he vindicated the honesty of the much-maligned Father Hell, who was one of the principal observers of the transit of 1761 and was afterwards accused of "cooking" his observations. The importance of the velocity of light as a means of determining the sun's distance caused him to become interested in Michelson's experiments, and led him to make similar experiments himself. The acurracy secured far exceeded that of values previously obtained. Professor Newcomb's discussion of all the determinations of solar parallax given in the supplement to the American Ephemeris for 1897 may be considered the last word on the subject up to the present time.

In 1865 Professor Newcomb published an investigation of the orbit of Neptune, including tables of its motions. A similar treatise on the motions of Uranus was published in 1873. Both of these memoirs appeared in the Smithsonian Contributions to Knowledge. Having thus begun the study of the motions of the solar system, on taking charge of the Nautical Almanac office, he "deemed it advisable to devote all the force which he could spare to the work of deriving improved values of the fundamental elements and embodying them in new tables of celestial motions." This gigantic purpose he lived to see completed so far as the major planets were concerned. As the orbits of Neptune and Uranus were the first to receive his consideration, so the tables of these planets based upon newly revised theories were his last contribution to the Astronomical Papers before his retirement from the Nautical Almanac office.

For the solution of the problem of their motions the major planets were separated into three divisions: (1) The four inner planets; (2) Jupiter and Saturn; (3) Uranus and Neptune. Reserving for his own consideration the four inner and the two outer planets, he assigned the orbits of Jupiter and Saturn to Dr. G. W. Hill, stipulating merely that care be taken to make the work of the latter homogeneous with the work on the other major planets; for instance, the values of the masses of Jupiter and Saturn to be used were to be assigned by Professor Newcomb. In order to obtain an accurate determination of the mass of Jupiter, a careful study was made of the motions of the asteroid Polyhymnia, the eccentricity and major axis of whose orbit are so large that at times it approaches so near to Jupiter as to give rise to large perturbations.

As a supplement to the American Ephemeris for 1897, Professor Newcomb published a brief summary entitled "The Elements of the

Four Inner Planets and the Fundamental Constants of Astronomy." All known meridian observations of the sun and of the planets Mercury, Venus, and Mars were reduced to a uniform equinox and system of declinations and compared with Leverrier's tables. A similar exhaustive comparison was made for the transits of Venus and Mercury. The results of these comparisons were then combined and upon them was based a new determination of the orbits of the four inner planets, including a more accurate determination of the deviation of the observed values of the motions of the perihelion of Mercury and of the node of Venus from the values computed in accordance with the law of gravitation. It was found that the observed discrepancies could be accounted for by assuming a ring of matter lying between the orbits of Mercury and Venus. Professor Newcomb's conclusion was, however, for reasons which he gave, that we can not, in the present condition of knowledge, regard this hypothesis as more than a curiosity.

It is true the discussion of theoretic methods of celestial mechanics was carefully subordinated by Professor Newcomb to the practical purposes kept steadily in view. Only in this way was it possible to accomplish such monumental practical results. Nevertheless, his work did not consist merely in applying the methods of others to the determination of the actual motions of the planets under consideration; his own contributions to planetary theory were important. In 1874 his paper "On the General Integrals of Planetary Motion" appeared in the Smithsonian Contributions to Knowledge. Assuming that the differential equations of motion can be satisfied approximately by infinite series containing only terms of the forms

$$p=c \cos (a+bt) \text{ and } q=a+bt$$

where t is the time, and a, b, c are arbitrary constants, he showed that these series could be replaced by similar ones having a higher degree of approximation, and thus the problem of three bodies could be solved formally by series containing no terms except of the given form. Poincaré devotes a large part of the second volume of "Les méthodes nouvelles de la mécanique céleste" to applications of Lindstedt's method, which he shows is essentially that of Newcomb just mentioned.

Professor Newcomb's researches on the motions of the moon began with a paper read before the American Association for the Advancement of Science at its meeting in 1868 and written to show that there is no good reason to suppose that there is any want of coincidence between the center of figure and the center of gravity of the moon as maintained by Hansen. Next followed various papers calling attention to the extraordinary differences existing between the positions of the moon as given in Hansen's tables and as obtained

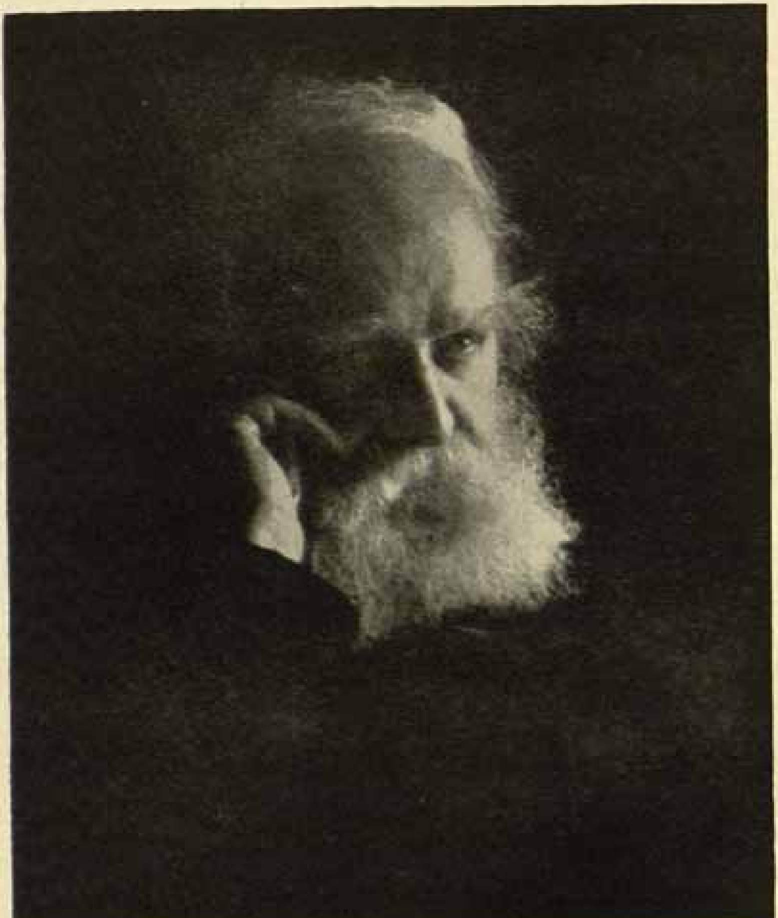
from the latest observations made at Greenwich and Washington. The elements used in Hansen's tables were based on observations made between 1750 and 1850. Having found that these tables failed to satisfy later observations, Newcomb compared them with all known observations made before 1750. This investigation was aided by a visit to the principal observatories of Europe which led to the discovery, especially in Paris, of numerous and valuable unpublished observations of eclipses and occultations. Also, a large part of the published observations had not before been used for determining the moon's place. The comparison when completed disclosed discrepancies that could be explained in two ways: (1) By supposing the discrepancies to be only apparent, arising from inequalities in the axial rotation of the earth; (2) by assuming empirically a correction to Hansen's value of a term depending on the action of Venus and having a period of two hundred and seventy-three years. Later, from the exhaustive study of the transits of Mercury from 1677 to 1881, already referred to, it was inferred that the discrepancies between the observed and the computed positions of the moon could not be accounted for on the assumption of inequalities in the axial rotation of the earth, and that "inequalities in the motion of the moon not accounted for by the theory of gravitation really exist." The last work performed by Professor Newcomb, while his life was nearing its end, was a comparison with Hansen's tables of all the observations of the moon to date, made with the aid of a grant from the Carnegie Institution, a result of which was the confirmation of the existence of deviations apparently not accounted for by the law of gravitation. The larger part of these he found could be reduced to a single term, as previously suggested, but the existence of well-marked smaller outstanding deviations of an apparently irregular character was also clearly shown.

While the comparisons of Hansen's tables with observations is probably the permanent result of greatest value that Professor Newcomb contributed to the study of the moon's motion, laying as it does a firm foundation upon which to base the determination of the numerical values of the constants employed, whatever method may ultimately be adopted for the analytical discussion, nevertheless, as in the case of his study of planetary theory, his theoretical study of the lunar problem would by itself have been sufficient to have secured for him a high and enduring place in the history of the subject. His most important contribution to lunar theory related to the action of the planets on the moon. His first memoir on this subject appeared in Liouville's Journal in 1871. Afterward he published a rediscussion of the problem in the Astronomical Papers. Only a few years before his death he took up the whole subject again and published a final memoir in 1907 under the auspices of the Carnegie Institution.

Among Professor Newcomb's other investigations may be mentioned determinations of the orbits of the satellites of Uranus and Neptune from observations made with the 26-inch refractor of the Naval Observatory, and his paper on Hyperion, explaining the remarkable retrograde motion of the line of apsides of that satellite.

His Spherical Astronomy and The Stars are both in their way pioneers and will ultimately be ranked among the classics of astronomical literature. The Stars, while essentially a statistical research on the structure of the universe, is written in a simple and lucid style that gives it an interest to others besides astronomers. As a result of his remarkable power of discussing scientific subjects in a manner capable of comprehension by the intelligent general reader, his popular works on astronomy are models of their kind and have the advantage that, being written by a master of his subject, they have an intrinsic and enduring value not possessed by most other works of that class. His ability as a popular writer is also seen in his Reminiscences, whch is one of the most attractive autobiographies ever written.

Recognition of the fact that Professor Newcomb was the leading astronomer of his time was shown by his election to honorary or corresponding membership in all the great scientific societies of the world and by the numerous medals, academic titles, and other distinguished honors that were showered upon him.



JULES CÉSAR JANSSEN.

SOLAR-RADIATION RESEARCHES BY JULES CÉSAR JANSSEN.[a]

[With 1 plate.]

By A. de la Baume Pluvinel.

The scientific career of Janssen was passed far more in temporary observatories built in remote parts of the globe and with equipments easily transportable than in fixed establishments provided with great instruments. Janssen was thus notably a missionary of science always ready to devote himself to new efforts in the organization and leading to success of some new expedition for science. This spirit of enterprise made him love those voyages where he was sustained with the knowledge that he was devoting himself completely to science rather than working quietly in his laboratory.

The principal missions undertaken by Janssen had for their objects the observation of phenomena observable only from some limited portion of the earth or where he must find a sky favorable to some delicate experiment. But in either case, Janssen carried on researches which had the same goal, so his work presents a remarkable unity. We might indeed say that all his studies were made upon the selective absorption for radiation by gases. His devotion to this class of researches was determined by Kirchoff and Bunsen's discovery of absorption spectra; indeed the first spectroscopic experiments of Janssen date from 1862, very shortly after the German physicists had published their results.

Janssen studied the absorption for solar radiation, on the one hand, by the surrounding envelopes of the sun itself, on the other, by our own terrestrial atmosphere. It was while observing these gaseous envelopes of the sun, which may be seen only during the few short moments of a total solar eclipse, that he accomplished the first part of this programme, and in undertaking his classic researches on the telluric lines, the second. We will follow Janssen through his studies in these two groups of problems.

[a] Translated by permission from Astrophysical Journal, September, 1908.

Janssen impatiently waited for the total solar eclipse of 1868, for it was to furnish him the opportunity of studying for the first time with the spectroscope these solar envelopes. In order to prepare himself in some manner for the observation of this important phenomenon Janssen asked that he might be sent, in 1867, to Trani, in Italy, to observe an annular eclipse of the sun. His purpose for studying the spectrum of the sun during the annular eclipse was to see if he could then detect any trace of absorption due to the solar envelopes. But he found the spectrum of the annulus the same as that from the central part of the sun's disk. During this same eclipse he unsuccessfully tried to see the corona.

But the eclipse of 1868 had in store for him the honor of making a great discovery. We know that, after having seen in his spectroscope the brilliant rays of the protuberances, which appeared during the totality, that he did not hestitate to affirm, with all the authority which his great experience in spectroscopy allowed, that he would be able to see these same rays without an eclipse. On the next day he had the joy of confirming his predictions.

We know that Sir Norman Lockyer made the same discovery independently in England, so that the names of these two scientists are associated with this so fertile application of spectrum analysis. Janssen appeared to realize from the very first day all the importance of the discovery which he had just made. Of this we find the proof in a letter which he sent to his mother and in which he said: "I read to-day from a book which, until now, was closed to all and from which but glimpses could be got during the few short moments of a total eclipse."

The results obtained from the eclipse of 1868 were too enticing for Janssen to stop on the path which he had just opened for astronomers, and so he decided to go to Algeria for the total eclipse of December, 1870. He was unfortunately prevented from observing this eclipse on account of bad weather, but it furnished remarkable evidence of his devotion to his work. Apparently imprisoned in Paris by the siege, Janssen did not fear to risk the dangers of a balloon voyage in order to break through the lines of the enemy. This act of courage did more to make him popular than his beautiful discovery about the prominences and, for the public which realized the real dangers of that time in daring a voyage through the air, this audacious way of escaping from the beleagured capital gave a measure of the devotion to science of which Janssen was capable. Janssen retained from this aerial trip, made under such perilous conditions, a sincere love for aerial navigation. Many occasions came for proving his interest in this science in giving to aeronauts valuable counsel, in consenting to preside over various

aeronautical meetings, and in giving bountiful hospitality, at Meudon, to the International Congress of Aerostation.

In the year after the eclipse of 1870 there came another, visible this time in India and Java. Janssen was careful not to lose this new opportunity for the examination of the solar envelopes. A careful study of the meteorological aspects of the various places where the eclipse might be visible made him adopt a station in India, in the Neelgheries; the outcome showed the justice of his choice, for it would have been scarcely possible to observe an eclipse under more favorable conditions. This time Janssen confined his attention principally to the corona. He noted in the spectrum of this, not only the green ray, whose presence was already known, but also dark lines, indicating that a part of the light of the corona is reflected sunlight, and tending to prove that the coronal envelope is not exclusively gaseous but composed partly of liquid or solid particles.

In 1875 we again find Janssen observing an eclipse, this time near the island of Malacca, on the return voyage from a trip to Japan.

Then, in 1883, with no fear for the fatigue of a difficult voyage, he went to the island of Carolina, in the middle of the Pacific Ocean, in order to observe a total solar eclipse remarkable for the duration of totality. Thanks to the silver-bromide gelatine dry plates, which had then just been invented, he was able to photograph the phenomena of this eclipse under very varied conditions, and brought back data of the greatest interest on the extent of the solar corona.

Before terminating this work Janssen wished to observe for a last time these beautiful phenomena, which for him had always had such a fascination. So, in 1905, despite his advanced age, he went to Spain to have the pleasure of seeing an eclipse, more as a curious human being than as an astronomer.

We have now seen what Janssen accomplished in the investigation of the gaseous surroundings of the sun by the application of the spectroscope to the study of solar eclipses. We will now pass in review his work upon the absorption of our own atmosphere for the radiation from the sun.

The first of these spectroscopic studies relates to the black bands which appear in the sun's spectrum as the sun nears the horizon. These had already been noted by Sir David Brewster, but the latter recognized neither the real structure of these bands nor the cause of their appearance. By observations made in Rome from 1862 to 1863 Janssen found that these bands were resolvable into lines, and proved that their origin must be attributed to the selective absorption produced upon the solar rays by the gases of our own atmosphere. Later it was found that the oxygen in the air produced the bands A, *a*, and B, which appear in the solar spectrum. But the oxygen of our atmosphere might not be the only oxygen giving

birth to these lines, for its existence in the envelopes of the sun could as well play in the production in the phenomena. With respect to the theory of the sun, it is of the greatest importance to know whether oxygen coexists with hydrogen in the solar envelopes. Janssen, indeed, attributed to the question of this existence of oxygen in the sun a capital importance, and so he searched by all the methods available to find out whether the bands, A, *a*, and B, had their origin in both solar and terrestrial absorption or were produced solely by our atmosphere. In order to solve this problem he produced these absorption bands in his own laboratory in such a manner as to see whether a column of oxygen equivalent to the oxygen contained in the air would produce bands of the same intensity as those we observe in the solar spectrum. The same train of thought caused him to observe the spectrum of a luminous source so far distant that the air intervening between it and his apparatus would produce an absorption equivalent to that of all the air between us and the sun and at different heights of the sun above the horizon. Then we find him making, in a sense, the reverse experiment—diminishing sufficiently the action of the interposed air until the bands under examination are no longer visible.

The study of gaseous spectra was carried on very extensively by Janssen. He examined at his spectroscope the light from a source producing a continuous spectrum after this light had traversed tubes containing gases under various pressures and temperatures. His laboratory, situated in the old stables of the chateau at Meudon, allowed him to use tubes reaching a length of 60 meters. His researches related chiefly to oxygen. By varying the pressure of the gas in the tube he could at will make the absorption lines of oxygen disappear, especially the line B. His experiments showed that certain absorption lines—B, for instance—always appeared when the product of the length of the tube by the pressure of the gas reached a certain value.

The experiments upon the absorption lines of oxygen led Janssen to a remarkable phenomenon which required repetition with the perfected means at the disposal of modern physics. He discovered that, besides the telluric rays, the absorption spectrum of oxygen showed, under certain conditions, a system of bands difficult to resolve into lines, and whose production was ruled by an entirely different law than that stated above for the telluric lines. These bands appear when the product of the length of the tube by the square of the pressure reaches a certain value. This law had a remarkable confirmation when Olszewski studied the spectrum of liquid oxygen. It was found that the bands of Janssen appeared when the layer of liquid oxygen reached a thickness which the law of the square of the pressure would require. Janssen confirmed his law in yet another

manner. He calculated that when the height of the sun above the horizon is less than 4 degrees the thickness of the layer of air traversed by the solar rays would be sufficient to produce these lines. And so he went to the Desert of Sahara in order to observe the sun under these conditions and noted the presence of these bands when the sun had reached precisely this altitude of 4 degrees.

This remarkable law must have an importance for the theory of molecular physics which has not yet been sufficiently appreciated.

In his researches at the laboratory of Meudon, Janssen was not content with trying the effect of the variation of the length and pressure of his column of gas traversed by the light; he also raised the gas to high temperatures in order to approach somewhat the conditions as they exist in the sun. By electrical means, very remarkable for the time when they were devised, Janssen was able to raise his gas to a temperature of 900° C. No new phenomenon appeared at that temperature, but the visibility of the absorption bands was somewhat increased.

The absorption produced by water vapor also was studied at Meudon. Already at the beginning of his spectroscopic studies in 1867, Janssen had observed the absorption spectrum of water vapor by causing the luminous rays to pass through a tube 37 meters long filled with this vapor. This remarkable experiment, made at the gas manufactory of Vilette, allowed Janssen to recognize the principal lines due to the absorption of water vapor. This research was taken up under better conditions and with better apparatus at the laboratory at Meudon in 1887.

The object of this study of the spectrum of water vapor was to find out whether it exists in the atmospheres of the planets. This question, which is of capital importance to astronomers, always very greatly interested Janssen. In 1867 on Mount Etna, and then in 1869 on the Himalaya Mountains, Janssen observed the spectrum of Mars to see whether he could detect in its spectrum the principal lines due to the presence of water vapor. To that end he compared the spectrum of Mars and the moon when these two bodies were at the same altitude above the horizon. Janssen concluded from his observations that the spectrum of Mars gave plain evidence of the presence of the vapor of water in the atmosphere of that planet and he considered this evidence sufficiently decisive to maintain these conclusions when, in 1895, Campbell announced that the great instruments of the Lick Observatory would not show to him the trace of any water vapor on Mars. And now, very recently, Mr. Slipher, of the Lowell Observatory, has obtained photographs in which the lines due to water vapor appear more intense in the spectrum of Mars than in that of the moon. This seems to support Janssen's conclusions.

Let us return to Janssen's researches on oxygen. After his laboratory studies of the conditions relating to the production of these absorption bands of oxygen, Janssen wished to obtain them by interposing between the luminous source and the observer a column of air sufficiently long to produce them. In 1889 the Eiffel tower had just been constructed and a great electric light placed at the summit could be turned toward the observatory at Meudon, and furthermore the distance between the tower and the observatory was 7.7 kilometers, so that the light, before reaching the observatory, traversed a column of air exactly equivalent, so far as its absorption goes, to our own atmosphere. These conditions produced the lines of the absorption spectrum of oxygen of exactly the same intensity as in the solar spectrum and brought a new confirmation of the exclusively terrestrial origin of these bands.

This experiment of the tower of Eiffel is practically a repetition of another ingenious one made by Janssen, about 1864, on the shores of Lake Geneva. A large wood fire was kindled at Nyon upon one of the banks of the lake; although close-to the spectrum of this fire appeared continuous, yet it showed, when observed at Geneva, at a distance from the fire of 21 kilometers, the telluric rays, including those of water vapor.

We have already said that Janssen was not content with having produced artificially by one method the absorption lines of water vapor; he wished to make the reverse experiment and assure himself that as we go higher and higher up in the atmosphere the telluric lines tend to disappear; that is to say, in proportion as we decrease the layer of air interposed between the sun and the observer. It was with this object in mind that Janssen undertook several mountain ascents; that of Faulhorn first, in 1864, then the Pic du Midi, and more recently of Mount Blanc. In the first ascent of the Grands Mulets, in 1888, he demonstrated clearly that the lines of the group B were less intense at an altitude of 3,000 meters than at Meudon, and in the ascent to the summit in 1893 and 1895 he believed that the last doublet of the B group had disappeared completely. His lameness made this mountain climbing particularly difficult, as in order to reach the summit of Mount Blanc he had to be carried along either on a litter or on a sledge. From these expeditions to Mount Blanc Janssen came back convinced that an observatory built on the very summit of this famous peak would render important service to science and help to solve many problems of astronomy, meteorology, and physiology. The astronomer ascending to this altitude would be free from what has been called by some one "atmospheric mud," and the light from the stars would appear less deviated and diffuse; the meteorologist, placed in the very bosom of the atmosphere, could

snatch the secrets of the formation of the clouds; and finally, the physiologist, in this elevated laboratory, could study the conditions of life where the atmospheric pressure had become one-half that at the ordinary level.

When this observatory at Mount Blanc had been decided upon it required no common strength of purpose in Janssen to carry out the project. By his convincing words he succeeded in gathering together the necessary money and then braving his critics he fearlessly built his structure upon the snow on the very top of Mount Blanc, overlooking from that culminating point all the surrounding Alps. Perhaps it is in this project of the creation of the observatory of Mount Blanc that we get the best measure of the energy, the tenacity of purpose, and the audacity of which Janssen was capable. And it was indeed concerning the realization of this project that he said, "I have always thought that there are very few difficulties which can not be surmounted by a will strong enough or by study sufficiently profound." During the last years of his life Janssen had for this observatory on Mount Blanc the solicitude of a father for the child. Each year he took delight in giving advice to those observers who proposed to ascend this giant of the Alps for the purpose of some new research; he organized the expeditions even to the smallest details, aided in this task by both Mme. and Mlle. Janssen.

Janssen was an enthusiast of the mountains and never ceased to praise their benefits. He loved to repeat to the mountain climbers that phrase of our great physicist, Foucault, "The mountain makes the man, the city destroys him."

We have seen the train of thought which led Janssen to observe eclipses of the sun, to carry out his laboratory researches, to analyze at high altitudes the light of the sun, to study the absorption produced by the gases of the sun and by our own atmosphere. But beyond the limits of these studies Janssen took interest in other questions which brought with them the opportunity of satisfying his taste for long voyages. In 1874 and in 1882 he was in charge of the parties sent by France to observe the transits of Venus over the sun's disk. For the study of this phenomenon the idea occurred to him of using a revolving photographic plate. With this instrument could be obtained a series of photographs separated by short intervals of time, so that the precise moment of the contact of Venus with the solar disk could be told. This revolving photograph was the precursor of the apparatus of M. Marey for the study of the movements of animals, and it is upon its principle that the motion pictures of to-day are made.

The study of volcanoes, and especially the spectrum analysis of the gases which escape from the craters, attracted the attention of

Janssen and was the cause of voyages to Santorin, to the Azores, to the Sandwich Islands, and finally to Mount Vesuvius.

Oftentimes these voyages were utilized for the determination of the magnetic elements of the earth. Indeed, his first scientific expedition had for its object the determination of the magnetic equator in Peru; then later he made, in the Azores, magnetic observations for geological purposes, and to him also we owe the determination of the magnetic equator in India and the neighboring island of Malacca.

But all these voyages were not enough to use up his energy. Between whiles he founded, in 1874, the Observatory of Meudon, and apart from the observations on the absorption spectra of gases, of which we have already spoken, he was busy with applications of photography, notably to the solar disk. Janssen was one of the first to foresee the services which the photographic plate could render in the observatory, and he tersely indicated the rôle which it would play in the science of observation when he said that it would be the "true retina of the scientist."

Assisted first by M. Arents, and then by M. Pasteur, he obtained at Meudon the remarkable series of solar photographs of which the more characteristic ones have been embodied in an atlas which is a true monument to the history of the sun. These photographs were made especially for the study of the character of the solar surface and show most delicate details of the photosphere. Examining them closely, Janssen found that the solar surface has a peculiar texture, to which he gave the name photospheric "reseau." The existence of this reseau was at first attributed to real displacements of the granulated structure of the photosphere, but later it seemed more probable that the cause must be looked for in the irregular refractions produced perhaps by our own atmosphere but possibly by the gases surrounding the sun itself.

Photography has always occupied a place of honor at the Observatory of Meudon, and, not content with the qualitative results which it had hitherto given, Janssen wished to make use of it for quantitative observations. And so we owe to him numerous photographic photometric researches and, notably, the determination of the relative brilliancy of the sun and the stars. He was one of the first to make use of out-of-focus stellar disks for photometric measures. Janssen had a predilection for photography which embraced all the application of this science and of which he gave proof by accepting the invitations to preside over numerous reunions and congresses of photographic societies.

Janssen was above all an observer and man of action. He did not allow himself to be tempted by the desire of giving his name to a

theory of the sun. He knew that it is more useful to gather together observations than to build theories upon facts insufficiently demonstrated. But we must not conclude that the mind of Janssen was indifferent to speculation. In a number of his writings is found a depth of reasoning which gives evidence of his care in going to the very roots of matters.

Born in 1824, Janssen did not devote himself completely to science until toward 1860, at the age of 36, but his scientific career was, nevertheless, as long as that of many scientists, for he retained until late all his faculties for work and died on the 23d of last December, after having reached his eighty-fourth year.

THE RETURN OF HALLEY'S COMET.[a]

[With 4 plates.]

By W. W. CAMPBELL.

A celestial event of unusual interest is expected soon—the return of Halley's comet. Its appearance will be welcomed as the coming of a faithful friend, whose visits to the sun's domains have repeated themselves every seventy-seven years since long before the time of Christ. Any day may bring the news that this object has been rediscovered, near the northern edge of the constellation Orion; but we are really not expecting the announcement until the last third of 1909. The comet will be faint when first seen, for we know quite closely where to look, and the most powerful photographic telescopes in several countries are periodically "prospecting" the critical region.

Why is this comet known as Halley's? The incidents connected with its christening form an interesting chapter in the early history of astronomy. A brilliant comet appeared in 1682, when Halley was a young man, in England. This was Halley's comet, but his name was not connected with it until much later, as we shall explain. Halley's friend, the great Sir Isaac Newton, had but recently (about 1670–1680) discovered the law of gravitation, and had proved that a comet or other body completely subject to the sun's attraction must move in an ellipse around the sun. Newton was of a retiring disposition and took no steps to make known his immortal discoveries. Halley, on the contrary, was a man of action. These characteristics of the two men are apparent from their portraits. The manuscript copy of Newton's Principia was intrusted to Halley, and the latter, in the absence of other funds available for the purpose, published the book in 1686, at his own expense, though he was a man of small financial means. This act alone stamps Halley as worthy of our homage.

Halley realized the wonderful import of the great law, certainly as early as 1685, but his opportunity for systematic work in astron-

[a] Reprinted by permission from Publications of the Astronomical Society of the Pacific, San Francisco. Vol. 21, No. 128. October, 1909.

omy did not come until 1704, when he was appointed professor of geometry at Oxford. He immediately began the study of comets, basing his studies upon Newton's law. He became the first great calculator of comet orbits. In a little more than a year he had twenty-four to his credit; orbits of all the comets, in fact, for which he could find accurate observations. This meant prodigious labor, in those days, for the good observations and the highly developed methods of our time were unknown. He found that three comets out of the twenty-four had traveled from distant space, around the sun, and out into distant space, along the same path, whereas the other twenty-one had each a different path. Were these three comets one and the same body? If so, their common orbit must be an ellipse. The crude observations of the sixteenth and seventeenth centuries did not permit him to decide whether the orbit was a long ellipse or a parabola (a curve extending out to an infinitely great distance). If the latter, the three comets would have traveled away from our solar system never to return. If they were the same body, they should have returned at about equal intervals of time; and this is what did occur, for the dates when the three comets had been nearest to the sun were August 24, 1531; October 16, 1607 (interval, 76.2 years); September 4, 1682 (interval, 74.9 years).

The small inequality of intervals he correctly attributed to the disturbing attractions of the planets Jupiter and Saturn. He predicted that the great comet would complete another revolution in its orbit in seventy-five or seventy-six years and reappear about 1758. He said that he could not predict the time more accurately, for the effects of Jupiter's and Saturn's disturbing attractions were not yet computed. Halley (born 1656, died 1742) knew that he would not live to witness the return, but he confidently and patriotically called upon posterity to remember that this prediction had been made by an Englishman—"ab homine Anglo."

The comet did return in March, 1759. It was a little later than expected because of the disturbing attractions of the planets Uranus and Neptune, which had not yet been discovered, and whose influence upon the comet's orbit, therefore, could not be taken into account. This was indeed a great triumph in exact science, made possible by Newton's overwhelming genius and Halley's vigor. It is easy to predict the returns of comets in the twentieth century, but this is so because Newton and Halley lived and labored as pioneers.

Halley's comet reappeared in 1835, within a few days of the predicted time. It is due to be again "in perihelion," i. e., nearest to the sun, in the first half of April, 1910. The comet, though invisible, is at present (April, 1909) much closer to us than Jupiter is, and slowly drawing nearer to the sun. When we may expect to see it

without telescopic assistance and how bright it will be at maximum are too uncertain for prediction. Certainly for a few months in the first half of 1910 it should be a conspicuous object. Comets brighten and develop their tails as they approach the sun, reaching their greatest development when in or near perihelion. For this reason it is their unfortunate practice to disappear from view in the sun's glare just when they are largest, and Halley's comet will be out of sight for a few days while it is passing on the other side of the sun, probably in March, 1910. We should see it at its best just after perihelion passage.

The history of this most famous of comets prior to Halley's first date, 1531, has been traced by three able English astronomers, Hind, Cowell, and Crommelin, as far back as B. C. 240. In all, twenty-nine appearances recorded in history have been identified. These have occurred at average intervals of seventy-six and three-quarters years. The individual values of the intervals have varied between seventy-four and a half and seventy-nine years, according as the disturbing actions of the planets combined to shorten or to lengthen the period.

There are extant several quaint pictorial representations at many of its early returns. An especially interesting one, though of minimum scientific value is for the return in 1066—the year of William the Conqueror's invasion—as preserved in the famous Bayeux tapestry. Sir John Herschel's drawing is probably our best record of its appearance at the 1835 return. Fortunately we now have photography to make permanent records of both its general and its detailed structure. The dry plate puts down details which the eye can not see, and it does the work with great accuracy. Since Barnard's pioneer success in the photography of comets at the Lick Observatory, about 1890, no one seriously attempts to "draw" a comet. An inspection of the two photographs of comet Morehouse, just visible to the naked eye in the fall of 1908, will show the richness of structural detail, none of which could be seen in any existing telescope.

The long elliptical orbit of Halley's comet and the nearly circular orbits of the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune are represented in the figure—approximately to the correct scale; but it should be said that the plane of the comet's orbit makes an angle of 18° with the earth's orbit plane. The comet's orbit therefore passes "through" the planetary orbits like the two adjacent links of a chain. The comet will approach within 56,000,000 miles of the sun, and then recede during thirty-eight years until it is far beyond Neptune's path. In perihelion it must travel 34 miles per second, but at the outer turning its speed will be less than 1 mile a second. (See fig. 1.)

For purposes of description, it has been found convenient to divide the structure of a comet into three parts, as follows:

1. The densest and brightest part near the center of the head, called "the nucleus." Nearly all the mass of a typical comet resides in the nucleus.

2. The coma, or envelope, of low density surrounding the nucleus. In occasional comets the head consists entirely of coma without an apparent nucleus.

3. The tail, which always points approximately away from the sun. When the comet is traveling toward the sun the tail follows the head; when the comet is going away from the sun the tail precedes the head. This is illustrated in the drawing of the comet's orbit.

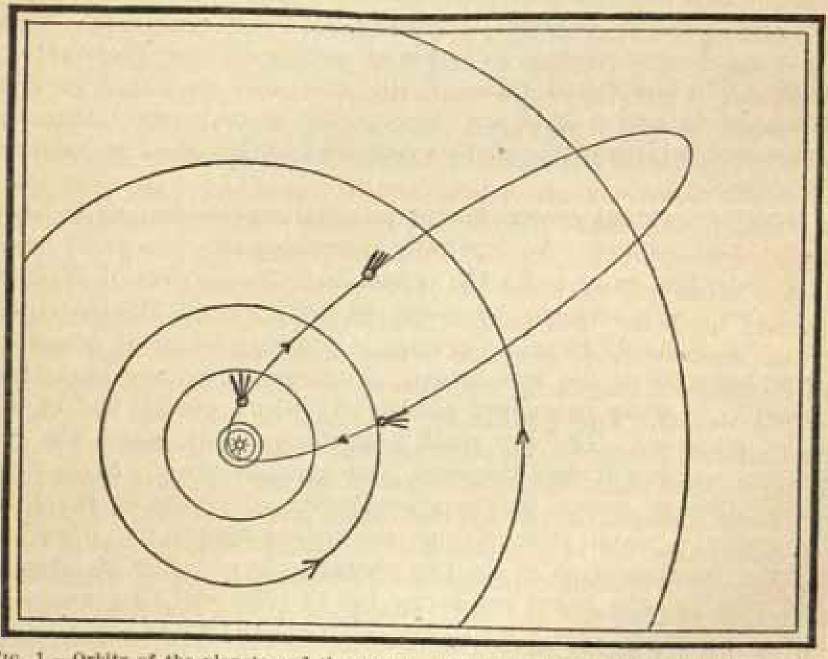


FIG. 1.—Orbits of the planets and the comet. (The smallest circle is the earth's orbit.)

The fact that a comet's tail always points away from the sun was early recognized. There could be no doubt that some force originating in the sun was repellent to the materials composing the tail; but to determine the nature of this force defied us for generations.

Since the coming of photography and the accurate recording of details of comet structure utterly invisible to the eye, it has been possible to measure these motions. Comparisons of photographs of the same comet made two or three hours apart have shown that condensations and other structural forms have moved rapidly outward during the interval; only a few miles per second at first, but faster and faster as the distance out in the tail increased. Some observed speeds have been nearly 50 miles per second. Fifty miles per second

is more than 4,000,000 miles per day. If such motions exist, the constituents of the tail on one night are not the constituents of the tail of the following nights. Photographs of many comets taken on certain nights seem to bear no resemblance to those taken on the preceding or following night. The tails of the earlier dates have been driven off into space, scattered into invisibility, and entirely new tails have taken their places. The forces acting outwardly from the sun and responsible for these expulsions were mysterious, and it is only within the last ten years that a fairly satisfactory theory has been established. Half a century ago the great physicist, Clerk-Maxwell, in developing the electro-magnetic theory of light, deduced mathematically that the so-called light and heat waves, in striking upon any object, exert a pressure upon that object, very much as ocean waves falling upon the cliffs press against the obstructing rocks. The pressure due to light and heat waves, called radiation pressure, is extremely slight; so slight, in fact, that skilled experimenters were unable to detect its existence for many years. At last, about the year 1900, a Russian physicist, Lebedew, was able to observe this effect; and a few months later two American physicists, Nichols and Hull, were even more successful, for their accurate observations showed a satisfactory agreement with the demands of Maxwell's theory.

Almost immediately the famous Swedish scientist, Arrhenius, expressed his belief that in this pressure of the sun's heat and light waves we have the force which forms comets' tails. All the materials of a comet are necessarily attracted by the sun, according to the law of gravitation. There can be no doubt that they are also acted upon by radiation pressure. The former seeks to draw all into the sun, the latter to drive them into outer space. These are opposing forces. On the more massive parts of a comet, comprising the nucleus, radiation pressure is ineffective; and the nucleus moves along in its prescribed curve with remarkable precision. Not so with the finely divided materials of the coma and tail. Gravity acts as a function of a particle's mass, whereas radiation pressure's action is dependent upon the surface-area of a particle in relation to its mass. As particles become smaller and smaller a size will be reached such that these opposing forces will be precisely balanced. Particles larger than these will be drawn nearer to the sun. Particles smaller will recede from the sun.

What seems to take place in a comet is something like this: Minute particles of solid matter or molecules of gas are expelled from the nucleus chiefly on the side toward the sun, probably under the influence of the sun's heat. Radiation pressure acts upon these particles to turn them directly away from the sun; and the cloud of particles thus projected forms the tail. As the repellant forces act continuously, the particles must travel continuously faster; and this is the

observed fact. Smaller and less dense particles must travel more rapidly than the larger and denser ones.

The constant expulsion of matter along the tail into outer space must of necessity cause a comet to grow smaller. Disintegration is continuous, and the tail at any moment is made up of materials lost forever from the nucleus. Several faint comets moving around the sun in small orbits have been observed to be fainter at each successive return. Some have even disappeared entirely. Two such comets, now lost to view, reveal themselves only by virtue of meteor showers about the middle of August and the middle of November; the matter composing their nuclei has been scattered along their orbits, and the annual passing of the earth across these orbits leads to collisions between the cometary fragments and our higher atmosphere. There is no reason to doubt that Halley's comet is slowly disintegrating, and, after long ages, will suffer some such fate.

Our knowledge of the chemical composition of comets and of the state in which cometary matter exists is meager and unsatisfactory. A few give spectra very like that of our own sun, indicating that they are shining by reflected sunlight, as the planets shine. Other comets send out their own light, almost exclusively, the radiations coming chiefly from carbon and cyanogen sources. Still others have mixed spectra, showing both inherent light and reflected light. Why comets shine by virtue of light within themselves is a mystery, for it is difficult to conceive that such attenuated bodies should have the heat of incandescence throughout their mass. Although many comets have volumes thousands of times as great as the sun's volume, their total mass is insignificant even in comparison with that of the earth; and such mass as they have is nearly all in the nucleus. The tails are surely less dense than the most perfect vacuum we can produce in the laboratory.

Halley's comet is due to pass near the earth in May, 1910, perhaps within 10,000,000 miles of us. Let no one draw the inference that there may be a dangerous collision with the earth, for such is not the case. Their paths are too widely separated. Even if the path of the comet were entirely unknown, we could say that the chance of a collision with the denser nucleus is so small as not to call for consideration. And if we should pass through the tail there would be no evidence of such an encounter, unless it consist of a harmless meteor shower, for the tails of comets are certainly composed of exceedingly minute and widely scattered particles.

The ancients thought of comets as hairy objects, from the appearance of the tails; hence the origin of the term "comet," from the Greek kometes, signifying "long-haired." This belief prevailed certainly up to Halley's day and generation.

All sorts of fantastic and fearsome ideas have attached to comets, from early historical times to near the close of the nineteenth century. The writer remembers clearly that his neighbors of thirty years ago considered comets to be messengers of disaster. The greatest comet of the nineteenth century, Donati's, of 1858, was the accredited forerunner of our civil war. Medieval representations of comets as flaming swords were common. (See fig. 2.)

In Homer's Iliad, XIX, 381, we read:

> Like the red star, that from his flaming hair
> Shakes down disease, pestilence, and war.

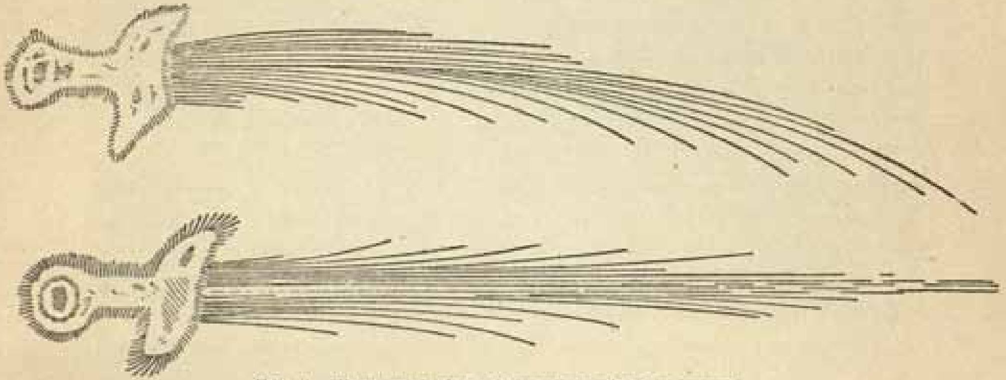


FIG. 2.—Representation of comets as flaming swords.

From Evelyn's Diary of 1624:

> * * * the effect of that comet, 1618, still working in the prodigious revolutions now beginning in Europe, especially in Germany.

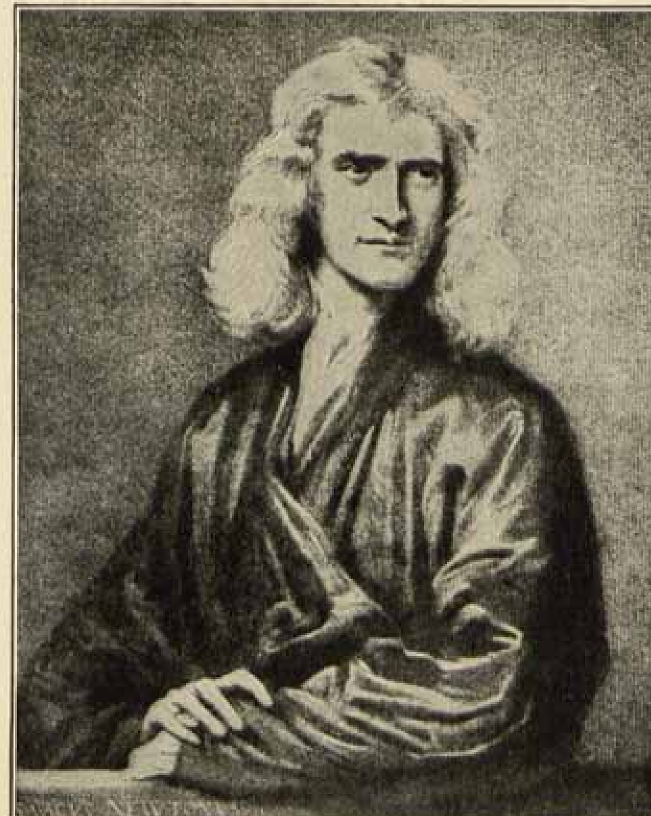
From Milton's Paradise Lost, II, 708–711:

> * * * and like a comet burn'd,
> That fires the length of Ophiuchus huge
> In th' Arctic sky, and from his horrid hair
> Shakes pestilence and war.

Not the least of the services of science to civilization has been the gradual emancipation of humanity from all fear of comets.

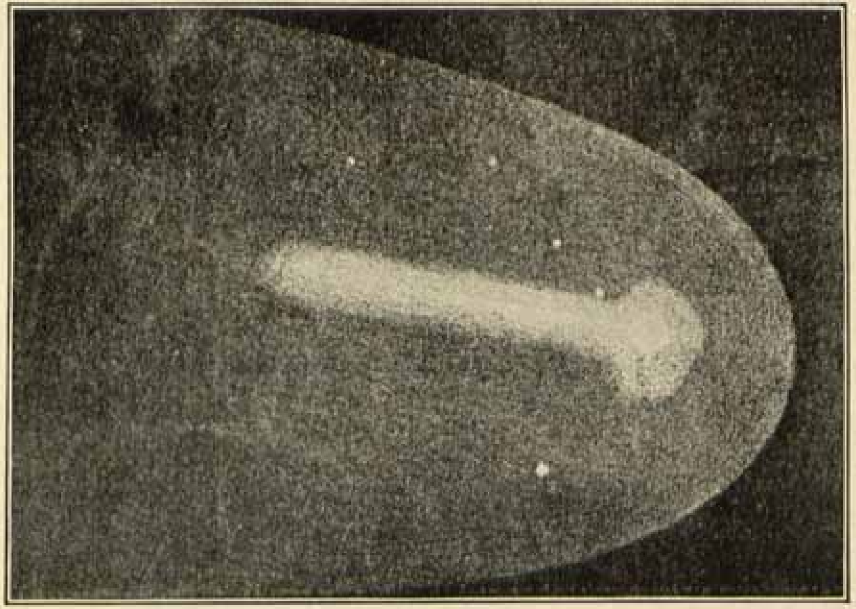
Astronomers will welcome the coming of Halley's comet, full of hope that the photo-dry-plate, the spectroscope, and other ways and means of attack invented since its last visit in 1835 will enable them to remove something of the mystery of comets, the most mysterious of all celestial bodies.

EDMUND HALLEY.



SIR ISAAC NEWTON.

HALLEY'S COMET IN 1066, ON THE BAYEUX TAPESTRY.



HALLEY'S COMET IN 1835.

(By Sir John Herschel.)

COMET MOREHOUSE, PHOTOGRAPHED AT LICK OBSERVATORY, NOVEMBER 18, 1908.

THE UPPER AIR.[a]

By E. Gold and W. A. Harwood.

The past decade has been very fruitful in the investigation of the upper air. By the use of kites sufficient results have been obtained to furnish a tolerably complete knowledge of the variation in the meteorological elements up to a height of 2 kilometers, while registering balloons have furnished information regarding the distribution of temperature up to heights of 15 to 20 kilometers. The results of the Berlin manned balloon ascents were arranged and discussed very fully ten years ago, but no such comprehensive discussion of the much more numerous kite and registering balloon ascents has yet been attempted. The present report deals with the instruments and methods of investigation, and with the results for temperature and for wind.[b]

The most important series of the earlier ascents with manned balloons was that made by Glaisher in 1860–1870. Unfortunately he was led to believe that artificial ventilation of the thermometers was unnecessary, with the result that his observations at great altitudes are untrustworthy. In the series of ascents made from Berlin in 1888–1895 observations made with careful ventilation proved beyond doubt that large errors would arise in the absence of proper ventilation, and that Glaisher's results were almost certainly affected by such errors.

[a] Report on the present state of our knowledge of the upper atmosphere as obtained by the use of kites, balloons, and pilot balloons. Report of the committee, consisting of Messrs. E. Gold and W. A. Harwood, presented at the Winnipeg meeting of the British Association, 1909. Reprinted by permission from Nature, London, No. 2089, vol. 82, Nov. 11, 1909.

[b] The full report of the committee is printed in an octavo pamphlet of 54 pages, with diagrams and tabulated observations, and gives an interesting historical review of the upper atmosphere investigations since 1784.

The following table shows the nature of the errors, and incidentally furnishes a comparison with one of the earlier ballon-sonde ascents:

Height (meters).	Fall of temperature °C per 1,000 meters.		July 31, 1901.	
	Glaisher.	Berson.	Berson and Süring.	Ballon-sonde.
0-1000	7.5	5.0	7.2	8.3
1000-2000	6.5	5.0	6.8	6.1
2000-3000	5.0	5.4	3.7	4.2
3000-4000	4.2	5.3	5.2	5.1
4000-5000	3.8	6.4	7.4	5.7
5000-6000	3.2	6.9	5.5	6.3
6000-7000	3.0	6.6	7.2	4.7
7000-8000	2.0	7.0	7.2	7.6
8000-9000	1.8	9.0	3.6	7.1

Temperature observations in manned balloons are now usually taken with an Assmann's aspirator, in which a ventilating current of about 4 m. p. s. is forced by a fan through a polished tube containing the thermometer and screening it from radiation.

The instruments used with registering balloons are of two types. In the large type the record is made on a metal or photographic sheet, covered with lampblack, and wrapped round a revolving cylinder driven by a clock. Pressure, temperature, and humidity are recorded by separate pens. The barometer is a Bourdon tube or an aneroid, the thermometer some form of bimetallic instrument, and the hygrometer a bundle of hairs. In the small type the temperature record is traced on a cylinder or plate, which is itself moved at right angles to the direction of motion of the temperature lever by the changes of pressure. The temperature and pressure are then given by the ordinates and abscissæ of the trace obtained. The advantage of this arrangement is that no clock is required, and the instrument can be made much lighter and is more easily tested. The loss of the humidity trace is unimportant, because the hygrometric records at low temperatures are very untrustworthy, and the observations in the lower layers can be made with kites or manned balloons.

The instruments used with kites are similar to the ballon-sonde instruments of the larger type, but they have an arrangement for recording wind velocity. In the Dines instrument the records are traced on a flat, circular sheet of cardboard rotated by means of a clock and resting on a wooden tray beneath which the instruments are placed.

The ballon-sonde instruments are tested either (1) by keeping the thermometer at ordinary atmospheric pressure in testing for temperature and the barometer at ordinary temperatures in testing for pres-

sures, or (2) by testing the thermometer through the temperature range at different pressures and the barometer through the pressure range at different temperatures. The second is, of course, the more desirable plan, but the difficulties involved in applying it to the larger type of instrument are so considerable that the former method is generally adopted where such instruments are used. The simplicity of the smaller type of instrument devised by Dines enables the second method to be adopted in testing it without elaborate and expensive apparatus.

Temperature records obtained simultaneously with different instruments show differences which, in the mean, do not exceed 1° C., and the temperatures may, in general, be taken to be correct to this degree of accuracy, but lagging of the instruments makes it doubtful if in all cases the recorded temperatures and heights actually correspond.

In dealing with the observations it is found convenient to express temperatures in degrees centigrade above the absolute zero, —273° C. on the ordinary scale. Where necessary the letter A is used to characterize this scale. Atmospheric temperatures, both at the surface and in the upper air, lie almost always between 200° A and 300° A, so that the 2 may be dropped without risk of confusion. Gradients of temperature are expressed in degrees centigrade per kilometer, and are reckoned + when temperature decreases upward.

The mean value of the gradient up to 3 kilometers is as follows:

	Degrees.
From the Berlin manned balloon ascents, 1888–1897	5.1
From the Berlin manned balloon ascents, 1897–1907	4.8
From the Berlin and Lindenberg kite ascents	4.7
Calculated by Hann from mountain observations	5.7

It follows from these results that the mountains are colder than the free atmosphere at the same height, and maney observers have verified this fact by direct comparison. Shaw and Dines found that in July, 1902, the temperature on Ben Nevis was 2.6° C. below that of the free atmosphere at the same height to the west of the mountain. Schmauss found that the temperature on Zugspitze (nearly 3,000 meters), which lies on the northern edge of a mountainous region, was continually lower than that of the free atmosphere, but was higher than that at the same height on Sonnblick, which lies in the middle of the Alps.

It was pointed out by Von Bezold that increase of temperature on a mountain is limited by convection, whereas no immediate limit is set in this way to cooling. There is a one-sidedness in the heat exchange between the mountain surface and the atmosphere which would tend to produce the result found by observation. Moreover, convection always tends to raise the temperature of the upper air above what it would be otherwise, and in addition the cold of winter is, as it were, stored up in the snow, while no such process holds for

the warmth of summer. Both conditions are probably effective in increasing the temperature difference. The most important deduction to be made from the results is that the mountains are not cold because the upper air is cooled by convection, but they are cooled by their radiation to space.

The mean values of the gradients up to 15 kilometers, found from registering balloon ascents at ten European stations and for St. Louis, Mo., are given in the table:

Height.	Gradient.		Height.	Gradient.	
	Europe.	St. Louis.		Europe.	St. Louis.
Km.			*Km.*		
0-1	3.6	5.1	8-9	6.8	7.4
1-2	4.3	5.3	9-10	5.0	6.7
2-3	5.2	4.7	10-11	3.3	5.5
3-4	5.8	5.2	11-12	0.7	2.9
4-5	6.3	5.9	12-13	−0.8	1.4
5-6	6.8	6.2	13-14	0.0	0.6
6-7	7.2	7.8	14-15	−0.1	−0.9
7-8	7.4	8.7			

The maximum value occurs in the layer 7 to 8 kilometers, and its magnitude indicates that the effect of radiation is to leave practically unchanged the natural gradient in air in vertical motion. Gold showed that in the upper layers absorption exceeded radiation and in the lower layers radiation exceeded absorption, and both processes would diminish the temperature gradient. At an intermediate stage absorption and radiation must balance, and the results indicate that this is the case at a height of 7 to 8 kilometers. The temperature at different heights up to 15 kilometers shows practically no variation for the ten European stations, except in the case of Pavlovsk, where the temperature is uniformly lower up to 10 kilometers and higher above 10 kilometers than at the other stations. The difference of temperature between Strassburg and Pavlovsk, taken to represent latitude 50° and latitude 60°, respectively, is sufficient to produce a gradient of pressure at a height of 10 kilometers which would correspond to a steady west wind of about 24 m. p. s. (54 miles per hour). The difference between Strassburg and St. Louis (representing latitude 39°) would at the same height correspond to a steady west wind of 15 m. p. s. in intermediate latitudes. The observations are not sufficiently extensive to warrant much stress being laid on the absolute values of these velocities, but it is of interest to note that the approximate ratio of the west winds in latitudes 45°, 55°, deduced from Oberbeck's solution by a purely theoretical treatment of the problem of the general circulation, is 16/21 for the upper strata, a result in tolerable agreement with the ratio of 15/24 deduced from the temperature observations.

The problem of the vertical distribution of temperature in cyclones and anticyclones depends for its solution on upper-air observations. Hann deduced from the temperatures at high-level observatories that cyclones were colder than anticyclones, the mean difference of temperature up to 3.5 kilometers being as much as 5° C. Grenander found similar results by a consideration of the kite and balloon ascents at Hald and Berlin, while Von Bezold deduced from the Berlin manned balloon ascents that the relative coldness of the cyclone was maintained even up to 8 kilometers.

The results in the present report, obtained by taking only those cases in which the sea-level pressure exceeded 770 millimeters or was less than 750 millimeters, and correcting the observations for seasonal and local variations, showed that the cyclone was colder than the anticyclone up to 9 kilometers, while at greater heights the conditions were reversed, and the anticyclone became much colder than the cyclone; but the effect of the temperature difference in the lower layers on the pressure difference is so considerable that even at 14 kilometers the pressure gradient is not reversed. In these circumstances it is difficult to see how air can be brought into the anticyclonic and out of the cyclonic regions in the upper air. The cirrus observations imply a definite outward motion over cyclonic regions, but a rotation in the same direction as at the surface, which can be the case only if the gradient of pressure is also in the same direction as at the surface. These results imply that there is motion across the isobars from the lower to the higher pressure. Now, although it is possible for such motion to exist if the velocity in the cyclonic region exceeds a certain value, or, in the anticyclonic region, lies between certain limits, it is not possible to have steady motion of this type, and the effect of damping would be to make the motion from the higher to the lower pressure. The evidence points to the conclusion either (1) that cyclones and anticyclones arriving in the European area are in general dissipating systems which are continually replaced by other systems arriving from what may be called productive regions, or (2) that there is interchange of air with regions in which the surface temperature or the temperature gradient differs sufficiently to produce mean temperatures greater in low-pressure areas and less in high-pressure areas than are found over Europe.

It is interesting in connection with this part of the subject to note that Shaw and Lempfert deduced from a discussion of surface air currents that the central areas of anticyclones were not the regions of origin of currents, and could not, therefore, be places where descent of air was taking place to any considerable extent. The temperature observations in the first 3 kilometers agree with this conclusion, since they show that there is no approach to a regular adiabatic gradient near the centers of anticyclones.

Perhaps the most remarkable phenomenon revealed by the observations from registering balloons is the comparatively sudden cessation of the fall of temperature at a height which varies from day to day, but is roughly equal to 10 kilometers. Above this height, which may be regarded as the height of an irregular, but roughly horizontal, surface dividing the atmosphere into two regions, the temperature at any time varies very little in a vertical direction, showing, on the average, a slight tendency to increase. The lower and upper regions are characterized by the terms "convective" and "advective," respectively, and the height and temperature of the dividing surfaces are denoted by H_c and T_c. The following table gives the values of H_c, T_c, for certain places in Europe:

	Mean of 13 stations.	Munich.	England.	Strassburg.	Paris.	Pavlovsk.	Koutchino.	Milan.	Vienna.	Berlin.
H_c	10.6	10.9	10.8	10.8	10.4	9.6	10.6	10.7	10.2	10.7
T_c	16°	16°	18°	15°	18°	18°	14°	17°	15°	16°
Number of cases	336	53	32	67	57	28	18	25	24	32
Latitude	—	48°	52°	49°	49°	60°	56°	45°	48°	52°

There is very little variation for places between latitude 45° and latitude 55°, but at Pavlovsk H_c is about 1 kilometer below the average. Observations made in the equatorial regions show that the value of H_c there exceeds 15 kilometers, so that there must be a considerable increase in its value in crossing the limit of the trade-wind region, and it appears probable that the equatorial currents and the trade winds form a closed system with little interchange of air with higher latitudes.

The annual variation in H_c, T_c is shown by the following table:

Annual variation in H_c.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean of 13 stations	10.3	10.4	9.1	10.1	10.5	10.7	10.9	11.4	10.4	11.9	10.8	10.1
Number of cases	26	22	32	39	31	27	24	61	46	38	25	25
Munich	10.0	10.4	9.2	9.2	11.2	11.0	11.7	12.0	10.3	12.3	11.8	11.4
Number of cases	4	3	6	4	2	4	3	11	5	5	2	5
Strassburg	10.5	10.6	9.4	9.4	10.6	10.9	10.8	12.3	10.9	11.9	11.0	11.1
Number of cases	5	5	5	5	4	5	4	9	8	6	6	5

Annual variation in T_c.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean of 13 stations	13	11	16	16	17	20	20	18	22	14	15	14
Munich	14	10	16	19	25	20	15	16	26	9	10	17
Strassburg	11	10	18	20	17	17	21	15	23	13	12	10

The remarkable feature is the relatively high temperature and low value of H_c in March and September. This peculiarity and the fact that T_c is least near the equator suggest that the general nature of the process may be as follows. The cool air above the equator moves polewards, and in the natural course descends again to feed the trade winds. Owing to the irregularities of the earth's surface, the change of seasons, and the very considerable difference between the northern and southern hemispheres, the process will be neither regular nor symmetrical. Consequently, the equatorial cold air will encroach on the advective region of temperate latitudes, and such encroachments will produce anticyclonic regions. The advective atmosphere would be reached there at a higher level, and initially at a lower temperature than in the average state, but the temperature would be gradually raised by absorption of thermal radiation to the normal value for that latitude.

The fact that H_c has minimum values in March and September, when equatorial temperatures are highest, appears at first to be contrary to this view; but the first effect of increased temperature will be to increase the strength of the trade winds, and as at the same time there is a transference of air across the equator to the southern hemisphere, a transference which can be made only through the upper return current, there will be a deficiency of descending air, and the equatorial cold air will encroach less than usual on the northern advective region. The reverse process would be expected to occur in September, but the autumnal transference of air to the northern hemisphere will be initially much more intense toward the great continental regions than to the Atlantic and European area, and it may well be that the equatorial current again encroaches less than usual on that region. It may be expected that the value of H_c in Asia and America will not show the September minimum.

The explanation of the discontinuity in the temperature gradient appears to be this. The fall of temperature is governed mainly by convection, and a necessary condition for convection to persist is that the radiation shall exceed the absorption in the upper layers of the convective system. A limit is therefore set to the height to which convection can extend, and at this limit the discontinuity in the fall of temperature occurs. It has been shown that the observed height is about the same as the limiting height of the convective system found from theoretical considerations based on the experimental knowledge of the radiating power of the atmosphere.

The results of the observations of wind velocity may be briefly summarized as follows: In general, the velocity increases with height, the greater part of the increase up to 2,000 meters taking place in the layers immediately above the surface; 75 per cent of the total increase takes place in the first 160 meters. Above 500 meters numerous cases

occur where the velocity decreases with height. The velocity for heights up to 10 kilometers is given approximately by the equation $V\rho = V_0\rho_0$ (Egnell's law), where V is velocity and ρ density, $V_0\rho_0$ being the values near the surface. The law implies that the pressure gradient remains constant and independent of the height. Now, owing to the fact that the temperature is higher over regions of high pressure than over regions of low pressure, the ratio of pressure gradient to density increases with height. The condition for a constant gradient up to 8 kilometers is approximately

$$t_0 = \frac{74\,\delta p}{p} \text{ degrees C.},$$

where t_0 is the excess of the mean temperature of the air-column at a place at pressure $p+\delta p$ above that at a place at pressure p. Observations show that for $\delta p = 20$ millimeters, $t_0 = 4°$ C. nearly, or double the amount necessary for constant gradient. It is to be expected, therefore, that $V\rho$ will increase up to 8 kilometers, and the few pilot-balloon observations available point to such an increase.

The direction of the upper wind usually veers from that at the surface. The following table shows the deviations for winds from different quadrants in England and at Berlin:

Deviation of the upper wind.

ENGLAND.

Direction.	Heights.					
	0.5 km.	1.0 km.	1.5 km.	2.0 km.	2.5 km.	3.0 km.
	°	°	°	°	°	°
West	9	14	14.5	14	8	8
North	4	8	3	−1	−3	−15
East	15	22	20	28	35	21
South	14	26	32	38	41	50

BERLIN.

Direction.	0.5 km.	1.0 km.	1.5 km.	2.0 km.	2.5 km.	3.0 km.
	°	°	°	°	°	°
West	18	23	23	20	23	22
North	13	17	20	20	15	25
East	27	30	38	45	46	44
South	38	46	48	49	53	46

The deviation at Berlin is in nearly all cases greater than in England, especially for north winds, which back slightly in the upper air in England.

There is no marked difference between anticyclonic and cyclonic conditions in the change of wind velocity and direction with height.

The following table gives the values deduced from observations at Berlin and Lindenberg in 1905:

	Height.		
	Surface.	1 km.	2 km.
Anticyclonic (A):			
Deviation	....	30°	33°
Velocity	4.1	8.2	[a] 8.4
Ratio to surface velocity	1.0	2.0	2.05
Cyclonic (C):			
Deviation	....	30°	37°
Velocity	5.9	10.5	10.7
Ratio to surface velocity	1.0	1.78	1.82

[a] M. p. s.

The deviation is slightly greater and the ratio slightly less in C than in A. It would be natural to suppose that surface friction and irregularities would produce a decrease in velocity which increased at a greater rate than the velocity itself, and in that case the ratio in C would be greater than in A, as was actually found by Berson from the manned-balloon observations.

THE FORMATION, GROWTH, AND HABIT OF CRYSTALS.[a]

By Paul Gaubert, D. Sc.,
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A crystal arouses the interest of the observer not only by the regularity of its forms, the perfection of its surfaces and angles, its transparency, and its brilliancy, but also by the manner in which it grows, heals its wounds, is dissolved, and modified under the influence of the inclosing medium. To some authors the crystal, from certain points of view, appears analogous to living forms, and seems to undergo a sort of evolution.

Its formation, its growth, the variations of the faces under the influence of the inclosing medium, have been the object of numerous researches which have greatly modified our conceptions regarding them. The purpose of this article is to show the present state of our knowledge concerning these diverse and interesting questions of crystallogeny.

I.

As early as the seventeenth century Leeuwenhoek, who examined under the microscope everything that in his time lent itself to this line of observation, followed the formation and growth of the crystals of various substances (as sugar, tartar, sea salt, etc.). He was led to conclude that the cubic crystals of sea salt are formed of other minute cubes, themselves made up from cubes, the existence of which one has to accept through analogy with what is seen, since they are invisible under any magnifying power. Later, Baker, Ledermüller, and others also examined under the microscope the branched and varied forms that appear when a substance crystallizes on a sheet of glass; but it is to Nicholas Le Blanc that we owe the first systematic and effective researches in crystal genesis, and particularly in the variation of the form. In his very interesting work "De la Cristallotechnie" he gives methods for the preparation of crystals, and in particular does he set forth the process of renewing the solution,

[a] Translated by permission from Revue Scientifique, Paris, 48th year, No. 3, January 15, 1910.

of "feeding" the growing solids that they may attain a relatively considerable size.

In what form do we see the crystal with the aid of the highest magnifying power? Does it present from the first the form that it will have later? The biologists were the first to take up the matter of the formation of the crystalline "germ;" that is, of the form which it presents at the instant when it first becomes visible; and most of them have admitted the existence of an embryonic state, or a state in which the constitution and form are different from that of the crystal properly called; although this idea has been contradicted by Frankenheim, to whom we owe numerous crystallogenic observations. Vogelsang, in 1867, took it up again and made numerous ingenious and varied experiments to show its correctness. His observations are generally exact, but he has unfortunately misinterpreted them. To show the embryonic state of the crystal, Vogelsang tried to make the bodies crystallize under special conditions with the purpose of retarding their formation so as to enable him to observe all the steps of development. With this purpose in view he added to a sulphur solution a viscous body, Canada balsam. There were produced little spheres, to which Vogelsang gave the name of globulites, and which were thought to represent an embryonic stage. These globulites unite to form particular groups, each of which has received a special name, and at the expense of which the crystal would be produced only at a later stage.

Moreover, Vogelsang rests his experimental researches on observations made with crystallites of varied forms existing in a few rocks rich in silica and more or less vitreous, and in the slags of blast furnaces; but as was later shown by M. O. Lehmann, who made numerous researches on the formation of crystals, these globulites are but drops supersaturated with sulphur, and consequently have nothing in common with the crystalline state.

Brame, as well as Vogelsang, studied sulphur, but in a molten condition. He observed little supermelted drops (utricules) to which he attributes a considerable rôle in crystallization. His ideas differ from those of Vogelsang, but nothing in his experiments substantiates the existence of an embryonic state.

The observations of M. O. Lehmann have shown that the crystal possesses from the beginning a form identical with that which it has when it has attained larger dimensions. T. V. Richard and E. H. Archibald have employed the cinematograph to follow out the formation of the crystal, and obtained only figures of completely formed individuals.

I myself have made a great many experiments, and have always found that the first visible particle had all the properties of the crystal. It is, nevertheless, not to be disputed that in some cases

there takes place what Vogelsang and his predecessors have observed with sulphur or other bodies, but who worked with supersaturated drops or amorphous particles, or little spherulites of unstable form, which later underwent modifications into more stable forms, and the normal development of which can then be followed.

Nevertheless, in spite of the observations of Frankenheim, O. Lehmann, and others, the idea of the embryonic state of the crystal has not disappeared from science, and the hypothesis of Vogelsang, supported by De Schoen, Cartaud, and others, resting on misinterpreted observations, still finds some credit.

II.

When the crystal is once formed—that is, becomes visible under the microscope—how does it grow? Several cases may be presented: First, the mother liquid is in a state of rest, the cooling or evaporation is extremely slow, and the crystalline particles are built up by diffusion alone. In this case the growth is too slow to be constantly followed under the microscope. In the second case the liquid is cooled or evaporated with such rapidity that the quantity of matter deposited on the crystal produces an enlargement microscopically visible. Movements in the liquid are thereby set up. It is an established fact that currents called "currents of concentration" passing over a crystal, deposit a thin coating of substance, followed by a second, and so on, until, for example, one can see on a crystal of lead nitrate, having a diameter of half a millimeter, as many as twelve of these successive layers deposited. If the process were suddenly interrupted and the crystal examined any observed face would not be a plane, but would show a sort of step arrangement, of which the highest step would indicate the point of contact of the current of deposition.

These successive deposits have no interspaces and the crystal may be perfectly transparent. If the crystal of lead nitrate is, however, subjected to the influence of two or of several currents of concentration, the corresponding coatings laid upon it start from different points in the periphery and may not be of the same thickness. Ordinarily they do not join exactly at their point of meeting. In this way are then produced inclusions and the crystal is no longer transparent, but becomes milky. On a glass plate it is easy to produce at will a transparent or milky crystal of lead nitrate. In the experiment it is necessary to agitate the crystal very slightly with a needle in order to subject it to the influence of one or several currents.

These concentration currents produce other peculiarities (vicinal faces, etc.), which it would take too long to describe in detail. I shall confine myself to calling attention to the influence they may

have upon the faces of the crystal. The introduction of matter to one face only of a crystal causes it to develop unequally, and since all crystals of the same bath or magma are not influenced in the same way, they may present a number of different forms. The crystals formed at the bottom may be different from those which are deposited on the side walls or at the surface.

III.

If these concentration currents can completely change the habit of a crystal by producing elongation in one direction, the nature of the faces is not modified; an octahedral crystal always appears in octahedrons. But there are two other influences which modify the faces. One of them is the rapidity of crystallization, the other the constant absorption of foreign matter by the crystal in process of growth. Still other factors may intervene, but they are only indirectly concerned.

It has long been known that crystals formed rapidly possess simple faces, while those which have grown slowly are more complicated. Thus in nature the crystals rich in inclusions, sometimes of large size, are poor in faces, while the small crystals of the same substance, but transparent, are generally limited by a large number of faces. These differences are due to the rate of crystallization, the influence of which has been made known by the experiments of Frankenheim, Lecoq de Bosbaudran, O. Lehmann, and myself. In rapid crystallization the crystals have faces with simple symbols; in slow crystallization these same simple faces persist, but the angles and edges have been truncated and beveled, giving rise to new facets, and I have shown that in certain cases these facets make their appearance always in the same order. With varying rates of crystallization the dominant forms obtained in the case where the crystallization was rapid persist with more or less extensive development, but it may be otherwise in the case where the faces are modified by the regular absorption by the crystal during growth of foreign matter added to the mother liquor. This fact is easily made evident, as I have demonstrated, by adding a little coloring matter.

Rome de l'Isle and Berniard have observed that the crystals of sodium chloride formed in urine are regular octahedrons instead of cubes, such as crystallize from a pure mother liquor. Vanquelin and Fourcroy showed later that this curious modification is due to the urea present. Boydant also established a few phenomena of the same class, and tried without success to ascertain why the mere presence of a foreign substance can be thus effective.

P. Curie developed a remarkable and attractive theory, which apparently furnished the key to this curious modification. He

claims that the capillary action existing between the liquid and the crystal intervenes, an effect varying with the nature of the faces belonging to the diverse forms and with the nature of the liquid. Basing his belief on Gauss's theory of capillarity, he concludes that such faces develop or require the minimum expenditure of capillary energy. The dominant forms must consequently be conditioned by those faces the constant capillarity of which is the least. The addition of a foreign substance altering the different capillary constants may consequently induce modifications of form.

It appears, indeed, that the capillary forces must act, but up to this time there is no fact known which proves that they intervene sufficiently to modify the forms, in spite of the experiments of M. Berent carried out in the laboratory of Sohncke; moreover, I shall describe later an observation showing they are without influence.

IV.

The crystals of one substance rarely form synchronously with those of another dissolved in the same mother liquid, and it is on this property that chemists base their action when they attempt to purify bodies by repeated crystallizations; but there are exceptions, as in the well-known coloration of hydrated nitrate of strontium by extract of logwood, which was accomplished by Senarmont. Since then M. Lehmann and I have proved a few other cases of coloration of crystals by artificial organic dyes.

By making use of the artificial coloration of crystals so as to indicate the presence of foreign matter which has crystallized with the colorless substance I have been enabled to show that the absorption caused modification in form.

The absorption of foreign matter by crystals in process of formation is accomplished in two different ways: First, the coloring matter enters into the composition of the crystal, whatever may be its degree of dilution, and is shared between the crystal and the liquid; second, the coloring matter is taken up by the crystal only when the liquid becomes saturated.

The two processes may go on simultaneously. The study of certain properties of colored crystals, particularly polychroism, and the law of division, shows that the coloring substance in the first case is found in the crystal in the same state as in the liquid; in the second, on the contrary, the coloring matter is in the crystalline state, and we have to do then with a regular grouping of the crystalline particles of the colorless substance with those of the coloring material added to the mother liquor.

Lead nitrate is colored by methylene blue in the second manner; it appears in cubic crystals with the triglyphic striæ of pyrite in-

stead of in octahedrons. The modifications in the crystals of this salt produced in a mother liquor which holds methylene blue in solution, show that capillarity does not intervene to produce them. Indeed, in a solution depositing lead nitrate and saturated with methylene blue, without, however, giving crystals of this latter substance, the crystals of the nitrate are not at all modified. They are in octahedrons and colorless, but as soon as the coloring matter begins to crystallize synchronously with them the cube faces appear and finally are formed to the exclusion of all others. Nevertheless, the surface tension can not have been changed since the quantity of methylene blue has remained the same in solution. An interesting fact is the inequality of absorption of the foreign matter dissolved in the mother liquor by the different faces of the crystal. Thus, on the octahedral faces of the lead nitrate the methylene blue is not at all deposited, but only on the faces of the cube and the pentagonal dodecahedron. Similar examples can be cited which explain the appearance, frequent in minerals, known as hour-glass structure. In the case of cubic crystals, of all the possible faces it is only those which absorb the foreign matter which will develop.

The idea which first comes to mind is that the molecular structure of the crystal plays an important part in this synchronous crystallization. It is not so at all; different foreign substances may be absorbed by different faces, and in such cases the habit of the crystal is dependent on these diverse substances. If one causes the colorless substance to crystallize in a solution containing two colors, each one giving characteristic forms, the crystallizations thus obtained will be the two combined forms, so that one and the same crystal is composed of pyramids or of prisms of different colors. Thus the crystals of urea nitrate colored by methylene blue and picric acid show, if the crystallization has been carefully conducted, yellow triangular prisms corresponding to the faces g' and h', and blue triangular prisms corresponding to the prismatic faces m of the monoclinic system.

Not only may foreign crystalline matter be absorbed but also the liquid matter added to the mother liquid, and even the molecules of the latter may also pass regularly into the crystal to modify its form. I have been able to show this fact by crystallizing phthalic acid in a solution containing ethyl alcohol.[a] This explains why a crystal obtained from different solvents may show different faces.

Consequently a crystal, very pure in appearance, transparent, and without inclusions, may contain foreign matter, and in the case where

[a] To show this, it is enough to take a colored liquid, but with the exception of bromine there is no liquid which has a proper color at the ordinary temperature.

it is the mother liquid which is absorbed its purification is impossible. The solvent must be changed.

When the crystals of a determined substance obtained from two different solutions do not present the same forms, it is incontrovertible that in one of the cases, perhaps in both cases, since we do not always know the form of the pure crystal, there has been absorption of the molecules of the mother liquor. Sometimes it is the water which is absorbed, and this water has been regarded as water of crystallization or as water of constitution, according to the temperature at which it is driven off.

When purification is attempted by recrystallization, if the foreign substance which passes into the crystal is present in small quantities in the mother liquid, the first or the last crystals formed, according to the mode of synchronous crystallization, will be the purest. In case there is a division of the foreign matter between the crystal and the liquid, if the coefficient of its solubility in the crystal and the liquid are known, the number of crystallizations demanded for the purification of the crystals may be calculated under proper conditions.

V.

The natural crystals appear in such varied habits that before Romé de l'Isle no one could see the constancy of forms, and the genius of Hauy was necessary to establish their derivation. It is known that ordinarily the crystals of the same deposit and of the same generation are identical, and that those of successive deposits or generations may have different dominant forms. All these differences may be explained by the rapidity of crystallization, but especially by the constant presence of foreign substances. Unfortunately it is difficult to determine the nature of the latter, since the results of analyses made up to the present time have little value in solving this problem. Indeed, a very small quantity of matter is required to modify the forms of a crystal; sometimes an amount even less than one-one thousandth of the weight of the latter is sufficient.

In every case, whether we have to do with natural or artificial crystals, we need to determine their form in the pure state, a form which is constant and which I have called fundamental. It may be distinct from the primitive form chosen by crystallographers.

In closing, I shall observe that the substances prepared in laboratories seem rarely to show the numerous modifications of form, so frequent in the natural crystals. This is due to the fact that the artificial crystals are prepared almost always in the same manner, with the same reagents and consequently with the same foreign substances in the mother liquor. In nature, on the contrary, as the

analyses of mineral waters show, the composition of the solutions which deposit the crystals of a given substance varies from one region to another as much in the quality as in the quantity of the different elements dissolved. But all crystals do not lend themselves with the same facility to these modifications of the faces; and just as there exist in nature bodies like calcite which possess the most varied habits, there exist also artificial compounds, the crystals of which may appear in a great number of forms depending on the condition of crystallization, as, for example, phthalic acid, meconic acid, nitrate and oxalate of urea.

THE DISTRIBUTION OF THE ELEMENTS IN IGNEOUS ROCKS.[a]

By Henry S. Washington, New York, N. Y.

(Chattanooga meeting, October, 1908.)

I. INTRODUCTION.

During the last twenty years or so the chemical investigation of rocks has made great advances, and it is now generally recognized that a knowledge of the chemical composition is as essential as that of the texture or mineral composition, if not more so, for the proper classification of rocks and study of their origin and relationships. Rock analyses have vastly increased in numbers and, what is of greater importance, in quality. New and improved methods permit of greater accuracy than was possible in the early days, and the list of chemical constituents frequently determined has risen from the seven or eight of the greater part of the nineteenth century to twenty or more. Indeed, rock analyses with determinations of so many constitutents are now commonly made by the chemists of the United States and Australia, while in Germany, Great Britain, France, and Italy the rarer constituents are determined more frequently than formerly.

As a consequence of this modern, accurate work, it has been discovered that some elements which were formerly supposed to be rare are of widespread occurrence and are often present in considerable amount. The fact is further being developed that the elements tend to show certain relations of occurrence or abundance in connection with each other. This is a fact which is applicable to the rarer elements, and which also finds a broad geological and petrological expression in the recognition of petrographic provinces. We are beginning to obtain some definite, though as yet rudimentary, knowledge of the distribution of the elements among igneous rocks.

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[a] Reprinted by permission from Bi-Monthly Bulletin of the American Institute of Mining Engineers, New York, No. 23, September, 1908, pp. 809-838; also in Transactions, pp. 735-764.

Some of the results along these lines obtained by study of the vast accumulation of analytical data now available are well known to petrologists, while others do not seem to be so generally understood. To the nonpetrologist they are, naturally, mostly unknown, and, as the general principles involved, and, indeed, some of the specific instances, have a more or less important bearing on the occurrence and characters of certain deposits of metallic ores and other economically important minerals, a discussion of the subject may be of interest to mining engineers.

Indeed, to the observations and operations of mining engineers and mining interests generally, the petrologist is indebted and must look for some of his data. This is especially true of those relating to the precious metals and others of commercial importance, the amounts of which usually present in rocks are so small as almost or quite to defy detection by ordinary analytical methods, and whose presence is often revealed only through search for and the exploitation of localities where they have undergone concentration. It must be premised, however, that our knowledge is at present very uneven, allowing fairly safe and detailed generalizations as regards some of the elements, very rudimentary or general ones as regards others, and again allowing almost none at all.

II. GENERAL CHEMICAL COMPOSITION OF IGNEOUS ROCKS.

The first and most important fact to be noted of igneous rocks is that, with the exception of some rare ore bodies due to the differentiation of igneous magmas, they are composed almost wholly of silica and silicates. The vast majority of igneous rocks are silicate rocks, in which silica forms the most prominent and the never-failing constituent. Most of the minerals which compose them are combinations of silica with various bases, and it is a striking fact that the number of minerals which go to make up the majority of igneous rocks, and which are most abundant and most often met with, is very small.

The proportions in which these minerals may be present vary very widely. Some rocks are known which are composed wholly, or practically so, of but one mineral. Combinations of two are not infrequent, while most rocks contain at least three, and usually many more, minerals and in the most widely diverse proportions. It follows, therefore, that the chemical composition of igneous rocks may vary within very wide limits, as regards any or all of the chemical constituents; and that, furthermore, some rocks may be of very simple chemical composition while others may be very complex, with many constituents present, since the minerals themselves may be either very simple or highly complex in chemical composition.

The most important chemical constituents (stated as oxides, in accordance with the usual custom) are as follows: Silica, SiO_2; alumina, Al_2O_3; ferric oxide, Fe_2O_3; ferrous oxide, FeO; magnesia, MgO; lime, CaO; soda, Na_2O; potash, K_2O; and water, H_2O. Some or all of these major constituents, as they are termed, are invariably present, so far as known, and collectively they constitute about 98 per cent of all known rocks. The chief oxides, from silica to potash inclusive, enter into the composition of the most important and most commonly occurring rock-forming minerals, as well as the glass of imperfectly crystallized rocks.

The rôle of water is somewhat different. It would seem to be universally present in the magma, and its presence (along with that of other substances) lowers the freezing point and increases the tendency to crystallization of the liquid mass. Most of this water is lost if the magma reaches the surface and it appears in the enormous clouds which accompany volcanic eruptions and the steam of volcanic fumaroles; and much of it also escapes if the magma solidifies beneath the surface, giving rise to subterranean water supplies, which are held by many to be an important factor in the formation of many ore deposits. A small proportion of the water originally present may remain in the solidified rock in a combined form, as part of the more complex mineral molecules, those of pyroxenes, amphiboles, and micas, for instance; and some may also remain as inclusions of water in the minerals of intrusive rocks.

There are almost invariably present in igneous rocks small amounts of titanium, phosphorus, and manganese, though these are often neglected and thus overlooked in the less complete analyses. Carbon dioxide is also met with, but its presence, as reported in analyses of igneous rocks, is almost invariably due to decomposition, and it can not be usually regarded as an essential or original constituent of rocks.

In addition to these most important constituents the refinements and increasing completeness of modern rock analysis show that many others are frequently present, often in scarcely more than traces, but again in very appreciable quantities. The most important of these minor elements are zirconium, sulphur (as sulphides and as sulphur trioxide), chlorine, fluorine, vanadium, chromium, nickel, barium, strontium, and lithium. Exceptionally, others may be determined, as boron, cobalt, copper, gold, silver, molybdenum, the metals of the cerium and yttrium groups, nitrogen, and others. Indeed, as Doctor Hillebrand[a] says, "a sufficiently careful examination of these rocks would show them to contain all or nearly all the known elements, not necessarily all in a given rock, but many more than any one has

[a] Bulletin No. 305, U. S. Geological Survey, p. 20 (1907).

yet found." The researches of Sandberger, Stelzner, and Dieulafait also point to the same conclusion.

Considering the quantitative distribution of the major constituents, silica is almost invariably present in igneous rocks, and almost always in greatest amount. In general, the percentage may vary from nearly 80, as in granites and rhyolites, to a minimum of about 24 per cent. Indeed, it may even form 100 per cent, if some dikes consisting wholly of quartz are really of igneous origin, as is believed to be the case; while in some ores derived from igneous magmas the amount of silica may drop almost to zero. Alumina is usually the next most abundant constituent, the percentage varying from a maximum of about 60, as in some corundum-syenites of Siberia and Canada, to a minimum of zero in certain rocks composed wholly of olivine. The two iron oxides each show maxima of about 15 per cent, except in the rare iron ores due to magmatic differentiation, where they constitute together almost all the rock. Magnesia attains maxima of from 45 to 50 per cent in dunites of New Zealand and North Carolina; while lime reaches a maximum of about 20 per cent in the anorthosites of Canada. Iron, magnesia, and lime may be practically absent in highly siliceous rocks, like granites and rhyolites, and in some syenites. Soda may be present up to 17 per cent in some rare rocks in which nephelite is abundant; while potash attains a maximum of only about 12 per cent in some unusual rocks rich in leucite, which are found in Italy and in Wyoming. Both the alkalies may be wholly wanting in rocks composed essentially of pyroxene or olivine.

The amount of water present in wholly crystalline rocks seldom rises above 2 per cent, if the rock is unaltered, though weathering very materially increases this quantity, and high figures for water are usually to be attributed to this cause. But some perfectly fresh, glassy lavas may carry up to 12 per cent of water, which was unable to escape from the magma owing to the rapidity of solidification.

Titanium dioxide may rarely reach figures of about 6 per cent, as in some basalts of the western Mediterranean which I am now investigating, but is usually present in much less quantity, though it is seldom or never entirely absent. In some titaniferous iron ores of igneous origin, as those of the Adirondacks and Norway, it may even reach 18 per cent. The amount of phosphoric pentoxide is rarely over 3 per cent, and that of manganous oxide is scarcely ever above 1 per cent, the higher figures sometimes reported for this latter constituent being almost invariably due to errors of analysis. It is but seldom that either of these three is entirely absent.

The maximum amounts of the other minor constituents may be briefly stated, as attention will thus be called to their relatively great

rarity, it being understood that the maxima are seldom attained and that very frequently these elements are wholly absent.

Zirconium is much less common than the chemically related titanium, and seldom exceeds 0.20 per cent, though in some very exceptional cases it may reach 2 per cent. Chromium seldom occurs in amounts above 0.5 per cent, though a few rocks are known in which it is reported to range between 2 and 3 per cent. Nickel seldom exceeds 0.20 per cent, and the allied cobalt is scarcely ever present in more than mere traces. The maximum amount of copper found in unaltered igneous rocks may be placed at about 0.2 per cent of CuO. Barium almost always exceeds strontium in quantity, but only very exceptionally exceeds 0.25 per cent, though some rocks are known in which about 1 per cent is present; while the amount of strontium is usually much less than 0.1, but may occasionally reach 0.3 per cent in the rocks very high in barium. Although figures of 0.1 or 0.2 per cent have been reported for lithium, these are somewhat doubtful, and it seldom occurs in more than spectroscopic traces. Sulphur and chlorine may both be present up to 2 per cent or slightly more, but both usually occur only in tenths of a per cent, and the latter amount is the maximum for fluorine. Of the other minor constituents the amounts present are so small as usually to be insignificant except as to their actual presence.

III. THE AVERAGE COMPOSITION.

The estimation of the average composition of igneous rocks as a whole is not such a simple matter as may be thought at first, because of several complicating factors which should be taken into account, and certain corrections in some of our data which should be made, to obtain fairly satisfactory results. We are not yet in a position to make precise allowance for these, into the discussion of which we can not enter here, so that the results so far obtained can be regarded as but first approximations, only roughly correct, but of some value.

The most recent and reliable calculations are three made successively by Prof. F. W. Clarke, of the United States Geological Survey, two of the igneous rocks of the British Isles by Prof. A. Harker, of Cambridge, and one made by myself some years ago.[a]

Clarke's latest estimate is based on more than a thousand analyses of igneous rocks of the United States made by the chemists of the Geological Survey, and mine is based on about one thousand eight

[a] F. W. Clarke, Bulletin of the U. S. Geological Survey, No. 148, p. 12 (1897); No. 168, p. 14 (1900); No. 228, p. 18 (1904); A. Harker, Geological Magazine, vol. 36, p. 18 (1899); Tert. Ign. Rocks of Skye, p. 416 (1904); H. S. Washington, Professional Paper No. 14, U. S. Geological Survey, p. 108 (1903). I am at present engaged in new calculations of the average rock, based on more than three thousand analyses, but this is not yet ready for publication.

hundred analyses of igneous rocks from all parts of the globe and made by many analysts of various nationalities. These are shown, respectively, in columns I and II of Table I, only the more important constituents being considered and the whole being reduced to 100 per cent. Harker's estimates are omitted, but in general they conform to those here presented.

TABLE I.—*Average composition of igneous rocks.*

	I. United States, Clarke, 1904.	II. The world, Washington, 1903.	III. Complete average, Clarke, 1904.		IV. Clarke, 1904.
SiO_2	60.48	57.78	59.87	O	47.09
Al_2O_3	15.17	15.67	15.02	Si	28.23
Fe_2O_3	2.61	3.31	2.58+	Al	7.99
FeO	3.44	3.84	3.40+	Fe	4.46
MgO	4.10	3.81	4.06	Ca	3.43
CaO	4.84	5.18	4.79	Na	2.53
Na_2O	3.43	3.88	3.39	Mg	2.46
K_2O	2.96	3.13	2.93	K	2.44
H_2O (110°+)	1.48	1.42	1.46	Ti	.43
H_2O (110°−)	.41	.36	.40	H	17
TiO_2	.72	1.03	.72	C	14 −
P_2O_5	.26	.37	.26	P	.11
MnO	.10	.22	.10	S	.11
CO_2			.52−	Ba	.089
S			.11	Mn	.084
BaO			.11	Cl	.07 −
Cl			.07	Sr	.034
Cr_2O_3			.05−	Cr	.034−
SrO			.04	Zr	.026−
ZrO_2			.03−	Ni	.023−
NiO			.03−	F	.02 +
V_2O_3			.03−	V	.02 −
F			.02+	Li	.01
Li_2O			.01		
	100.00	100.00	100.00		100.00

It is evident that the two are very closely alike, the only noteworthy divergence being in the amount of silica. The higher figure in I may be ascribed in part, as pointed out by Clarke, to the inclusion of many separate silica determinations, which were undertaken on rocks comparatively high in this constituent; in part to the inclusion in the estimate of some analyses of siliceous gneisses and schists, rocks which were not regarded in my estimate; and probably in part to the fact that in Clarke's estimate only rocks from the United States were considered. But notwithstanding the slight discrepancies and the uncertainty introduced by nonallowance for the disturbing factors mentioned above, the results of the two calculations are so concordant that we may feel a high degree of confidence in the belief that the

data given here approximate closely to the average composition of the earth's accessible igneous rocks.

In column III are given the results of a more complete estimate by Clarke, which includes the minor constituents frequently present in igneous rocks, but which are only determined in the more complete analyses, as those made by the chemists of the United States Geological Survey. It will be seen that the data are in agreement with the general composition of the most common rock-forming minerals, their constituents, silica, alumina, ferric and ferrous oxides, magnesia, lime, soda, potash, and water, making up 97.9 per cent.

The estimated amount of carbon dioxide is undoubtedly too high, and is due to the number of analyses of altered rocks which were included in the estimates.

We may examine the matter further and, resolving the oxides into their elementary components, ascertain the average amounts of the elements in the igneous crust of the earth. This problem has been studied by Clarke in the papers already cited, and by Vogt[a] in Norway. The results of Clarke's latest calculations are given in column IV of Table I, the figures including those for the minor constituents of column III, just noticed. In an earlier computation Clarke introduced estimates of the elements which make up the air, the water of the oceans, and such nonigaeous rocks as limestone and coal. But the introduction of these into the calculation does not materially alter the final results from those given here, in which they are omitted, since these bodies are of relatively very slight quantitative importance compared with the whole mass of known rocks, however large they may loom to our eyes. Ore bodies also are quite negligible in this connection.

These data show that oxygen composes almost one-half, silicon more than one-quarter, and aluminum about one-twelfth of the earth's crust (the three together amounting to 83.3 per cent), while iron, calcium, sodium, magnesium, potassium, and titanium follow after in the order named in decreasingly small amounts. Thus, only nine elements together constitute 99 per cent of the igneous crust. This is certainly a very remarkable fact, and one doubtless of great significance for the proper understanding of the true constitution of our globe, could we but interpret it aright, as some day we may hope to do.

The relatively high position occupied by titanium, ninth on the list in the order of abundance, is also a striking feature, as this element is commonly supposed to be rare. The establishment of this fact is largely due to the accuracy and completeness of the rock analyses made by the chemists of the United States Geological Survey, and

[a] J. H. L. Vogt. Zeitschrift für praktische Geologie, pp. 225–238, 314–325 (July and September, 1898).

its great abundance was unsuspected before they began their long series of excellent analyses, though its wide distribution had been noted.

It is also noteworthy that, with the exception of iron, aluminum, manganese, and nickel, none of the metals commonly used as such appear in the list, while others, which are of very limited practical application, are present. While nearly, if not quite, all of the elements are presumably present in igneous rocks, the average amounts of those not given in the list are so extremely small that they may be regarded as minor corrections to be applied in the future to certain of those here given, since nearly all of them would be precipitated and weighed in the course of analysis with some of those more abundant.

In the important paper cited above, Vogt has discussed the probable amounts of these missing elements, and a brief statement of those of his results which pertain to the more important metallurgical elements may be given. The estimates, it must be premised, are but approximations, and only indicate the magnitude of the several amounts as percentages of the earth's crust. But they serve to show the average extremely small quantities of many metals and other elements which are usually regarded as quite common or at least not very rare.

The percentage amounts of tin, zinc, and lead are expressed by a digit in the third or fourth decimal place, that of copper in the fourth or fifth, that of silver in the sixth or seventh, that of gold in the seventh or eighth, the amount of platinum being about the same. Mercury is rather more abundant than silver, and arsenic, antimony, molybdenum, and tungsten less than copper and greater than silver; while bismuth, selenium, and tellurium are less abundant than silver but more so than gold.

III. PETROGRAPHIC PROVINCES.

More than thirty years ago Vogelsang[a] pointed out that the igneous rocks of certain districts—called by him geognostische Bezirke—showed certain textural or mineral characters in common, which served to distinguish them from the rocks of other districts. The same idea was expressed later by Judd,[b] who introduced the term petrographic province, and was afterwards elaborated by Iddings,[c] who likened the districts of similar rocks to families and referred to their relationships as "Consanguinity." Neither Judd nor Iddings

[a] H. Vogelsang, Zeitschrift der deutschen geologischen Gesellschaft, vol. 24, No. 3, p. 525 (May–July, 1872).

[b] J. W. Judd, Quarterly Journal of Geological Society, vol. 42, pt. 1, No. 165, p. 54 (Feb. 1, 1886).

[c] J. P. Iddings, Bulletin of the Philosophical Society of Washington, vol. 12, pp. 128–144 (1892).

seems to have been aware of Vogelsang's prior publication. The first two statements referred only to geological occurrence and to textural and mineralogical peculiarities; while Iddings, writing at a time when the chemistry of rocks had begun to assume its due prominence (largely owing to the earnest labors of the chemists of the United States Geological Survey), showed that the relationship is also indicated by the chemical composition of the various rocks, and is fundamentally dependent on this, and he consequently devotes much space to the chemical evidence of consanguinity.

The doctrine of consanguinty, as it may be termed, has now received general acceptance, and it is commonly recognized that the igneous areas of the earth's surface are divisible into districts the rocks of which show certain features in common which serve to distinguish them from those of other districts. It is also assumed that the possession of these common features, especially those dependent on the chemical composition, indicates that the rocks of a given district have a common genetic origin; that is, are derived from a common parent body of magma. The processes by which this differentiation and derivation from a common magma are brought about are still obscure, and form the subject of much modern investigation and discussion, into which we can not enter here. Such areas of related rocks are usually called petrographic provinces, though the term comagmatic region, which indicates more clearly their derivation from a common magma, has recently been introduced.[a]

Though petrographic provinces represent one of the prominent phases of the distribution of the elements in the earth's crust, and though their existence is, in general, undeniable, yet their characters are so complex and made up of so many factors that the characterization in most cases can not be made very precise or the limits very sharply drawn. Their study is still almost in its infancy, and the accumulation of many more data, especially from the analytical side, is needed before definitive studies can be undertaken, and the characters of any petrographic province be precisely defined.

The geological evidence of consanguinity is at times clear. Thus, as Iddings[b] says:

> The constant recurrence of particular series of rocks, often with a certain order of eruption in different localities, and the frequent occurrence of such series at neighboring centers of volcanic activity, would be enough to justify the belief that there was a definite connection between the members of a group.

On the other hand, cases are known where such geological evidence is lacking or conflicting, or where the relations are so generally observed as to be meaningless in this connection.

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[a] H. S. Washington, Carnegie Publication No. 57, p. 5 (1906).

[b] Loc. cit., p. 43.

Geologically speaking, a petrographic province may belong to any period of geologic time, or may conceivably extend over more than one period. The region may be small or large, covering hundreds or hundreds of thousands of square miles. It may be of any shape, forming an elongated band or zone, a highly irregular area, or one more or less equidimensional. It may consist of a single, large area of connected intrusive or effusive rocks, or of adjacent but isolated areas.

The chemical characters which, being common to the rocks of a province, indicate consanguinity are manifold. The rocks may be uniformly high in soda or in potash, or in potash and lime, low in magnesia and high in iron, generally deficient in silica, and so on. Throughout one province the soda may increase relatively to potash as silica decreases, while in another the reverse holds good. Or again, there may be some combination of such two kinds of characters, called respectively absolute and serial. The subject is complicated by the possibility of local differentiation, so that in a region of unquestionably related rocks we may meet with some whose characters do not conform to the general law of the region, but whose presence is to be explained by the extreme differentiation of some portion of the general magma.

Conforming to the chemical features, and in general largely dependent on them, are the common mineralogical characters. These are very important, not so much in themselves, as because they often enable one practically to determine the general relationship without the necessity of a long series of analyses. The mineralogical similarity may be evident in two ways: Either by the general presence of certain minerals which are rare or are not usually found in certain kinds of rock, as the rare zirconium minerals, or nephelite, or leucite, the occurrence of hypersthene in the basalts and andesites, or of biotite in peridotites; or by certain peculiarities of color, form, or other characters shown among the more usual mineral groups, and which are dependent on the introduction of certain chemical constituents into the molecule, as bright green, pleochroic augites or blue hornblendes, due to their containing much soda, purple augites or red-brown hornblendes, due to titanium, and so on. Here again the possibilities of difference are numerous, but the mineralogical evidence of relationship is often so marked as to be unmistakable to the petrographer.

A good illustration of such petrographic provinces and of their distribution is furnished by the United States, which may be briefly described, though our knowledge is still incomplete. Stretching along and rather close to the Atlantic coast is a zone of small, isolated areas of igneous rocks which are chiefly characterized by a high content in soda, resulting in the common presence of nephelite-syenites

and other rocks containing nephelite, peculiar hornblendes, and other minerals characteristic of such magmas. This zone includes areas in Quebec, New England, New Jersey, Arkansas, Texas, extends into eastern Mexico and the West Indies, and probably as far south as Brazil and Paraguay. Parallel with this, but usually farther inland, is a second zone of areas of rocks which are low in silica and the alkalies, but high in lime and iron. This starts in the great anorthosite area of eastern Canada and Labrador, appears in New England, the Adirondacks, Delaware, Maryland, and extends to Georgia and possibly farther south. The rocks of this region are typically gabbros, diabases, and pyroxenites, dunite and other peridotites, with some granites high in lime, and are often accompanied by very basic ores and other products of differentiation which are very rich in iron and titanium. Farther inland and west of the Appalachian Range is another belt, less well defined but apparently in general parallel to the others, of widely isolated small occurrences of peculiar peridotites and other rocks, low in silica and very high in magnesia and iron, with little lime or soda but much potash. This last feature gives rise to the common presence of peculiar micas, which distinguish these peridotites mineralogically from those of the preceding region. These areas occur in Quebec, New York, Pennsylvania, Kentucky, Arkansas, and probably still farther south.

Passing over the broad central part of the continent, where igneous rocks are very sparingly present, we find a province east of the Rocky Mountains which is characterized by high alkalies, especially potash, so that the usually rare mineral leucite is here quite common. This region is best known in Montana, Wyoming, and Colorado, and may possibly extend into western Texas. In the region of the Rocky Mountains and the cordilleras generally the occurrences of igneous rocks are so numerous and the relations so complex that it is somewhat difficult to unravel the various petrographic provinces. As a whole, however, the igneous rocks of this part of the continent seem to belong to one very extensive province, which is continued into Alaska on the north and along the Andes to the south. In general chemical character the rocks show rather low alkalies, with more soda than potash, rather high lime, and but moderate amounts of iron and magnesia, leading to the abundance of such ordinary rocks as feldspar-basalts, andesites, dacites, and some rhyolites. There is some evidence that the province as a whole may be divisible into several subordinate districts, but it is noteworthy that rocks so high in soda or potash as to contain nephelite or leucite are practically unknown west of the Rocky Mountains. There are also indications of what may be a distinct region along the coast ranges which is characterized by high soda and generally high silica, but this demands further investigation.

A number of petrographic provinces outside of the United States may also be briefly indicated. One of the best known is that of southern Norway, which is prominent through the classic researches of Brögger, the rocks of which are characterized by high alkalis, especially soda, and the presence of many minerals elsewhere rare. This is possibly connected with the region of the Kola peninsula in northern Finland. The British Islands, with the Faeroes, Iceland, and probably Spitzbergen, form another well-defined province, the rocks of which resemble on the whole those of our Rocky Mountain region, though they differ in some respects. Leaving aside Germany, Austria, and France, each of which contains several petrographic provinces, the relations of which appear to be somewhat complex, in the basin of the Mediterranean we find at least three well-defined and quite distinct provinces. In the eastern part, including the Grecian Archipelago and parts of Asia Minor, the rocks are rather siliceous, with fairly high lime and rather low alkalies, soda dominating potash, so that dacites, andesites, and feldspar basalts are prominent. Hypersthene is here rather common. The Italian peninsula shows a second, very well-defined province, which embraces seven distinct volcanic centers along the west coast. The rocks of this are remarkable for their high content in potash, which at times reaches extraordinary figures, and leads to the abundant presence here of the mineral leucite, which is elsewhere decidedly rare. Lime is also rather high, while soda, iron, and magnesia are low. The other provinces of continental Italy have not been thoroughly studied and are less well known. In the western basin of the Mediterranean, including localities in Spain, Sardinia, some islands south of Sicily, and probably southern France, there appears to be a third province, which differs from the others in that soda is much higher and the more basic rocks (basalts) contain very large amounts of titanium, and in other ways. This last may be connected with a province in eastern Africa, running down the Great Rift Valley and including parts of Madagascar, in which rocks rich in soda are very common. A somewhat similar province appears to exist in New South Wales and Queensland in Australia.

The descriptions just given, which are but the barest sketches of only some of those which are known, and with no reference to authorities, will serve to give an idea of some of the leading distinguishing features of petrographic provinces, and how multifariously they are scattered over the earth's surface. Their existence and distribution indicate clearly that the underlying magma basins, or the sources from which the igneous rocks are immediately derived, are not everywhere uniform and alike, but that there exists a certain heterogeneity in the nonsedimentary parts of the earth's crust. It should, however, be noted that two provinces, though widely separated, may

be essentially alike in all their features, as is the case with that of the eastern Mediterranean and that which extends from the Andes to Alaska.

IV. THE CORRELATION OF THE ELEMENTS.

The existence of petrographic provinces is a broad phase of the distribution of the elements among igneous rocks, the distribution being essentially a spacial one and the evidence resting almost entirely on the relative proportions of the most abundant elements. But apart from this spacial distribution there is evident, also, a correlated variation among the elements; that is, a tendency for certain ones to increase or decrease, to be relatively abundant or not, according to the presence or absence of others. The causes of this behavior are obscure and apparently complex. In part they may be probably referred to certain fundamental relations among the elements, as shown by the periodic classification and chemical affinity; in part to the effect of certain physico-chemical laws leading to the mutual segregation of elements affected similarly; and possibly in part to the degradation of some of the elements, as indicated by recent experiments by Ramsay. But any discussion of the causes is outside the province of this paper, in which we can only deal briefly with some of the facts of distribution.

The study of these mutual relations among the elements in igneous rocks is of recent date, and has been made possible, especially so far as the rarer elements go, only by the completeness and accuracy of modern chemical analyses of rocks. Such analyses supplement the evidence afforded by study of minerals, mineralogical associations, and ore deposits, and, dealing as they do with what must be regarded as the ultimate source of the ores, are of the highest significance and importance. In the following brief discussion, therefore, stress will be laid on the evidence afforded by rock analyses, with some reference to chemical mineralogy, while ore deposits, as being more technical and better known to the mining engineer, will be alluded to only occasionally.

Considering first only the most abundant elements, study of the igneous rocks in general shows that silica, alumina, soda, and potash tend to increase or decrease together, though not always at the same rate; while, on the other hand, the iron oxides, magnesia, and lime tend to vary together and in general inversely as the preceding constituents. The more siliceous rocks almost invariably show relatively high alumina and alkalies and low iron oxides, magnesia, and lime, leading to the common presence in abundance of the alkali feldspars and the comparative paucity in calcic feldspars and the ferromagnesian minerals, which tend to increase rapidly with diminution in the silica content. Highly siliceous rocks which contain

more iron, magnesia, and lime than alumina, soda, and potash are of very exceptional occurrence. The rule mentioned above is so generally true that it may be regarded as the normal one for igneous rocks in general, and is commonly accepted as such in petrology.

At the same time, there is considerable evidence that certain subsidiary relations obtain among the constituents other than silica, which, while by no means universal, are at times very pronounced, and occasionally seem to supersede the more general law. Thus, soda not uncommonly tends to vary with the iron oxides, while potash shows similar relations to magnesia, resulting in the presence of potassium minerals in highly magnesian rocks and the abundance of sodium minerals in those high in iron. Again, while neither iron nor magnesia shows any marked affinity toward or tendency to vary with alumina, this constituent and lime are occasionally found to occur together in great abundance and to the general exclusion of the others. These relations are also evident in certain facts of chemical mineralogy, as the usual predominance of magnesium over iron in the potassic biotites and phlogopites, the abundance of soda and absence of potash among the highly ferriferous augites and hornblendes, and the numerous silico-aluminates containing much calcium, while those with iron or magnesium are comparatively very rare.

But this tendency to selective and correlated variation among the chemical constituents of igneous rocks is not confined to those which are present in greatest amount. It is equally well, and indeed in some respects more strikingly, shown among the rarer elements, both as compared with those which are most abundant and with each other. Furthermore, the distribution of some of these rare elements would seem to have important bearings on some of the problems of economic geology and the distribution of ore deposits.

The general facts of this distribution and variation of the rare elements have been summarized in several recent publications,[a] but many of the details are still uncoordinated and widely scattered through the vast mass of petrographic literature, and there are certain aspects and recent developments which are either neglected, or only briefly alluded to, in the publications referred to.

It is now commonly understood that certain elements are prone to occur most often and in largest amounts in rocks which are high in silica, the so-called "acid" rocks; while others are met with similarly in those low in silica, the "basic" rocks. This is essentially the only set of relations recognized by Vogt, while De Launay in

[a] J. H. L. Vogt, Zeitschrift für praktische Geologie, p. 326 (September, 1898); J. F. Kemp, Ore Deposits, 3d edition, pp. 34-37 (1900); H. S. Washington, Manual of the Chemical Analysis of Rocks, p. 14 (1904); L. De Launay, La Science Géologique, p. 637 (1905); W. F. Hillebrand, Bulletin of the U. S. Geological Survey, No. 305, p. 21 (1907).

addition to these two groups proposes two others, the "mineralizing agents" and the vein metals.

Evidence, however, is accumulating that the relations of the rare elements to the igneous rocks can not be expressed so simply as is done by Vogt and De Launay. Their relative abundance is not dependent on the silica alone, and hence referable only to the "acidity" or "basicity" of the rock. The relations are more complex and dependent, not so much on the amount of silica, as on the relative amounts of other constituents, notably soda, potash, iron, magnesia, or lime. They conform, on the whole, to the general relations of the most abundant constituents, some of the rarer elements being characteristically at home in the rock groups which show high alumina and alkalies, and which include those high in silica; while others again are most abundant in the rocks high in iron, magnesia, or lime, and which consequently most often show low silica percentages. Further than this, on the one hand, certain rare elements are not equally at home in the alkalic rocks in general, but are most abundant either in those high in soda or in those high in potash. On the other hand, some of the elements segregated in the basic rocks seem to be most at home in those which are highly calcic, others in those which are high in iron or in magnesia, though here the evidence is not so clear and the distinctions apparently not so well marked as in the preceding case.

We may consider first those minor constituents of rocks which are determined in the most modern and complete analyses, and next those which exist in rocks in such small amount as almost to defy determination by the usual analytical methods, but whose presence is made known either mineralogically or by their segregation in ore deposits. The second group includes almost all of the commercially important metals (except iron and manganese), while the former includes many elements which are assuming an increased practical importance as their economic possibilities and uses become better known. In a general way the elements will be taken up in the order of their positions in the periodic classification. No references will be given, as an attempt to render them complete would unduly lengthen the paper. This course seems the more advisable, in spite of the apparent injustice to those whose invaluable work and contributions must thus be ignored, since the present paper may be considered as merely a preliminary one to a more exhaustive and monographic treatment which it is hoped to publish later.

Lithium is very widely distributed among igneous rocks, but always in very small amounts. While it frequently is to be detected by the spectroscope, it seldom occurs in weighable quantities, and the difficulty of its exact separation from the other alkali metals and its comparative unimportance cause it to be but seldom estimated quantita-

tively. Although such minute traces are present in both acid and basic rocks, yet it is undoubtedly more closely connected with those which are highly siliceous and alkalic. The minerals in which it forms an essential component, as spodumene, lepidolite, amblygonite, and some tourmalines, are most often met with in granites and pegmatites derived from granitic magmas. Unfortunately, the granites and pegmatites which carry lithium minerals most prominently do not appear to have been analyzed, but there is reason for the belief that they are sodic rather than potassic in general character. The very common association of lithium with soda rather than with potash in many minerals also points to the same conclusion.

Beryllium is much like lithium in its associations, beryl and other rarer minerals which contain it occurring for the most part in granites or pegmatites. Few analyses exist of such beryl-bearing rocks, and beryllia has seldom been estimated separately from alumina in rock analysis, but such data as are available and the common mineralogical association of beryllium and sodium point to the conclusion that the element is most at home in sodic magmas.

Attention may be called to the fact that beryl, in spite of its common occurrence, is not given in the list of descriptions of the rock-forming minerals, such as those in the standard works of Zirkel, Rosenbusch, and Iddings, though Lévy and Lacroix briefly described it in their work [a] and it is placed on their large colored table of birefringences. In its optical properties it closely resembles nephelite and apatite, and being hexagonal in crystallization as well, might readily be mistaken for one of these minerals. I have noted the fact that analyses of nephelite-syenites and other highly sodic rocks frequently show a decided excess of alumina which can not be explained by the apparent mineralogical composition of the rock, and the suggestion is made that this is possibly due to the presence of beryl, the beryllia of which would appear as alumina in the course of analysis, unless special means were taken to separate the two. On the other hand, the excess of alumina may be real and due to the composition of the magma.

Strontium has been shown by the analyses of the United States Geological Survey to be widely distributed in the rocks of this country. I have found it almost invariably when looked for in many European rocks, and it is almost constantly present in those of Australia. But it seldom occurs in more than traces, and the evidence in regard to its distribution is as yet inconclusive, in spite of the many modern analyses in which it is now determined, chiefly because of the small amounts usually met with. It would appear to be most abundant in rocks somewhat high in lime and with mod-

[a] Les Minéraux des Roches (Paris, 1888).

erate to rather low silica, though it is worthy of note that the highest figures recorded for it are in some rocks of Wyoming which are low in lime and extraordinarily high in potassium and barium. Being but rarely a constituent of silicate minerals, decisive evidence from this side is wanting, though it occurs with lime in some heulandite and brewsterite.

Barium is another element which the analyses of the Washington chemists showed to be widely distributed, and almost invariably in decidedly greater amounts than strontium. It is now often determined by analyses of superior quality, and in a recent study, embracing the rocks of Italy, the United States, and New South Wales, I have shown that it is specially prone to occur in potassic rocks, sometimes when the potash is accompanied by considerable lime, but that it is rarely met with in notable amount in decidedly sodic or calcic rocks. Neither the amount of silica nor the relative proportions of iron and magnesia appears to be a determining factor of much importance. This association of barium and potassium in igneous rocks is in harmony with the mineralogical evidence. Barium is a frequent minor constituent in potassium minerals, as orthoclase, muscovite, and biotite, while potassium accompanies barium in hyalophane and harmotome. On the other hand, barium is not reported in analyses of sodium minerals, but occurs in small amounts in the calcium zeolites, brewsterite, and phillipsite. Barium also seems to tend to associate with manganese, as shown by its common occurrence in psilomelane and the occurrence of minerals of the two metals in certain mines.

Boron is seldom or never mentioned in rock analyses, chiefly because of the complexity and difficulty of its exact determination, especially in very small amounts. But it is not infrequently present in weighable amounts in granites and pegmatites, chiefly as a constituent of tourmaline. The few analytical data that we have of such tourmaline-bearing rocks are not decisive, but boron does not appear to have very decided preferences for either soda or potash. Its associations in minerals are likewise not strongly marked, but among the silicates calcium is the basic element which most frequently accompanies it, and soda is more commonly met with in boron-bearing minerals than is potash. Boron is commonly regarded as one of the pneumatolytic elements.

Cerium, *yttrium*, and the other metals of the so-called "rare earths," as well as *thorium* and *uranium*, are only rarely determined in rock analysis. Minerals containing them are commonly associated with acid pegmatites, which, judging from occurrences in Norway, Greenland, and elsewhere, are most apt to be sodic, though the few determinations available of the rare earths are in highly potassic igneous rocks.

Titanium is, as we have seen, far from being the rare element which it was formerly considered, and it is probably never wholly absent from any rock. It is distinctly much more abundant in basic than in acid rocks, and its affinities in the magma seem to be decidedly rather with iron than with magnesium, and still less with lime. While it is not commonly associated with alkalic rocks, yet when these are low in silica it shows a tendency to be present in considerable amount when the rock is sodic, as indicated by recent rock analyses; and this tendency to association of titanium with sodium appears mineralogically, as in the soda-amphiboles, some of which are highly titaniferous, and in certain rare minerals, as astrophyllite and rosenbuschite. Highly potassic and highly calcic rocks seldom show large amounts of titanium, though most of the mineral titanates contain calcium as the base.

Zirconium, so closely allied to titanium chemically, also shows certain analogies in its magmatic relations. While unlike titanium in being rare in the basic rocks, those high in iron, magnesia, and lime, and referred by Vogt to the acid rocks, presumably because of the common occurrence of zircons in granites, it is now commonly recognized by petrographers that zirconium is by far most abundant in the rocks which are high in soda. Indeed, zirconium may be considered to be a characteristic minor chemical constituent of the sodic rocks, whether the silica be so high that quartz is present, or whether it be so low that nephelite is abundant, as in the nephelite-syenites and phonolites. Practically all modern, complete analyses bear out this view, which is confirmed by the common association of sodium and zirconium mineralogically, as in eudialyte, catapleiite, wöhlerite, and the zirconium pyroxenes.

Phosphorus, as a constituent of apatite, is universally diffused in small amounts through igneous rocks, and is most abundant in the basic ones, though its relations to the constituents other than silica are not clear. Study of large collections of analyses indicates that it is usually, but not always, associated with high lime, rather than with high iron or magnesia, and in some distinctly sodic provinces the more basic rocks with high soda and abundant nephelite show high figures for phosphorus pentoxide. Some of the phosphates are met with in granitic and syenitic pegmatites.

Vanadium has been shown by the researches of Hillebrand to be quite widely distributed, but always in very small amount and almost wholly confined to the basic rocks. As it exists as the sesquioxide, V_2O_3, replacing alumina and ferric oxide in ferromagnesian minerals, it is especially abundant in rocks composed largely of pyroxene, hornblende, or biotite, while it is present only in traces or not at all in rocks very rich in olivine, where the iron is present mostly as ferrous oxide, as in the peridotites. It is associated with

iron rather than with magnesium, and occurs in most abundance in some iron ores of magmatic origin, but no definite relations to the alkalies can be made out. Its common occurrence in ashes of coals and its abundance in certain carbonaceous deposits recently described are noteworthy, though outside the present discussion.

Sulphur is, by far, more abundant in the basic than in the siliceous rocks. It may exist, in the oxidized condition, in the minerals hauynite and noselyte, in which case the rocks containing these minerals are almost invariably distinctly sodic; or it may form sulphides, as pyrite, pyrrhotite, and chalcopyrite, these being most common in rocks rather high in iron, magnesia, and lime.

Chromium, like vanadium, is a constituent of the basic rocks, but, unlike this, is most abundant when magnesia and not iron is high, and when olivine, rather than pyroxene or hornblende, is abundant, in spite of the fact that it occurs as the sesquioxide, Cr_2O_3. Presumably this is because, instead of replacing alumina and ferric oxide in the ferromagnesian minerals, it is most commonly met with in the minerals chromite and picotite. It is reported to reach very high figures again in certain effusive rocks which are so high in lime and low in silica that the rare mineral melilite is present.

Molybdenum is seldom looked for in rock analysis, and our knowledge of its magmatic relations is based almost wholly on an investigation of Hillebrand. He found that it is much less common and is present in smaller quantity than vanadium, and that, unlike the latter, it is present only in the more siliceous rocks, though in quantities too small to permit of further discrimination. As molybdenite it occurs most often in quartzose rocks.

Fluorine is almost universally present in very small amount as a constituent of most apatites, and is usually regarded as a "mineralizing agent," and, as such, is frequently present in pneumatolytic minerals. As stated by Vogt, it seems to be more common in the acid rocks, but there seems to be a marked tendency on its part to favor especially rocks which are high in soda. This is seen in the fact that fluorite is frequently present as an original constituent of such highly sodic rocks as nephelite-syenite, phonolite, and tinguaite; the association of fluorine and sodium in certain rare minerals, as leucophanite, meliphanite, johnstrupite, rinkite, etc., which are almost always found in sodic rocks; and by the recent discovery by Lacroix of sodium fluoride in nephelite-syenites of West Africa.

Chlorine resembles fluorine in being a pneumatolytic constituent, and is present in igneous rocks chiefly in the minerals sodalite and noselite, which are almost wholly confined to sodic rocks and especially those which are low in silica, in this resembling the occurrence of SO_3.

Manganese, though as widely distributed as titanium and phosphorus, is usually present in such small amounts as not to allow a clear judgment of its magmatic relations, especially as the high figures often reported for it are apt to be due to analytical error. As a general rule, its amount is greater in the basic rocks, and certain considerations indicate a preference for rocks high in iron rather than in magnesia or lime, but the variations are not very significant. We have already noted above the tendency to association of barium and manganese.

Nickel is preeminently at home in the basic rocks, especially in the peridotites and serpentines, where it replaces iron in the olivine, while it likewise occurs in small amounts in hornblende, biotite, and in pyrite and pyrrhotite. Certain rather high figures reported for it may be ascribed to analytical confusion with platinum derived from the utensils employed; but researches now in progress indicate that it may be present in considerable amount (up to about 0.20 per cent), not only in the "basic" but in the more siliceous rocks of certain localities where its presence has not hitherto been suspected. It is reasonable to suppose that it is most apt to be present in rocks which are relatively high in iron rather than in maganesia and lime, and the results of the investigation just mentioned are in harmony with this supposition.

Cobalt almost always accompanies nickel in igneous rocks, but always in extremely small and scarcely weighable amounts.

The elements belonging to the next group to be discussed, those which are scarcely detectable in igneous rocks by the usual analytical methods on account of the excessively minute amounts usually present, need not detain us long, even though they are commercially among the most important. Since the analytical data are either very scanty, untrustworthy, or wanting altogether, and their presence is revealed to us mostly through secondary processes of concentration in veins, placers, and other ore deposits, we are not yet in a position to generalize with confidence as to the magmatic relations of most of them.

Furthermore, having but slight affinity for silica, and thus (with few exceptions) seldom forming silicates or entering as minor constituents into the silicate minerals of other elements, we are deprived to a very great extent of this kind of evidence.

Copper is not infrequently reported in analyses of igneous rocks, but, as pointed out by Hillebrand, its apparent presence may often be attributed to contamination during the course of analysis, or as may be suggested here, to confusion with platinum likewise due to contamination, as was suggested in the case of nickel. But notwithstanding these sources of error, copper seems to be widely distributed among igneous rocks, though in very small amounts. There seems

to be little doubt that it is most abundant in the more basic rocks, especially those which carry pyroxene and hornblende rather than olivine, but no evidence seems to exist as to its relations to the chemical constituents other than silica.

Silver and *gold* have both been detected analytically in igneous rocks, while metallic gold has also been observed as an apparently primary ingredient of some rhyolites and granites. Both of these metals are "cosmopolitan in their relations," as Kemp puts it, and they are known to occur in such highly siliceous rocks as granite, rhyolite, and quartz porphyry, and, on the other hand, in diabase and gabbro. There is, however, good reason for the belief that gold, and probably silver as well, are most apt to occur in rocks high in silica, but their relations to the other elements are still quite unknown.

Zinc and *cadmium* (which latter is found only in connection with the former) are also very uncertain. There is, however, some reason for thinking that zinc is more apt to be present in acid rocks, as granites, this opinion being based on a few analytical data and the facts of some of its occurrences. The common occurrence of zinc in limestones, due presumably, at least in part, to the precipitating effect of the sedimentary rock, has no apparent bearing on its relations to igneous magmas.

Mercury is considered by G. F. Becker to be associated with granites, but his evidence is not very convincing. Its usual occurrence in sedimentary rocks tends to obscure its true relations, and, to the best of my knowledge, it has never been looked for or reported in an analysis of an igneous rock.

Tin, as the oxide cassiterite, almost invariably occurs as the result of pneumatolytic processes in pegmatites, granites, and other rocks high in silica, and the mineral has been found in some rhyolites. Judging from the common association of cassiterite with lithium and beryllium minerals, and the presence of small amounts of tin in certain feldspars, micas, zircons, and in the rare mineral stokesite, it is probable that tin is associated rather with distinctly sodic than with potassic or calcic magmas, but much more chemical study of the rocks in which it occurs is needed to elucidate its relations.

Lead can often be found in rocks by using large amounts of material, and is occasionally reported, as in the analyses of rocks from British Guiana by J. B. Harrison and in those of rocks from New South Wales. No generalization in regard to it is possible as yet, but I am inclined to think that, like zinc, it favors the acid rather than the basic rocks, though it has been observed in both. The remarks in regard to the occurrence of zinc in limestones apply as well to lead.

Platinum and the other metals of this group are, as is well known, most commonly found in connection with peridotites, rocks low in

silica and high in magnesia, though it has been observed by Kemp in gabbros, which were presumably connected genetically with peridotitic rocks. Recent developments point to a somewhat wider distribution than was formerly thought to be the case, and indicate that platinum not infrequently is associated with copper ores.

The true relations of such elements as arsenic, antimony, bismuth, selenium, and tellurium to igneous magmas are quite unknown. It is possible that arsenic and selenium are most at home in the basic rocks, while antimony, bismuth, and tellurium are more apt to occur in siliceous ones.

We may summarize the observations recorded above as follows: Of the rarer elements whose distribution is better known, lithium, beryllium, cerium, and yttrium, zirconium, uranium, thorium, sulphur (as trioxide), fluorine, chlorine, and possibly tin occur most abundantly in sodic magmas; barium in potassic magmas; titanium, vanadium, manganese, nickel, and cobalt in iron-rich magmas; chromium and platinum in magnesian magmas; and phosphorus (?) and chromium (?) in calcic magmas.

Of the other elements it can only be said that boron and molybdenum are certainly, and zinc, cadmium, lead, antimony, bismuth, and tellurium are possibly, connected with magmas high in silica; sulphur and copper almost certainly, and arsenic and selenium possibly, with those low in silica; while the relations of gold, silver, and mercury are very uncertain, but they are probaby most at home in acid rocks.

This statement, it will be seen, differs from that of Vogt, in that, in the best-established cases, silica plays a less determinative rôle than some of the other major constituents. At the same time, the influence of the general law of the association of the most abundant oxides comes into play, and in a general way the potassic and sodic magmas are most apt to be highly siliceous (though the facts of distribution are shown in them even when silica is low); while those which are high in iron, magnesia, and lime are most apt to be low in silica.

Possibly the most striking feature of the distribution as thus shown is the great number of elements which are prone to occur in highly sodic magmas. As is well known, such magmas are those which show most tendency to differentiation and the formation of a great variety of rocks, many of them characterized by the presence of rare or otherwise unusual and interesting minerals, and there may probably be some connection between the two features of these magmas.

It will be noted that some of these elements, as fluorine, chlorine, sulphur (as trioxide), and boron, are among those to which is usually attributed the rôle of so-called "mineralizing agents," they being supposed to be present as dissolved vapors in the magma and to exert

a marked effect on the crystallization of the mass, the formation of pegmatites, and so forth. It may be argued that such mineralizing and pneumatolytic elements are universally, and presumably quite uniformly, distributed among the rock magmas, and that their presence in the highly siliceous and sodic rocks is due to the greater viscosity of these when molten, which would hinder the escape of gaseous constituents, while the basic magmas are more fluid at low temperatures and would hence allow such gases to escape before or during consolidation. On the other hand, it may be urged that the undeniable distribution among magmas of distinctly different general chemical characters, of elements to which no such mineralizing or pneumatolytic rôle can be reasonably assigned, as barium, beryllium, zirconium, titanium, manganese, nickel, chromium, and platinum, would lead to the inference that the apparent distribution of the gaseous and "mineralizing" elements in igneous rocks is real and not dependent on physical causes. The subject is highly complex, and our knowledge of the fundamental facts and of the physico-chemical laws involved is as yet inadequate for solution of the problem, further discussion of which would be outside the scope of this paper.

V. PRACTICAL CONSIDERATIONS.

When the facts of the relations of the occurrence of the rarer elements to the chemical characters of igneous magmas are considered it is evident that their distribution over the earth's surface must be largely determined by that of the petrographic provinces. In other words, in any given petrographic province those rarer elements and minerals containing them would be most apt to occur abundantly which show a correlative tendency to association with the characteristic major constituents of the province. Thus, zirconium-bearing minerals and those of the "rare earths" should be most abundant in provinces whose magmas are highly sodic and where such rocks as nephelite-syenite and phonolite are common; while chromium, nickel, and platinum would not be expected in these, but would rather be likely to occur in provinces where such rocks as gabbros and peridotites are the prevailing ones.

This idea has been recognized by Spurr[a] in his proposed term of "metallographic provinces," which is based largely on ore associations, and which he applies more especially to those metals of most economic importance, such as gold, silver, copper, lead, and zinc. The probable very close connection between "petrographic" and "metallographic" provinces is pointed out by him, but the two classes seem to be regarded by him as distinct, at least to a certain extent.

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[a] Trans., 33, 336 (1903); Professional Paper No. 42, U. S. Geological Survey, p. 276 (1905); and No. 55, p. 128 (1906).

When we deal with such complex bodies as veins and other ore deposits, the matter is complicated by such factors as geological structure, the existence of faults, the occurrence of the igneous rock as plutonic masses, dikes or effusive flows, climatic conditions,[a] and other disturbing features. These may tend either to favor or to retard the processes of concentration which result in economically exploitable metalliferous deposits. But these, though undoubtedly of the highest commercial importance, are subsidiary to the more fundamental facts of the distribution of the elements in igneous magmas, and it seems reasonable to suppose that a study of these latter features should be susceptible of results of great practical importance.

It seems that, at present, the knowledge gained by exact chemical analysis that the granites of a certain region contain minute traces of gold or of copper would be of little use in guiding one in the search for the location of a gold or a copper mine. The prospector must always remain a valuable, indeed an invaluable, member of the mining fraternity. We can not enter here into the vast and vexed subject of the genesis of ore deposits, but if it were known by future researches that, for instance, gold or copper is normally associated with magmas of a certain general chemical character, a knowledge of this might conceivably be of material assistance in a search; not so much by indicating the exact position of a favorable location, but, in a more general way, by leading the prospector to confine his attention to a given region of favorable igneous rocks and to disregard one whose rocks, on theoretical grounds, would probably result in loss of time and effort. Such a knowledge could be gained not only by the complex and laborious methods of accurate and minutely complete chemical analysis, but more readily, at least in many conceivable cases, by simple petrographical examination and field study of the most abundant and characteristic rock minerals.

These considerations, it is true, are scarcely applicable as yet to search for such metals as gold, silver, or copper, concerning the magmatic relations of which our knowledge is of the vaguest description. But, in view of what has been ascertained by petrographical and chemical means of the distribution of other elements, it is not unreasonable to think that we shall eventually obtain well-founded and definite knowledge concerning the distribution of these also. Indeed, the opinion may be expressed that future petrographers will wonder at the fact that, for instance, the presence of such deep-seated and extensive deposits of copper as those at Butte and in Shasta County, California, was so long unsuspected, and that their discovery came as a surprise.

[a] H. V. Winchell, Popular Science Monthly, vol. 72, No. 6, pp. 534 to 542 (June, 1908).

At the present time a knowledge of the distribution of the elements is practically applicable not so much to the metals of greatest human utility as to certain elements whose economic possibilities are only recently beginning to be appreciated as their chemical and physical properties and the application of these to commercial and economic purposes are becoming better known. Some illustrations may be permitted of the practical application of the facts set forth in the preceding pages.

If, for instance, one were in a new country or were engaged in a search for minerals containing such elements as zirconium, uranium, the rare earths, or beryllium, one would welcome a district of highly sodic igneous rocks, where albitic granites, nephelite-syenites, and phonolites were abundant; in this the chances of success would be most favorable. If the rocks were prevailingly gabbros, diabases, or feldspar-basalts one would reasonably assume that such minerals could not be expected to occur, at least in such amount as to repay exploitation, and they would be neglected, or prospected for platinum or chromium, let us say. Similarly, if the platinum metals were found in the sands of a river the watershed of which covered areas of gabbros, granites, and limestones, one would naturally turn to and explore the first in an attempt to trace the grains to their source, and would, with good reason, leave the others alone.

Instances of this kind could be multiplied, and, indeed, some present applications of the general principles are now practiced not infrequently, but without any suspicion of the true principles underlying them or realization of their more general applicability. Thus, in certain districts the occurrence of topaz or spodumene may be recognized as generally indicating the possible or probable presence of cassiterite, without appreciation of the more general and fundamental fact that the conjunction of tin, fluorine, and lithium is due to the distinctly sodic character of the igneous rocks.

With increase in our knowledge of the origin of ore deposits, and a general agreement as to their ultimate source in igneous rocks (whatever be the divergence of views as to the processes of concentration), the probability of the future importance of such observations as have been outlined above, from a practical as well as from a theoretical standpoint, is fairly evident. We can not as yet predict the probable presence of gold, silver, or copper in economic quantities from the petrographical and chemical study of the country rock; but the time may come (and our increasing knowledge of igneous rocks justifies us in a certain degree of confidence that it will come) when such seemingly erudite and impracticable studies will be able to guide us in certain regions, as to either the probable absence or presence of ore bodies of such metals.

The problem is admittedly very complex, and is one which has not yet been studied enough to do much more than enable us to make a few broad guesses at the truth. But we are beginning to discern some glimmer of light, and the fact that we can not make out clearly our guiding stars, veiled as they are by the mists of imperfect knowledge, should not cause us to disdain such help as glimpses of them may now afford, or underrate their possible importance when the mists shall have been dispelled.

THE MECHANISM OF VOLCANIC ACTION.[a]

[With 3 plates.]

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In a discussion of this kind it is advisable to be as concise as possible, eliminating minor details, so as to give prominence to the main outlines of any theory one holds. This communication, which the Council of the Ninth International Congress of Geography have honored me by asking me to address to you, I propose to put into the form of a "credo." To this I shall add a few fundamental facts upon which my reasoning was based, leaving minor ones for discussion at greater leisure elsewhere. For convenience, I propose to divide my theory into two sections. In the first I shall review what may be conveniently called deep volcanic action, and in the second, that group of phenomena that occur when igneous matter nearly reaches the surface or actually finds an exit thereon. Unfortunately, in the first case I am obliged to rely on hypotheses and deductions, whereas in the second section, that of superficial volcanic action, there are a number of fundamental facts and observations upon which to base speculation, and to which I propose to draw your attention.

Of one fact we are certain, and that is our globe is surrounded by a solid crust, which wherever it can be examined shows unmistakable and almost universal evidence of compression, wrinkling, and dislocation. This crumpling and crushing are equally inexplicable, unless we admit that since the initial solidification of the earth's crust its lower, still cooling part or support has undergone contraction so as to crowd together the already cooled burden of the upper part that this contracting mass carries.

No one has yet attempted to even suggest that the part of our globe subjacent to the solid crust has shrunk from other causes than a loss of heat. We may, therefore, look upon the idea of contraction as due to cooling to be a universally accepted fact.

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[a] Reprinted by permission from The Geological Magazine, London, new series, decade v, vol. 6, No. 10, October, 1909. Address to the International Geographical Congress.

In the old theory of the earth crust crumpling over a contracting and cooling nucleus, fluid, or partially so, it always appeared to me to be inexplicable how fluid matter could be squeezed out, or why the water on the surface of the earth did not rush down to fill up the vacancy that the contracting interior tended to produce between itself and the arch of the crust. This perhaps is expressing the facts in simple commonplace terms, but is sufficient to illustrate the incompatibility of this hypothesis with the fact of some of the liquid interior of the earth rising through the fissures toward the surface and being squeezed out by the contracting crust.

The hypothesis that tangential thrust did not exist, but that the earth crust was shrinking on an entirely or partially fluid nucleus, would have satisfied the vulcanologist, but is contrary to the incontrovertible evidence of tangential compression, as seen in the plications and overthrusts existing upon the entire surface of the globe, or at least that part above sea level. This hypothesis was based upon the conception that the earth's crust was acting as a single unit.

To Messrs. Mellard Reade and C. Davison[a] is due the credit of making an analytical study of the functions of different parts of the earth's crust. That work demonstrated that theoretically we can divide the cooling surface of the earth into a series of shells. The outer shells that have reached approximately the mean atmospheric temperature will, of course, have stopped contracting, whereas the shells nearest to the heated nucleus will be those losing their heat most rapidly, and therefore undergoing greatest contraction. This contraction must inevitably cause crowding, crushing, and crumbling of those shells that are nearer the surface, just as a stretched sheet of rubber coated with a layer of stiff clay would do when allowed to contract.

Somewhere between the surface shells of compression and the deepest shells of greatest cooling and contraction there will be a shell in a state of equilibrium, which the authors call the zone of no contraction. This zone, which was originally quite at the surface of our globe, tends to sink lower and lower as the general refrigeration or isotherms of our planet proceed downward. Were the shells of cooling and contraction of great tensile strength, such as the experi-

[a] C. Davison: "On the Distribution of Strain in the Earth's Crust resulting from Secular Cooling, etc." (Phil. Trans. R. S., 1887, vol. 178); "Note on the Relation between the Size of a Planet and the Rate of Mountain Building on its Surface" (Phil. Mag., Nov., 1887); "On the Straining of the Earth resulting from Secular Cooling" (Phil. Mag., Feb., 1896); "On Secular Straining of the Earth" (Geol. Mag., May, 1889, Dec. III, vol. 6, No. 299, p. 220). T. Mellard Reade: "The Origin of Mountain Ranges," 1886. See also H. J. Johnston-Lavis: "The Extension of the Mellard Reade and C. Davison Theory of Secular Straining of the Earth to the Explanation of the Deep Phenomena of Volcanic Action" (Geol. Mag., June, 1890, Dec. III, vol. 7, pp. 246–249).

mental sheet of rubber, already referred to, we can quite understand how any fluid in the earth's interior would tend to be squeezed out, but are met by two difficulties—(1) is there any fluid in the earth's interior? and (2) is the tensile strength of the contractile shells sufficient to have a squeezing power?

Three classes of views have been held as to the constitution of our globe. Some hold that it is like an egg, a solid shell with a fluid interior; others maintain that by the increase of gravity as the center is approached there is a solid nucleus which is potentially fluid were it not for this gravitational condensation, so that there would be a solid nucleus, a solid crust, and a stratum of liquid rock separating them. Finally, there is a third school who holds that the highly heated nucleus, although potentially fluid, is really solid in consequence of pressure or, more correctly, gravitational condensation.

No known rock that we are acquainted with gives the conception of having sufficient tensile strength to be capable of exerting any really contractile or squeezing power on fluid inclosed within it or surrounded by it. There will be a tendency as the inner shells contract to split by fissures. Such fissures would extend from within outward, and would be top-shaped in section, with the edge extending up to the neutral zone of no contraction, and their lower limit at the inner surface of the lowest shell (pl. 1, E, F.) Such a fissure might be simultaneously filled by the fluid rock paste beneath.

How this filling will take place requires consideration. As there is reason to disbelieve in any considerable constricting power of the inner cooling shells, and that even if such constricting power did exist is would be annulled by the development of fissures within its mass, it is evident one must look to other causes. The welling up into the fissure of the fluid rock, if we admit a fluid nucleus or a stratum or shell of such fluid, might be due to the settling down by gravitation of the cooled blocks[a] of crust limited by the fissures. If, on the contrary, we admit the immediate contact of the lowest cooling shell with a highly incandescent nucleus (P), solid by pressure, but potentially fluid when this pressure is removed, we can well see what would take place. As soon as the fissures and therefore fluid in the inner cooling shells begin to form, their location and their edges will represent a site of diminished pressure. The subjacent and neighboring but potentially fluid rock will in consequence liquefy and expand and fill the fissure. As the fissure broadens and extends so will the expansion and liquefaction increase pari passu.

Liquid rock may thus reach up to the neutral zone of no contraction, but its extension further must be a matter of chance. It is evident that if the shells of compression were in every part homogeneous and

[a] These blocks are quite different to the blocks referred to by some recent writers on terrestrial mechanics.

coherent, then no upward-pointed fissure could be formed. In practice neither of these conditions is fulfilled. It is obvious that the crowding and crushing will be most complete in the shells of compression (pl. 1, C) where these are carried on a continuous block of contraction (pl. 1, A). I mean by a block a portion bounded by fissures formed in the contracting part of the earth crust. Where the shells of contraction are fissured (E, F) there the crowding of the superincumbent masses of cooled rock will not take place. As a result, each block or island of contractile crust, with its compressed burden, will tend to tear away from the adjoining blocks or islands, so that the limiting fissures in the contractile joints will extend up into the compressional shells (G, H).

This exactly fits in with what is frequently found in the distribution of volcanoes along the edges of areas of marked compression or mountain regions. It will explain also the presence of volcanoes having a linear arrangement between closely situated mountain chains or areas, as in South America. Great rifts, such as those of Central Africa and some canyon districts, are probably of such origin. In earthquakes of tectonic origin it has been pointed out [a] that the piers of damaged bridges have usually been found to have approached each other. This would evidently take place in the areas of positive compression (pl. 1, C, C). On the other hand, in exceptional cases the piers have been found to have been separated. This might well occur in the area of negative compression (R), or what might well be termed the areas of retraction. The much larger proportion of the former effect on the bridge piers would no doubt be in the much greater ratio of compressional areas to retractional areas on the earth's surface.

May not ocean basins be in part due to blocks or islands of the contracting zones exerting that diminution of volume in a vertical more than in a horizontal direction, as we have so far been considering it to be? The peculiar abysmal ocean troughs, often at the edge of ocean basins and parallel to chains of volcanoes or interrupted by them, could well be explained by the same circumstances. I do not claim that ocean basins are alone due to this cause, but to a combination of these conditions, with perhaps the slipping, shearing, and corrugating of the primitive crust over a fluid envelope, and even the tetrahedral collapse of a cooling globe. I lay down here but a general principle to which there may be many exceptions, due to the vicissitudes of cooling and the variation in the materials concerned in any particular region, not to speak of the changing position of the earth's axis, the crustal inertia of Prof. G. H. Darwin, etc.

[a] Professor Hobbs, Ninth International Congress of Geography, 1908.

Liquid rock having thus reached a considerable way to the surface, either as simple dikes (pl. 1, I, I), laccolites, or sills (pl. 1, L, L), and so forth, is now in a situation suitable for the second series of phenomena, constituting what I call surface volcanic action, to come into play.

Surface volcanic phenomena.—Two schools of vulcanologists have held opposed views as to the origin of the volatile constituents contained in fluid igneous rock. One class of writers maintain that the gaseous contents are primordial, and have been contained in the igneous paste from the time that our globe condensed from the nebulous state. Others attribute all the volatile matter still retained in cooled igneous rock or evolved at volcanic mouths and fumaroles to the volatilization of water met by the igneous rock in its journey toward the surface. Probably both are right, but I propose to bring before you a series of my observations that point incontrovertibly to the fact that by far the major part of the volatile constituents of a magma are acquired by it on its journey toward the surface.

As condensation took place in our planet from a nebulous state, as each layer or shell of rock materials passed from the gaseous to the liquid state, and probably solid, it is evident that those most volatile would be the last to change their physical state. That some of the more volatile ones were entangled or held in solution by the less volatile is quite likely, but the amount must have been small.

Another possible source of volatile matter in the deep-seated igneous matter may well be due to a slow osmosis or diffusion extending over vast periods of time and directed by the varying affinities of one class of matter for the other.

A quarter of a century ago, as a result of a careful and detailed study of Vesuvius [a] and other volcanoes, I was able to show that a volcano the more continuously active it was in the emission of igneous material the more tranquil was the character of emission, and that practically under such conditions lava was the only product. I showed also that the longer were the intermissions in the extrusive efforts of a volcano the more the ejecta tended to issue in a broken up and fragmentary condition, from the larger and more violent evolution of volatile or gaseous materials. We thus had the whole gamut of products—scoria, pumiceous scoria, scoriaceous pumice, pumice, and pumice dust—bearing a distinct ratio to the time that any volcano had been in a condition of "repose."

Two explanations offered themselves to my mind for this state of things. One was that the persistent evolution of volatile materials primordially stored up in the original volcanic paste escaping con-

[a] "The Geology of Monte Somma and Vesuvius:" Q. J. G. S., 1884, vol. 40, pp. 35-119.

tinually therefrom had collected in the volcanic chimney and blew out the magma; the other that the volatile materials were acquired by the igneous magma where in contact with water-bearing rocks in the upper strata of the earth's crust.

Were the former the case one would expect that the first products of an eruption should be less gas filled or gas bearing than the latter, but this is not the case. My observations, which demonstrate the fundamental facts upon which eruptive action of a volcano depends, shows unmistakably that the first materials yielded in a normal eruption after a long period of "repose" of a volcano are the richest in volatile elements, and that as the eruption proceeds the amount of gases in the issuing magma steadily diminishes, as shown by the diminished vesicularity and increased crystalline individualization of the essential ejecta.[a]

The class which interests us in the present question is the group of the essential ejecta. I found that when one examines the stratified deposits of the ejecta thrown out during an explosive eruption—that is, an eruption of great violence taking place after a long period of repose of an old volcano, or the initial outburst of a new one—the materials, as they fell from the air, show a definite arrangement, and vary in character in correspondence with different phases of the eruption.

To illustrate what these characters are I propose to choose a classical example in that of the great outburst of Vesuvius that overwhelmed Pompeii, Herculaneum, Stabia, Oplontis, and other towns around the foot of Somma Vesuvius. If we examine the deposit of materials that fell during the eruption of A. D. 79 in the streets of Pompeii, or preferably outside the town, as the falling houses have disturbed the regularity of the stratification within the walls, we find it made up of several beds. Immediately reposing on the old land surface is a stratum of very white light pumice. I use the word "white" in comparison with that above it. If we collect a quantity of this we shall see that its bulk is very great for its weight. To the naked eye it is composed for the most part of a glassy vesicular base, with here and there scattered crystals of felspars, hornblende, pyroxene, and biotite, besides occasionally extraneous minerals

[a] In my paper "On the Fragmentary Ejecta of Volcanoes" (Proc. Geol. Assoc., vol. 9, pp. 421–432 and 3 figs.) I divided such ejecta into three classes. *Essential ejecta* are those materials that issue in a fluid state, and consist either of the volatile constituents or the magma in which these were contained, that produced the particular emission in question. *Accessory ejecta* consist of the older volcanic materials of the same vent torn away, expelled, and mixed with the essential ejecta of an eruption. *Accidental ejecta* consist of either volcanic materials from other centers, or sedimentary or other rocks of the subvolcanic platform, also torn out, expelled, and mixed with the two before-mentioned ejecta.

caught up in the magma. Microscopically it is made up of a network of straw-colored glass, with innumerable minute micro-crystals of leucite, all of a remarkably uniform size, besides which are a very few scattered microliths of hornblende, augite, mica, and felspars, obviously preeruptive in birth. (Pl. 3, figs. 5 and 6.) At wide intervals, of course, occur the porphyritic crystals above named. The main mass, however, is made up of glass, so that all the vesicles have been able to assume well-rounded outlines. The size of the vesicular spaces is very great in proportion to the amount of solid material inclosing them, making the pumice a very light one in weight.

Reposing on the bottom stratum, and rather suddenly graduating up from it, is the main bulk of the ejecta. The pumice composing this is much heavier, darker in color, ranging from a brownish gray to a greenish gray. The porphyritic inclosed crystals are the same as those in the bottom, white pumice, and practically average the same size. They appear to be more frequent, but this is due to the pumice being denser; more of them are therefore to be seen in the same area, as it were more crowded together.

Microscopically this pumice very much differs from the subjacent white variety. (Pl. 3, figs. 7 and 8.) Nearly the whole of the glass has been replaced by innumerable microliths. The small leucites have increased but little in size, though they seem more numerous. This I attribute to the less amount of open space left by the vesicles. The augite microliths constitute the main bulk, and minute grains of magnetite are abundant. Some small microliths are probably distinguishable as felspars. Generally the vesicular cavities are much smaller. The vesicle walls are no longer smooth, but rough from the projecting microliths that in the process of rapid cooling grew and projected in all directions, and are not arranged with such parallelism that is seen in flow structure with rods already in existence at an earlier date.

Both these divisions of essential ejecta are more or less mixed with accessory and accidental ejecta torn from the sides of the crater and the subvolcanic platform. I mention this as it has a bearing on the composition of the third and uppermost part of the materials shot out during an explosive eruption. This third or uppermost portion consists of a coarse or fine dust (ash), and when examined microscopically is seen to be to a large extent composed of detached microliths and loose crystals mixed with a large quantity of pulverized accessory and accidental ejecta. Whenever one examines the ejecta of explosive eruptions the same order is found. The above-mentioned characters are better seen in the case of very fluid intermediate or basic magmas, and I have given figures of the ejecta of an earlier explosive eruption of Somma Vesuvius, Phase III, which is free from leucite. (Pl. 2, figs. 1–4.)

When eruptions are of a less violent explosive character the first part may be pumice and later a more compact and micro and partially crystalline rock may issue, such, for instance, as the black pumiceous trachytic scoria ejected by the last efforts of Monte Nuovo, the main mass of the cone having been built up of a light buffish-white trachytic pumice.

In still less marked explosive eruptions, or where a large amount of material is ejected extending over some time, the final product may issue as a continuous mass and constitute a lava.

What, then, is the interpretation of this regular succession of ejecta having different characters? We know that the surface rocks of the earth's crust are as a body usually very aquiferous, and that as one descends the rocks become drier and drier. All the water has been squeezed out by superincumbent pressure. Of course, we know that according to the nature and composition of the rocks the depth to which aquiferous material extends will be extremely variable.

Let us figure to ourselves what would take place in a mass of fused silicates and oxides filling a fissure extending up through non-aquiferous into more and more aquiferous rocks. The prolonged contact would result in the gradual solution of the H_2O of the aquiferous strata in the fused paste, just as carbonic acid would be dissolved under pressure, but at ordinary temperature, in water. In the former case the critical point of H_2O does not come into the question. We know little of the temperature and pressure that this compound can exist at when dissolved in silicates and oxides. Furthermore, even if dissociated probably its components could pass into solution and recombine again when temperature was lowered sufficiently. A careful study of volcanic action leads me to believe this process to be a slow one, so that if a fairly regular flow of melted rock takes place up the fissure through the aquiferous strata little H_2O is absorbed, and igneous outflow shows little violence, so that lavas are the chief products.

If the volcanic canal has never reached the surface, or is cut off from it by an old plug of solidified ejecta, then as the igneous magma acquires more and more H_2O its tension will steadily rise. Its loss of heat energy will be very little, as the H_2O and other volatile matters it has dissolved occupy a small volume. Still, in certain cases the magma may, as the result of different sources of heat loss, undergo complete cooling and consolidation. Not unlikely many hydrated rocks owe their origin to this cause. All evidence points to the heat energy or specific heat of basic rocks being lower in relation to their fluidity, which would explain in part why hydrated rocks are more frequent amongst them than are acid ones, as more frequently they would be cooled to consolidation before they found issue at the surface.

In many cases, however, the tension of the magma will steadily rise as it acquires more and more volatile matter from the surrounding rocks.[a] A moment will be reached when the tension has gradually attained such intensity that the earth's crust is rent by an extension upward of the fissure. This fissure may reach the surface and make a new volcano, or the obstructing plug of an old one may be cleared away. In either case an explosive eruption will result.

Now the first portion to issue will be that part of the magma at the top of the fissure that has been in contact for the longest time with the more aquiferous rocks, and consequently will be richer in acquired volatile materials than that below. It may be a pure glass, or a certain number of crystals may have individualized under the intratelluric conditions of slow cooling. Once free from compression H_2O, etc., will separate from the nonvolatile silicates and oxides as bubbles, undergo enormous expansion, escape in great part, and afford the explosive agent in the ejection of the remaining fluid-froth still holding much gas in the vesicles. This sudden expansion means a tremendous loss of heat energy, and the vitreous matter is so rapidly cooled that it has no time to individualize into microliths or crystals, or the crystals already existing to grow in size.

We know from the effect of pumice on combustible substances, as wood, bread, cloth, etc., as at Pompeii, that nearly all the latent heat has been used up in this expansion, so that only partial roasting has resulted. Thus has been produced the first white light pumice of an explosive eruption by the extremely rapid expansion and cooling of a pure or nearly pure glass.

As the upper contents of the volcanic canal blows out, that part of the magma lower down follows. This next portion has been a shorter time probably in contact with aquiferous rocks; these latter, being deeper, are usually poorer in H_2O. The consequence is that this second batch of magma will contain less volatile matter, expansion will be slower, there will be less loss of heat required for expansion, so that there will be time and other more favorable conditions for part of the glass to individualize into microliths. (Compare 1, 2, 5, 6, with 3, 4, 7, 8, pls. 2 and 3.) This second batch of magma furthermore will have lost less heat energy in consequence of having had less H_2O to dissolve, but also being deeply seated and in hotter rocks it will have lost less heat by conduction.

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[a] I use H_2O not to assume any special physical state of that substance. I also refer to it specially as being the principal volatile material of igneous magma; but I fully appreciate the salts and gases derived from their decomposition, as likewise the rarer materials that were acquired by and can be separated from igneous rocks by a high temperature, to which Monsieur Brun and others have furnished us with such interesting details by their studies.

As we go deeper in the volcanic conduit these same differences will be exaggerated, so that as the magma escapes almost all the glass may be converted into microliths so as to leave little material to hold them together, whilst the evolution of volatile gases will be sufficient to separate them into dust, producing the pulverized material constituting the essential part of the last and topmost deposit of an explosive eruption.

If the igneous paste rises from still greater depths it may come from little or nonaquiferous parts of the conduit, which, together with a higher specific heat from fewer losses thereof, will allow it to gush forth in a nonfragmented state as a lava.

The want of uniformity in the water-bearing rocks at different depths is too well recognized for us not to see the influence on possible departures and irregularities which might result in the sequence of ejecta having the characters I have shown you as the simplest expression of an eruptive phase.

In an open chimney of a volcano in chronic activity the constant circulation up the volcanic conduit allows of too little time for the magma to acquire much volatile materials, and it is only when this outflow is more or less impeded at the vent that more volatile materials are acquired and the volcano assumes paroxysmal or explosive fits.

In conclusion, I may say I have tried to summarize the trend of my researches for the last thirty years, and if you will try to read the whole phases of volcanic activity in this light you will find it the only satisfactory explanation universally applicable to all cases of the eruptive mechanism. No other theory that has been advanced has ever been based on the characters of the actual essential ejecta, and no other one fits without exception the whole range of the very varied phenomena of volcanicity.

EXPLANATION OF PLATES 1, 2, AND 3.

PLATE 1.

A Shells of contraction.

B Neutral zone or zone of neither contraction nor compression.

C Dry shells of compression.

D Aquiferous shells of compression.

E Fissure between shells of maximum cooling and contraction filled by liquefaction of the edges of these shells by diminished pressure.

F Same, but in the shells of less cooling and contraction.

G Fissure extending up between two areas of compression and islands of contraction, but not reaching the aquiferous shells.

H The same, but reaching into the aquiferous rocks.

I The same, but having reached aquiferous shells, has been enabled to extend upward by explosive action into a laccolite and sill in one case and directly to a volcano in the other.

L Laccolite and sill exposed by erosion at M.

N Volcano supplied from uncooled part of laccolite, aquiferous rocks, and from rift I.

O Volcano supplied from rift I and aquiferous rocks around top of same.

P Portion of globe undergoing practically no cooling.

R Area of ineffective compression or retraction and depression.

S Area of ineffective contraction and of low pressure.

Pumices and pumiceous scoria from explosive eruptions of Monte Somma and Vesuvius (essential ejecta).

PLATE 2.

Fig. 1. Light white pumice, bottom part of Phase III, period 1. The section is seen to be mostly composed of a clear glass with only an occasional porphyritic crystal or microlith. Magnified 11 diameters.

Fig. 2. Part of the same section, magnified 50 diameters. Most of the vessels are sectionized and open, and support the very rare porphyritic crystal by sections of the thin shells of glass. A few vesicles still contain air.

Fig. 3. Heavy chocolate-brown pumiceous scoria produced later by the same eruption, Phase III. Notice how much smaller are the vesiculæ and how the mass of rock material is principally composed of microliths. Magnified 11 diameters.

Fig. 4. The same, magnified 50 diameters. Here the numerous large smooth-walled vesicles of figure 2 are replaced by few small rough-walled spaces into which the microliths project.

PLATE 3.

Fig. 5. Light white pumice, bottom part of Plinian pumice that buried Pompeii, Phase VII, period 1. The section shows the material to be mostly a clear glass crowded by microliths of leucite only with few exceptions. Magnified 11 diameters.

Fig. 6. Part of same section, magnified 50 diameters, showing these characters more accentuated.

Fig. 7. Heavy greenish-gray pumice from high up in the pumice stratum. Here the rock is composed of a dark, almost opaque network of microlithic matter in which magnetite is abundantly distributed. The microliths are almost hidden by the opacity of the magnetite and augite grains. Magnified 11 diameters.

Fig. 8. The thinnest possible section to make is shown in this figure, magnified 75 diameters, exhibiting the extensive indivdualization of the glass into opaque microliths. The leucite microliths are represented by spots of imperfectly transmitted light where the crystal grains reach both sides of the slice, but are partially overlapped by augite and magnetite all around.[a]

[a] Had this specimen been chosen from the top of the essential ejecta of Phase III the thinnest section capable of being cut would have been opaque. It was taken, therefore, from a transition stratum (see p. 312).

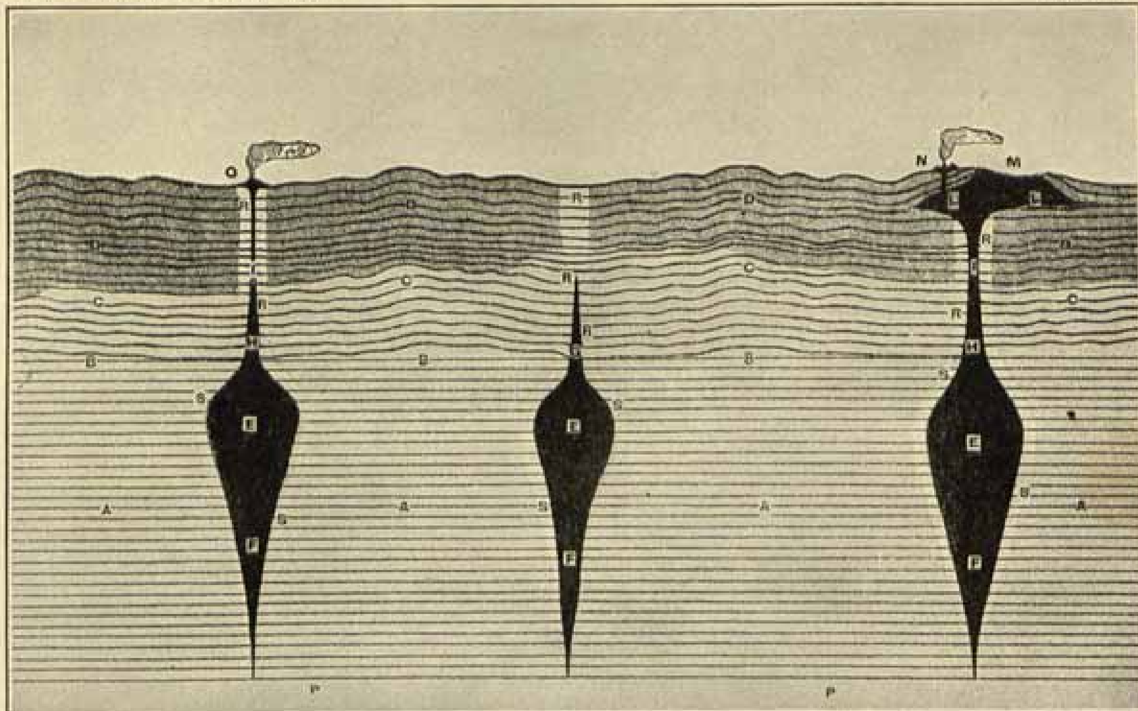
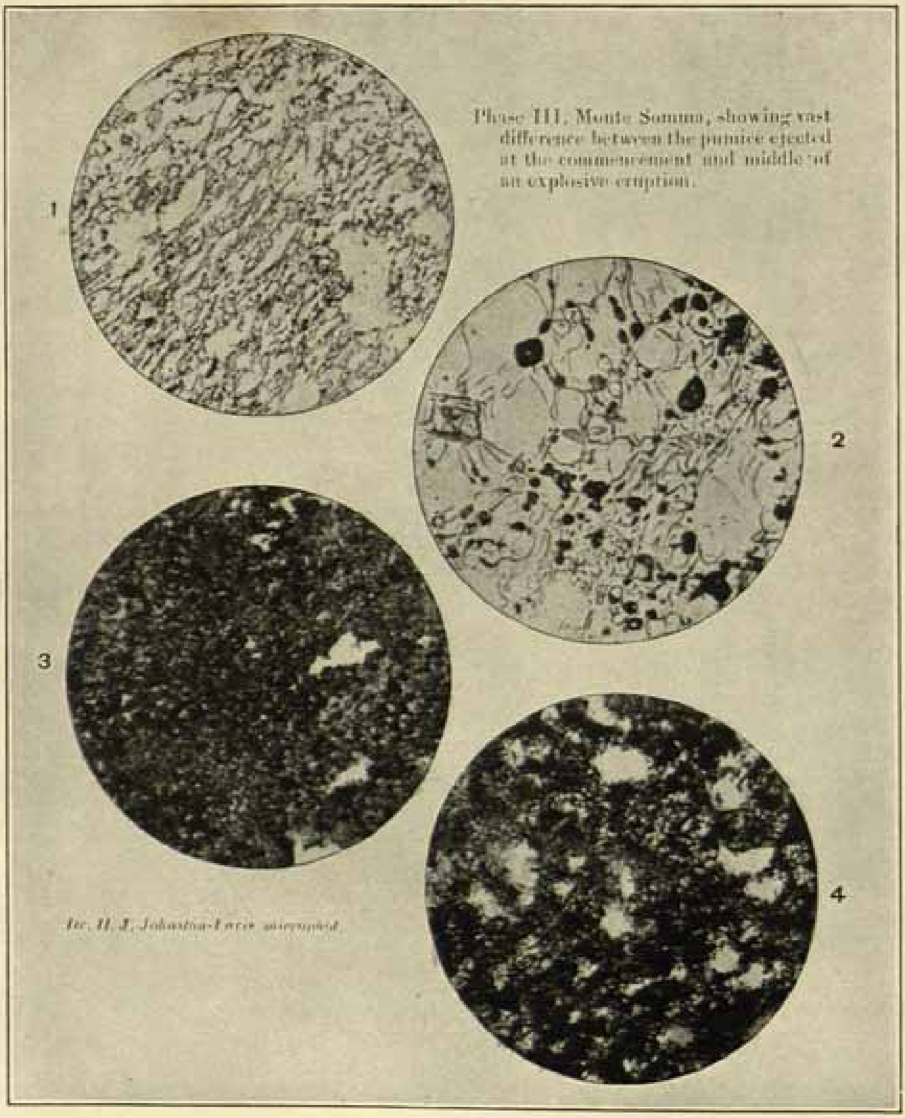
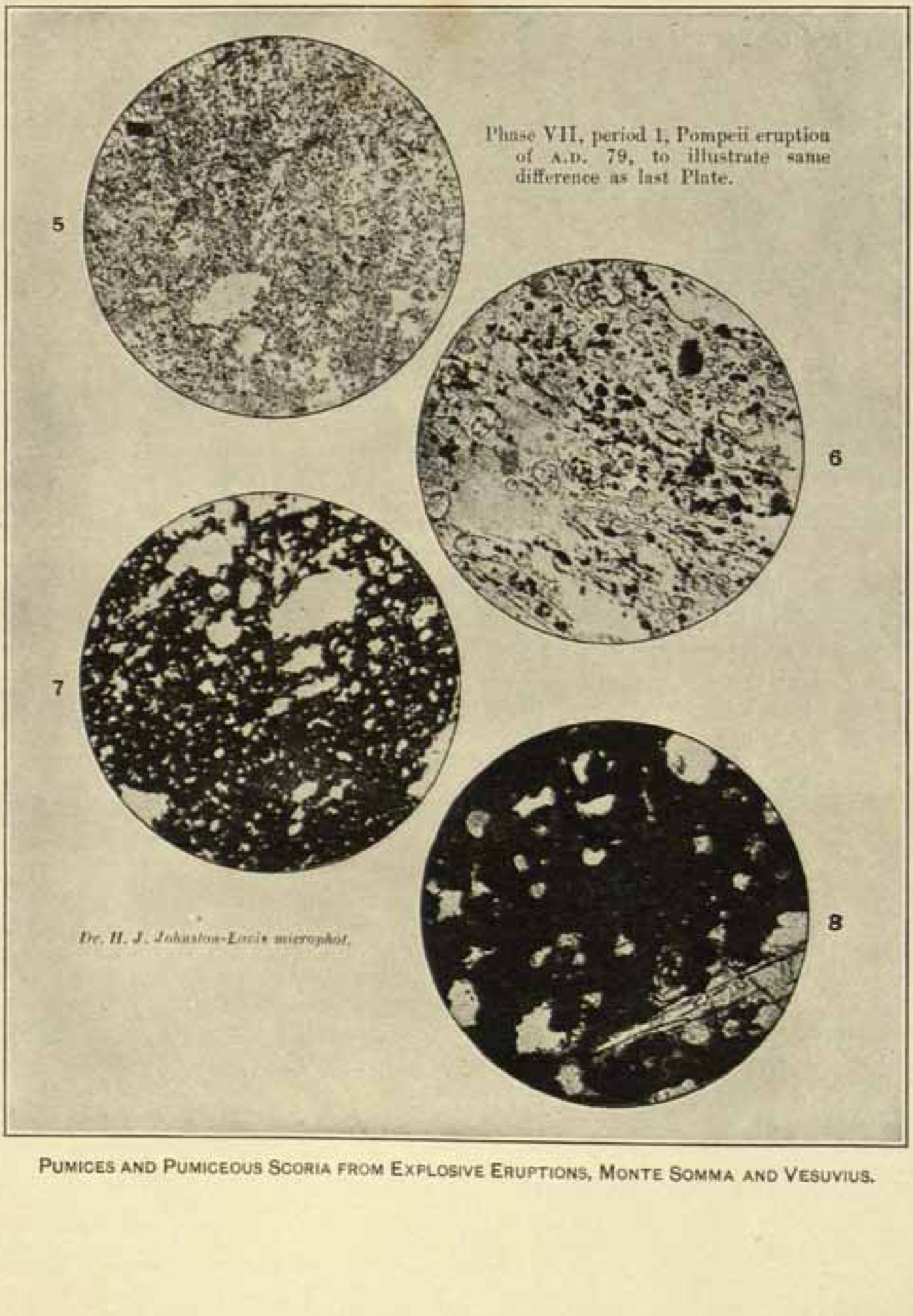


DIAGRAM SHOWING THE THEORETICAL SHELLS OF CONTRACTION, COMPRESSION, AND FISSURING ON THE EARTH'S CRUST BY PROCESS OF COOLING. PROPORTIONS GREATLY EXAGGERATED.



PUMICES AND PUMICEOUS SCORIA FROM EXPLOSIVE ERUPTIONS, MONTE SOMMA AND VESUVIUS.



PUMICES AND PUMICEOUS SCORIA FROM EXPLOSIVE ERUPTIONS, MONTE SOMMA AND VESUVIUS.

CONSERVATION OF NATURAL RESOURCES.[a]

By JAMES DOUGLAS, New York, N. Y.
(New Haven meeting, February, 1909.)

In discussing the waste upon which hinges, or is supposed to hinge, so largely the preservation of our national resources, the conclusions reached would be more reliable if actual experience were consulted, and fewer deductions were drawn from general statements, which are often the product of the imagination.

It can not be questioned that the value of by-products has not been sufficiently appreciated by us, and that our tardiness in recovering the useful ingredients of the escaping gas of our coke ovens is one of the most glaring instances of shortcoming in that direction. And yet even for that sin there is some palliation in the immature condition of affiliated industries. I presume that it is admitted without argument that, except under very exceptional conditions, all the elements can not be recovered from most of the ores or natural products which we treat. While it is a shame that the by-products from our coke ovens should be dissipated, Edward W. Parker's report to the United States Geological Survey for 1906 [b] supplies a fairly good excuse in justification of this appalling waste. He says (pp. 773 to 774):

What has been already commented on in previous reports about the slowness of manufacturers to change from the better known but wasteful beehive practice to the by-product recovery method of coke manufacture is particularly emphasized in the statistics presented in this chapter. For it would appear from the table following that the construction of by-product ovens had about come to a standstill, especially when the records for the preceding five years are taken into consideration. At the close of 1901, when there were only 1,165 by-product ovens completed in the United States, there were 1,533 in course of construction, 498 of which were completed during the following year. At the close of 1902, 1,346 retort ovens were building, 293 of which were added to the completed plants in 1903. At the close of 1903, 1,335 new ovens were building and 954 of

[a] Reprinted by permission from Bulletin of the American Institute of Mining Engineers, New York, No. 29, May, 1909, pp. 439–451; also in Transactions of American Institute of Mining Engineers, 1909, with discussion thereon.

[b] Mineral Resources of the United States for 1906, U. S. Geological Survey (Washington, 1907).

these were put into blast before January 1, 1905, at which time 832 new ovens were in course of construction. At the close of 1905 there were only 417 new ovens building, and at the close of 1906 new work was limited to 112 Otto-Hoffmann ovens, which were being added to the 260 ovens already built at Johnstown, Pennsylvania, by the Cambria Steel Company. These new ovens were completed and put in blast in February, 1907.

This condition is somewhat difficult to understand when the economies effected by the use of retort ovens have been so clearly demonstrated. These economies consist not only in the higher yield of coal in coke, but in the recovery of the valuable by-products of gas, tar, and ammonia. One of the reasons that has been assigned for the comparatively retrogressive condition exhibited by the statistics for 1905 and 1906 (comparison being made with beehive oven construction, 5,893 new beehive ovens having been completed in 1906, with 4,407 building at the close of the year) is the lack of a profitable market for coal tar, and yet the United States is importing coal-tar products to the value of several million dollars annually, while the development of the fuel-briqueting industry has been held back because of the lack of assurance of a steady supply of coal-tar pitch for a binder, and users of creosoting oils for the preservation of timber complain of an insufficient domestic supply of this product of coal-tar distillation.

The truth is that one branch of industry is so dependent upon another that there must be equal progress along the whole line of industrial life if complete recovery of all the available elements of our natural resources is to be effected. The chemical industry must keep pace with the mining and metallurgical industry. We may be moving too slowly in that direction, but we can distinguish a steady movement toward this needful cooperation. It is encouraging, for instance, to find that the waste gases from the furnaces of the Tennessee Copper Company are being turned into sulphuric acid for the manufacture from southern phosphates of the superphosphates which the fertilizers of the southern cotton fields need. Failing this mutual relation between the metallurgist of Tennessee and the chemical manufacturer, the blame should not rest entirely upon the metallurgist for wasting that for which, heretofore, he has been unable to find a market. The same justification exists abroad as in this country for similar waste in other branches of industrial activity.

It is nevertheless true that legal compulsion alone has driven manufacturers to introduce improvements and economies which were demanded by public safety, and which have redounded to the benefit of the reluctant corporations. In Germany and England the disposal of noxious vapors and noxious liquors has been required of the manufacturers, but their compulsory removal from the atmosphere and the water has resulted in their conversion into useful products, and the building up of new technical industries. An agitation is springing up in the West against the fumes from smelting works being turned loose into the atmosphere. While in some cases the injury done to vegetation may have been falsely attributed to the smoke from metallurgical works, the agitation has been followed

by some good results. For instance, the Mountain Copper Company, having been driven out of Shasta County, California, by the farmers, has erected chemical works as an annex to its smelter at Martinez, on San Francisco Bay. Here, as elsewhere, manufacturers are reluctant to go to the heavy expense involved in abating such nuisances, even though they may know that in the end the abatement will be profitable. As far back as 1881 Mr. Vivian admitted that in recovering 47 per cent of all the sulphurous acid emitted from his furnaces in Swansea he condensed 3,666 tons of oil of vitriol at a great profit. This valuable asset, though he does not so state, was secured in spite of bitter opposition on the part of those who were ultimately the most benefited by it. One looks with wonderment at the clouds of valuable fumes which float from the New Jersey shore over Staten Island to the sea, instead of flowing inland as acid to the chemical manufacturers in the neighborhood.

Our industrial development, however, has reached such a state of advancement, especially in the densely populated portion of the country, that however averse some of us may be to expend a large share of our profits in improvements, designed primarily to relieve the public of nuisances, we must submit whether we will or not. And having obeyed the mandate of the law, not many years will elapse before we come to realize that what we do under compulsion is as much for our own good as for that of our neighbor.

I promised, however, to confine myself in my remarks to matters of experience. I have been identified with the copper interests of the Southwest since 1881. Though the Southern Pacific Railroad had only just traversed the territory, mining was immediately stimulated by railroad transportation, and the Copper Queen Company, at Bisbee, the Old Dominion Copper Company, at Globe, and the Lezinskys (the predecessors of the Arizona Copper Company), as well as the Detroit Copper Company, were actively at work at Clifton. All three of the most productive districts, therefore, of southern Arizona were being explored, and, through the influence of the railroad, vigorously exploited at that time. But none of them were situated on the main line, or were linked to the transcontinental road by branches. The Copper Queen was 60 miles from its nearest railroad station, Benson; the Old Dominion was 140 miles from either Wilcox or Bowie; and the mines of the Arizona Copper Company and the Detroit Copper Company were 80 miles from Lordsburg. Coke and supplies had to be hauled in and copper teamed out those long distances.

The ores in all three camps were thoroughly oxidized. At the time this was supposed to be a condition of the highest advantage, upon which the only possibility of economical treatment depended; and not without good grounds, for the tedious methods of treating

sulphide ore, so expensive in labor and fuel, were still practiced. We all, therefore, imagined in our shortsightedness that the day of doom for the copper interests of southern Arizona would date from the transition from oxidized to sulphide ore. Of the three districts, the only prosperous one during the succeeding fifteen years or so was the Warren, and for reasons which we now more clearly appreciate than we then did. The ores of the Copper Queen, or rather such of them as were then selected for treatment, were self-fluxing. They contained about 10 per cent of copper. The slags of that period, which we are now resmelting, contained about 2.5 per cent of copper. Assuming the slags to represent 65 per cent of the charge, about 16 per cent of the total copper content was being stored away in them. Less favorable conditions, however, existed at both Globe and Clifton. The ores of both these districts were extremely siliceous and the furnace charge of ore had to be diluted with from 40 to 50 per cent of limestone. The siliceous ores as treated were probably of about 12 per cent. The furnace charge was reduced by fluxing to between 7 and 8 per cent of copper. The old slags—65 per cent of the total charge—yield at Globe about 3.5 per cent and, therefore, must have carried from 30 to 32 per cent of the total copper fed into the furnaces. We have re-treated all the old slags of the Detroit Copper Company, at Morenci, near Clifton, and know that they carried on an average of 4.5 per cent of copper and must, therefore, have contained at least 40 per cent of the copper in the ore. At neither Clifton nor Globe was the dust collected, which probably represented a loss of another 5 per cent. Considering the high cost of fuel and labor, it is not to be wondered at that neither the Old Dominion, the Arizona Copper Company, nor the Detroit Copper Company, was financially successful for the first fifteen or sixteen years of their existence. It was not until all the richer carbonate ores had been wasted by being largely converted into slags that the companies recognized that their salvation depended upon securing sulphide ores; upon making metallic copper through the medium of matte, and throwing away less copper in their slags. So little, however, was this fact appreciated at first that we all envied the Arizona Copper Company, because it could turn the San Francisco River into its works and granulate and wash away this valuable refuse. And when the Old Dominion mine struck large volumes of water, the Old Dominion Company committed the same act of folly, washing its 3.5 per cent slags into Pinal Creek.

Had the companies realized the losses they were incurring and the only remedy applicable, they would have been obliged to close both mines and furnaces; for except at the Copper Queen, where sulphide ores were encountered within three or four years after the mine was opened and were considered a nuisance, heavy sulphides are rare.

Though the Old Dominion Consolidated Company has explored its property to the sixteenth level, between 100 and 200 tons daily are imported from California and Bisbee, the company's own mines producing only about 60 per cent of the sulphur required by the furnaces. And at least one of the Clifton smelting companies is obliged to draw daily from abroad by railroad about 160 tons of sulphides high in sulphur and low in copper. It follows, therefore, that there was no alternative in the early days between either suspending operations or making copper in the wasteful manner which the companies then pursued.

Looking at the situation from the standpoint of to-day, if we place the advantages and disadvantages side by side, we have on the side of the advantages:

1. The experience which was gained during that long period of adversity, which is now being turned to good account, not only by the original companies, but by the many other enterprises which have entered the same field and are profiting by the losses of the pioneers.

2. The southern portion of the territory has increased in population and in wealth, mainly through the exertions of these copper companies, even while they were losing money on the copper produced. They not only employed thousands of men, but they made a market for the agricultural development of the small amount of arable land within reach of the mines. Had the mines of Globe and Clifton not been operated because pecuniarily unsuccessful, and had not the shareholders been willing to accept hopeful promises in lieu of dividends, Arizona would not to-day be making an unanswerable plea for admission to the Union as a State.

3. The ultimate success has been due to the advent of the railroad; for railroads are seldom built into unproductive regions in the expectation of creating traffic that does not exist.

If we turn to the disadvantages, they are, of course, palpable. At the present time, when we are matting our copper ores instead of making black copper direct, the slags from those three groups of copper furnaces run from 0.4 to 0.5 per cent of copper. Even when the slags are re-treated, copper in the slags resulting from the slag treatment runs higher than in slags from the treatment of ore, owing to the difficulty of reducing silicates. Thus, when the slags are re-treated, there is the double waste of fuel and the double waste of labor.

Even supposing that our economic system were different, and that necessity did not drive public corporations to utilize wastefully the resources they acquire, I think that the balance of advantage to the country at large, as well as to the district, would indicate that it is better to make progress and thereby gain experience, even at the expense of such waste as I above indicate, rather than stand still and do

nothing, in the hope of more favorable conditions being brought about by Providence rather than by our own efforts.

Certain lessons, however, the above recital of experience teaches. One of them is, never to throw away anything that contains material of any value, even though it may seem to be valueless. The time inevitably and invariably comes when, through improved conditions or better methods, what was waste to one generation becomes of value to another. Most of the filling of the old stopes in the Copper Queen mine and in the Old Dominion mine has already been re-treated. In the case, therefore, of sulphide ore, which is too lean to handle, it should be stored underground rather than exposed to the weather at the surface. I am not sure whether we are justified in ballasting our railroads with the slags which we are making now, lean as they are. One can not see how 0.5 per cent of copper and a little gold and silver can possibly be recovered to any advantage, and yet the future may reveal secrets which will convert such impossibilities into possibilities. The slags from the iron blast furnaces, which were deemed valueless a generation ago, are made into hydraulic cement to-day.

We all recognize the waste that has resulted in the past from washing away gold tailings, which often ran several dollars in gold to the ton. Had they been impounded, the minerals now, through weathering, would be in the fittest possible condition for cyaniding, and would give up to this process their residual values to within a trifle of their contents. The same rule of preservation should be applied to the tailings from copper works. The sulphides, no matter how small their percentage, slowly decay, and give off their copper as soluble sulphate, which can be precipitated on scrap iron at a very inconsiderable cost. If the locality be such that these waste materials can be stored, care, and some outlay, if necessary, should be expended in their preservation.

There seems, however, to be a fascination in contemplating loss rather than saving, and while we can not exaggerate the follies of waste, it is not fair to the profession to overlook the efforts that have been consistently made within the last three-quarters of a century, and are still being made, to eliminate waste. One of the anomalies, however, of the problem is that the accused mining and technical engineers compose the only section of the public which really appreciates the cost of waste and tries to save.

The recovery of heat units in our domestic fireplaces and furnaces is far less than the recovery of heat from coal burned under our best boilers, when measured as power generated in our steam engines. And the waste in our kitchens and at our tables involves a greater national loss than the waste in our coal mines. In the one case the people at large are making no effort to minimize it, while every technical man of repute is putting his best endeavors into devising means

of getting the highest efficiency out of nature's forces, with a view to turn nature's resources indirectly to the greatest good for the greatest number.

If we look backward to what has happened within our own day and experience we may justly feel some resentment at the harsh criticism which is now being so generally aimed by the press and the public at technical men. And this is partly true likewise of the strictures so indiscriminately passed upon the corporations which are instrumental in developing the country's natural wealth.

In the middle of the last century less than one-half of the iron made in this country was smelted with anthracite, and the balance with charcoal or charcoal and coke.[a] The devastation of the forests was awful. Pearse[b] gives the consumption of wood in Berks County, Pennsylvania, in making 19,000 tons of charcoal iron in 1828, 1829, and 1830 at 250,528 cords. To secure this amount about 8,000 acres of the finest forest land in the country must have been stripped. In England, where most of the iron was made with coke as fuel, at the same date and until 1875, there were consumed from 35 to 37 hundredweight of coke per ton of pig iron. In 1875, when the Whitwell stove was introduced to heat the blast, the quantity of fuel consumed was reduced by 3 or 4 hundredweight. By improved mechanical and metallurgical appliances that consumption in the Middlesbrough district is now lowered to 22 hundredweight.[c]

This saving of fuel in the blast furnace has, in this country as well as in Europe, been effected through the sleepless activity of metallurgists and engineers, by modifying the size and shape of the great iron stacks, increasing and regulating the temperature and the pressure of the blast, and by the introduction of appliances for utilizing the waste heat. The difference between the 37 hundredweight of coke formerly needed to make a ton of pig iron and the 22 hundredweight now consumed, multiplied by the number of tons of pig iron made in the United States in 1906, represents a saving (assuming 1.75 tons of coal as required to make 1 ton of coke) of approximately 30,000,000 tons of coal.

The progress along this line in blast-furnace practice has been steady and wonderful, and has culminated in the ingenious device of James Gayley, which still further economizes fuel, by freezing the blast before admitting it to the stove, in order to eliminate moisture,

[a] In the Iron Manufacturer's Guide (1866), Lesley gives the total production in 1854 at 724,833 tons, of which 417,123 tons was charcoal or charcoal-and-coke iron.

[b] Concise History of the Iron Manufacture, p. 156.

[c] A description of Messrs. Bell Brothers' Blast Furnaces from 1844 to 1908, and other papers, Journal of the Iron and Steel Institute, vol. 78. (No. 3, 1908.)

and thus supply the stack with a gaseous element of as constant and reliable a composition as the solid elements of fuel and ore.

The advances in blast-furnace practice in the direction of fuel saving have been great. But they are not as startling or as picturesque as the economies which followed the introduction of the pneumatic method as applied through the mechanical and metallurgical skill of Bessemer, and as developed in the United States through the genius of Holley. We can all recollect the distressing sight, especially in summer weather, of the puddler, stripped to his waist, toiling over his furnace, while burning up from 20 to 27 hundredweight of coal in converting 1 ton of pig iron into puddle bar. Leaving out of the question the fuel used in generating the power for operating the Bessemer converters, which, however, is generally recovered from the waste heat of the blast furnace, the amount of coal saved in making Bessemer steel instead of wrought iron during the same year of 1906 exceeded 22,000,000 tons.

The metallurgy of copper has benefited as acutely as the metallurgy of iron and steel from the combined science and skill of the mechanical and metallurgical engineers. One recollects distinctly how, in the old brick furnace, a campaign of ten days, with a daily charge of 10 tons of ore, was looked upon as almost phenomenal; and that from the time we began roasting sulphide ore in heaps until the refined copper was turned out after endless handlings of the mattes, as they were worked up from lower to higher grades, about three months was occupied. Now, by means of mechanical roasting furnaces, large jacketed cupolas, electrical cranes, the Bessemer converter, and the Walker casting table, the ore is turned into metal in fewer hours than it formerly took weeks, and at the same time almost dispensing with hand labor.

While these industrial changes were going on in the mining and metallurgical fields, the electrical engineer was bringing under control that tremendous force which Faraday investigated as dynamic electricity; and we metallurgists have not been slow to apply it, both to the saving of fuel and other natural resources, and to the conservation of human labor. The modern rolling mill, in which a motor replaces the small engine and boiler that used to operate the rolls, and the modern electrolytic plant which turns out electrically pure copper, are only the more visible benefits that electricity is conferring. When some of us commenced our technical experience the deduction in precious metals made by the refiner of copper before any contribution was made to the miner or the seller was $60 worth per ton of ore or metal. Under such heavy charges comparatively small amounts of gold or silver were or could be saved. To-day, through the application of electrolysis to the metallurgy of copper, about $8,000,000 in value, which was formerly lost, is now

recovered annually and goes into commerce as a by-product; for the world's copper may be assumed to carry an average of $10 per ton in gold and silver.

The last application of this mysterious force, by transmitting from stationary engines electric current for the movement of trains, aims at reducing what is certainly one of the most wasteful uses of coal—its consumption in the locomotive for the generation of steam. In distributing our coal supply, the railroad burns up from 20 to 25 per cent of the total production of our coal mines. This will be notably reduced, though to what extend has not yet been determined. But before this desirable consummation is attained, if electrical engineers continue to extend the limits within which long-distance transmission can be applied economically, they will bring the latent, neglected forces of the whole continent to our doors, and the water powers a thousand miles away, as well as the winds and tides, will propel our railroad cars as well as heat our houses. The service which coal now performs will be fulfilled without the expenditure of human labor and the diffusion of so much obnoxious smoke and vapor. Long before our coal supplies are exhausted, even on the most pessimistic calculation, our children will gladly leave the balance in the ground, and charge off to profit and loss some of what we now consider our most valuable natural asset.

There is no doubt whatever that the destruction of our forests is attended by a host of such terrible consequences that a halt must be called. In the early days at Bisbee, when we were at a distance from the railroad, we of necessity almost stripped the hills of their scanty clothing of stunted wood, for we were forced to use wood for the generation of steam. I find from one of the earliest statements that the company burned about 4,000 cords of wood for the year. The hills for miles around were completely denuded, with the result that disastrous floods have ever since almost annually deluged and damaged the town, which is built in the troughs of two converging valleys. As mining engineers we are sensible of the ruin which reckless lumbering involves, and we lower with regret every stick of timber that we bury underground. Nor are we satisfied to bemoan the fact without making some effort to remedy the evil. It has been suggested, and we are trying the experiment, to replace wood by iron. The forests can be restored in time by reforestation, but iron ores can not be replaced. And, therefore, it is a false economy to attempt to save a reproductive material by substituting one which rusts and can not be regenerated. Concrete is also being used more and more in mining operations, and against its substitution for wood there can be no objection; but the most notable economy will result from improved methods of mining, especially from the introduction of the caving and slicing systems. These were introduced into the Cananea

mines when Arthur S. Dwight was manager; and Doctor Ricketts and Mr. Kirk have extended the use of the methods and applied them so successfully that less than half the timber is used per ton of ore extracted to-day than was buried in the mine three years ago. The following data, kindly supplied by Doctor Ricketts, represent the saving which is going on at Cananea, and in many mines where the same method is applicable:

Timber consumed per ton (wet) of ore produced at Cananea, Mexico.

Period.	Tons ore mined.	Feet timber used.	Feet per ton.
August 1, 1905, to January 31, 1906	463,039	10,774,342	23.27
February 1, 1907, to July 31, 1907	554,473	8,268,682	14.96
August 1, 1908, to September 30, 1908	97,510	1,091,837	11.20

While it would be presumptuous to pretend that, as a people, we are economical, and to deny that, under modern corporate control of large national resources, the temptation, under necessity of making large profits, is not betimes stronger than the appeals which conscience makes to subordinate personal gain to the national welfare, I am sure that neither our largest mining and metallurgical companies nor ourselves, as their working agents, are recklessly indifferent to the preservation of those very materials upon which the wealth of the corporations and our own salaries depend. No large corporation would to-day use an old boiler and slide-valve engine with a consumption of 6 pounds of fuel per horsepower hour in preference to a triple-expansion, cut-off engine which will do the same work with 1.5 pounds per horsepower hour, and so on through the whole gamut of operations which these large corporations conduct and which we, as their managers, advise them to adopt, because we believe them to be the best and most economical methods.

While public policy may not be the prime motive for saving, every thinking man in a large institution, from the manager downward, takes a pride in knowing that he is saving and feels a sense of shame when he is conscious of wasting. And in economic life—I do not speak of social and domestic life—the rules against waste are becoming more and more rigid and are better enforced. The public outcry, therefore, against the large corporations for wasting the natural resources of the nation is unjust, in so far as it fails to recognize what they have done and are doing in the direction of conservation, and inasmuch as it gives the working staff of these great corporations so little credit for the marvelous progress the world has made through their instrumentality. They have saved where formerly, through ignorance and inexperience, their predecessors

were wasting. With more profound knowledge and better instruments for observation and investigation they are patiently unraveling nature's secrets and learning how to turn her forces to human uses. I cited a case of the unavoidable waste of copper ore, of fuel, and of human labor in the treatment of the oxidized copper ores of Arizona twenty years ago. The men who were wasting acted upon their knowledge and skill. So now it often happens that in response to the urgent call which modern society makes by fits and starts for enormously increased productiveness of various commodities, the demand can be met only at the expense of waste of nature's resources, of human energy, and even of human life. If a more staple balance could be maintained between supply and demand; if the current of domestic and economic life would run more smoothly; if wealth were not accumulated so easily and spent so lavishly; if those marvelous improvements to which we have referred were not periodically made, which give these irresistible impulses to world-wide human energy, thereby bringing about these oscillations between hard times and good times, between labor dearth and labor surplus; if all these disturbing elements were obliterated, certainly there would be less waste, and possibly there would be more happiness. But it is neither our part nor within our power, as mining and metallurgical engineers, to reconstruct society or renovate the world. Yet it is our duty to continue using our best efforts—whether the world recognizes our merits or not—to get the utmost energy out of human life as well as out of the inert material we handle, with the least possible exhaustion of human tissue and the smallest possible waste of mineral or vegetable material.

DISCUSSION OF THE PAPER OF JAMES DOUGLAS, PRESENTED AT THE NEW HAVEN MEETING, FEBRUARY, 1909.

James Douglas, New York (communication to the secretary[a]): In my paper on the Conservation of Natural Resources I referred to the slow replacement of beehive ovens by the by-product ovens as a most notable instance of waste. And I quoted from Mr. Parker's report for 1906 an explanation given by him in accounting for the small production of by-product coke. It was that the market for the by-products of the coke ovens was so limited that some of the ovens constructed were out of operation. His report on the manufacture of coke in 1908[b] does not record an improvement, and at-

[a] Received February 2, 1910. Reprinted from Transactions of the American Institute of Mining Engineers, 1909, pp. 341-343.

[b] Mineral Resources of the United States for 1908, Part II, U. S. Geological Survey (1909).

tributes the strange fact that we alone of all the industrial peoples delay the adoption of this cardinal improvement from the continuance of the same almost inexplicable cause. To quote again from his report, he says (p. 241):

> The year 1908 was not marked by any notable gain in the construction of by-product coking plants, though some new work was done. There was a net increase of 115 in the number of completed ovens in 1908 over 1907, the totals for the two years being, respectively, 3,892 and 4,007. The additional equipment consisted of 140 Koppers regenerative ovens built at Joliet, Illinois, by the United States Steel Corporation, but this increase was partly offset by the dismantling of 25 Semet-Solvay ovens at Sharon, Pennsylvania, the net gain being 115 ovens. Included in the total of 4,007 completed ovens in 1908 are 152 Newton-Chambers ovens at Vintondale, Pennsylvania, but as no recovery of by-products was made at this plant in 1908, the production of coke is included with that from beehive ovens. The 56 ovens of the same type at Pocahontas, Virginia, have not been in practical operation since they were first installed. In addition to these there was one other by-product plant of 120 ovens that was not operated during the year. The number of retort ovens producing coke in 1908 was 3,679, as compared with 3,811 active ovens in 1907.

In describing the anomaly he says (p. 249):

> It has been contended that the development of the by-product coking industry would have shown more rapid progress if markets for the by-products were assured. This pertains essentially to the coal tar and its products, as there is no difficulty in disposing of the surplus gas, and there is practically at all times a fair demand for ammonia. As to the coal tar, the total value of this by-product from retort ovens at first hand in 1908 was $1,007,613. The value of the coal-tar products imported into this country in 1908, including duty paid, was $8,560,406. The values in all cases of imports are at point of shipment, and do not include ocean freights, commissions, and other expenses. It is probable that these importations have reached the consumer at a total cost of not less than $12,000,000, and in the three preceding years the cost probably reached $15,000,000.

These coal-tar products, however, which are imported into the United States at such a heavy figure, are all chemical extracts from coal tar, such as salicylic acid, aniline dyes, and alkaline salts, the manufacture of which has passed in great measure into German hands. Some peculiar attribute of the German temper, and the thorough character of their technical educational methods, have given them a monopoly of this delicate branch of the chemical industry. Even England, where originated the manufacture of the coal-tar products, and where the first patents were taken out, has been unable to compete with her more precise and painstaking rival.

As the utilization of the tars is therefore the function of the chemical manufacturer, and the production of the crude material alone falls to the coke maker, the one industry must keep pace with the other if progress along either line is to be made. As the profits of certain European coking plants collecting the by-products are

generally supposed to be from $0.75 to $1.25 per ton of coke on the by-products alone, it would seem as though capital, skill, and science could not be more profitably employed in the United States than in removing this crying disgrace by turning the waste products from our coking establishments to such profitable use.

With regard to what will happen in the distant future when our coal supply is exhausted, Dr. Robert Thomas Moore, in his presidential address[a] before the Institution of Mining Engineers in London on May 27, 1909, says (p. 455):

> Whether, indeed, it is a profitable matter to attempt to imagine the state of Britain three hundred years after this, with its coal exhausted, or a world, say, two hundred years later when it is all finished, is open to question. It is certainly beyond the scope of the objects of the Institution.
>
> I do not think it commends itself as an economic principle to restrict in any way the legitimate development of our mineral resources. They are a source of wealth to ourselves, and we are helping to develop the world. Is it not more reasonable to trust to the progress of science to discover some fresh method of utilizing the resources of nature to provide a substitute? Who would have expected, even thirty years ago, the immense possibilities for distributing light and heat and power that the development of electricity has opened up? We have the forces of the rainfall, the wind, and the tides to utilize to the utmost. We may even get our heat and power direct from the sun!
>
> Those who come after us have a long time in which to consider the problem, and we may safely leave it to them to solve in their own way.
>
> But that of which we should be careful is, that we should use our coal in the best possible manner; that in the working of it and in the using of it there should be no waste, either of men, of material, or of treasure; and it is the duty of an institution such as ours to afford every aid to the presentation of any plan which will further the attainment of these objects.

His remarks upon the ever-increasing consumption of coal, despite the efforts of the engineer to economize, are worthy of quotation. He says (p. 453):

> It is a striking fact that notwithstanding all the improvements which have been introduced to economize coal in the various industries, the total consumption has gone on increasing. It seems as if the greater the economy becomes the larger is the consumption.
>
> There have been atmospheric engines, Watt's condensing engines, high-pressure engines, compound engines, triple and qaudruple expansion engines, turbines, and gas engines, each being an improvement on its predecessor, until the coal consumed per horsepower per hour has been reduced from over 10 pounds to three-fourths of a pound; the methods of iron smelting have been improved until the amount of fuel used has been reduced from 8 tons per ton of pig iron to considerably under 2 tons; the processes for the manufacture of gas have been improved; and the whole history of the century has been a long series of savings in fuel. Yet the total consumption goes on steadily increasing. It would seem that the more the cost of power is cheapened, the more are the purposes for which it becomes available.

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[a] Transactions of the Institution of Mining Engineers, vol. 37 (1908-9).

THE ANTARCTIC LAND OF VICTORIA. FROM THE VOYAGE OF THE "DISCOVERY."[a]

By Maurice Zimmermann.

It is now possible to measure the full significance of the results obtained by the great British national expedition of the *Discovery* to the Antarctic Land of Victoria and Ross Barrier during the period from 1901 to 1904. Prior to 1905 fairly abundant but preliminary information was furnished by the Royal Geographical Society of London, faithfully kept up-to-date by its former president, Sir Clements R. Markham, who had been one of the most ardent promoters of the enterprise. Then came the admirable account of the expedition by Capt. R. F. Scott, one of the most sincere, humane, and substantial, which it has been our privilege to read, and the book of Lieut. A. B. Armitage.[b]

Finally, there began to appear in December, 1906, under the direction of the Royal Society of London, the volumes of scientific memoirs. Their publication has been effected with remarkable rapidity, nine volumes having already appeared and an album of maps, of which the Geographical Society of London has assumed the expense of publication. The Royal Society had given the surveillance of elaboration of the various documents into the hands of a special commission and Sir Archibald Geikie, its secretary. The trustees of the British Museum took the collection of natural history in charge. The distribution of the collections and the selection of specialists was the work of Mr. E. Ray Lankaster, director of the Natural History Museum, and of Mr. Jeffrey Bell.

The scientific results appear in very luxurious form. The selection of paper, the beauty of the photographs, the abundant panoramic views and the colored plates, the frequent reproduction of

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[a] Translated by permission from Annales de Géographie, Paris, No. 98, 18th year, March 15, 1909.

[b] Capt. R. F. Scott, "The Voyage of the *Discovery*," London, 1905, and Lieut. A. B. Armitage, "Two Years in the Antarctic, Being a Narrative of the British National Antarctic Expedition," London, 1905.

certain documents for the reader's benefit, all attest a disposition to do the work on a very liberal scale.[a]

I. GEOLOGY.

Victoria Land, to-day elevated and clearly delineated, constitutes a chain, or rather a series of mountain chains extending in a nearly straight line from 71° to 83° south latitude, for a distance of nearly 1,300 kilometers. Some portions rise to an altitude of 3,900 meters, and it may here be remarked that none sink much below 1,200 meters. Victoria Land thus presents to the sea an imposing coast line in the form of an abrupt wall aligned at the foot by volcanic islands and a sea (350 to 500 meters deep, according to the soundings of Ross and the *Discovery*) which might well constitute a gulf. Doctor MacCormick, of the *Erebus*, believed that the entire chain was volcanic. The observers of the *Discovery*, which cruised nearer the coast, showed that this could not be so; the regularity and tabular aspect of the coast line and the readily perceptible lines of stratification indicating rather a plateau structure. Mr. Ferrar was later able to study close at hand a portion of the range which they have called the "Royal Society Chain," and to determine its geological structure.

The subbasement of Victoria Land seems constituted of a plateau of gneiss and crystalline limestone which elsewhere forms, on many portions of the coast, a belt or zone of some 1,200 to 1,500 meters mean height, in advance of the great tabular escarpment so characteristic, to which reference has been made. These foothills, or "avant-monts" are themselves separated by a north-south depression, or rather by a series of north and south valleys from the mountain wall, perhaps 3,000 meters in height, which succeeds it, and is cut up into pyramidal peaks. This structure is very plain for a distance of 400 kilometers between Cape Adare and Cape Washington; it is found also in the Royal Society Range. A sort of piedmont or low foothill region lies in front of the bold escarpment of the chain and is separated from it by a valley, the Snow Valley, filled by a glacier.

This platform of gneiss carries a series of beds some 3,600 meters in thickness composed, from below up, of granites, sandstone, and doleritic basalt. Mr. Ferrar noted in particular the escarpment of Cathedral Rocks forming the right bank of Ferrar glacier, as furnishing an epitome of the geological history of the region, with its base of gneiss, surmounted by granite and cut by granite dikes, while the upper horizons comprise a bed or sheet of dark dolerite capped

[a] The full title of the book is: "National Antarctic Expedition, 1901–4;" (*a*) Natural History. Vol. 1, Geology (Field Geology; Petrography). Vol. 2, Zoology. Vol. 3, Zoology and Botany. Vol. 4, Zoology; (*b*) Physical observations; (*c*) Meteorology; (*d*) Album of photographs and sketches with a portfolio of panoramic views.

by yellow sandstone (the "Beacon sandstone"). This aspect is presented with great uniformity, the pronounced color of the dolerite forming a contrast apparent even in the photographs, with the clear, often yellow or white tints of the sandstone. It is, nevertheless, ordinarily the strikingly horizontal sheets of the dolerite which constitute the crown of the cliffs and whence they derive their tabular aspect. The dolerite frequently alternates, moreover, in thin sheets of surprising regularity with the beds of sandstone, from which they are scarcely separable. Mr. Ferrar thinks that these volcanic outpourings have formed a continuous sheet, at present more or less eroded, and he calls attention, above all, to the fact that in spite of their striking regularity the beds have, beyond doubt, an intrusive origin, and there is nothing to indicate that they were superficial outpourings (lava flows). Mineralogically, this rock greatly resembles, according to G. T. Prior, the augitic diorite which, in form of dikes, cuts the granulite and gneiss of meridional India. The Beacon sandstone has a total thickness of about 600 meters. It is distinguished by the very evident stratification and horizontality of its bed, by a remarkable uniformity of texture, and by the vertical escarpments which it affords. These beds are in places impregnated by irregular dark bands, due to carbonaceous matter. Samples collected by Mr. Ferrar in the cliffs overhanging the glacier bearing his name were examined by the paleobotanist, Mr. Newell Arber. Unfortunately the impressions were too greatly altered to permit the drawing of exact botanical conclusions therefrom; but they were, nevertheless, regarded as of vegetable origin, though no opinion was rendered as to geological age. One can only draw the conclusion that at some earlier, undetermined period, plant life flourished in latitude 77° 30′ south.

The complex of sandstone and dolerite of Victoria Land has been studied in detail only in the Royal Society Range on an area that Mr. Ferrar estimates at 7,000 square kilometers; but it probably occupies as vast an extent to the south as to the north. The reports and photographs of Lieutenant Shackleton, and, above all, the marvelous panoramic drawings of Dr. E. A. Wilson, show that even above 80° of latitude the same horizontality of the escarpment prevails. During a period of some weeks the three men of the southern expedition skirted along this escarpment, the summits of which appeared, according to the angle of view either as table-land or as pyramidal peaks. These "massifs," of which Mounts Longstaff and Markham, latitude 83° south, mark the terminal boundary, with altitudes of 3,150 and 4,600 meters, are ordinarily upward of 2,000 meters. They are divided into five distinct groups by four fjords or inlets into which debouch immense glaciers and to which were given the names of the officers of this expedition. The four inlets, then, are, from north to south,

Skelton, Mulock, Barne, and Shackleton. In this assemblage of mountains, seen for a distance of 700 kilometers, Captain Scott and his companions had for a long time as a familiar landmark Mount Albert Markham (3,200 meters), which they had at first named "Table Mountain," and its southern satellite of geometric aspect, Pyramid Mount. Elsewhere, toward latitude 74° 30′ south, Mount Nansen, with its plainly horizontal crest and abrupt escarpments, recalled strikingly to mind the Table Mountain of Cape of Good Hope. Finally, in the excursion that he made to the east and which carried him 450 kilometers into Victoria Land, Mr. Ferrar, in company with Captain Scott, reported that the geographic features we have described continue as far as land remained visible. In proportion as one advances into the interior, the inland ice submerges the mountains. The ancient rocks of the subbasement are first to disappear, then the lower and upper bed of sandstone. The last peak, the "Depot Nunatak," presenting only a huge mass of columnar dolerite of an actual height of 2,330 meters, but projecting only 150 meters above the snow fields. This is situated about 95 kilometers from the coast and in complete isolation, since separated some 13 kilometers from the dolerite crowned table-land to the east.

It appears that the eastern escarpment of the mountains thus constituted corresponds to a profound north and south line of fracture. The escarpment thus formed has evidently undergone a reelevation which Mr. Ferrar believes to have been recent, since the beds of both dolerite and sandstone were dissected by erosion before the tectonic movements occurred to disarrange the continuity of the latter. That these tectonic movements occurred is attested by the fact that the sandstones, without losing their horizontality, have undergone a reelevation *en masse* in those chains that border on the coast. Thus is explained the fact that the Royal Society Range affords altitudes of 3,000 to 3,900 meters (Mount Huggins 3,918 meters, Mount Lister 3,960 meters), and that the outlines of the coast, so clearly reelevated and cut by the profound breaches of the glaciers take on a pyramidal aspect. Farther into the interior, toward the inland ice, the altitude is peculiarly less; Knob Head 2,530 meters, Beacon Heights 2,400 meters, Depot Nunatak 2,330 meters. This last height is maintained for immense distances over the interior ice sheet. There is, then, no reason for surprise that the lands which have a constant tendency toward a diminished elevation toward the interior become finally entirely submerged by the snow fields of the inland ice cap.

The probability of a line of fracture is confirmed by the alignment of the isolated volcanic cones which are arranged along the low hills immediately bordering the coast, in constant parallelism with the mountain wall. These cones are individually distinct.

That of Cape Jones (73° 30′ latitude south, 170° 30′ longitude east from Greenwich) may be taken as the type. Of the same general class are Cape MacCormick (72° latitude south); Mount Brewster, 900 meters; Mount Melbourne, 2,540 meters; Mount Evans and, finally, the twin cones of Mount Morning, 1,760 meters; and of Mount Discovery, 2,770 meters, adjoining the Royal Society Range. It is to be noted that there are no cones between Cape Washington and Cape Bernacchi, over a distance of 3 degrees of latitude, and that this gap accords with the disappearance of the zone of gneissic hill constituting the foreland of the mountains. The mighty chain of the Admiralty to the north of Mount Melbourne is, in its turn, preceded by a coast uniformly constituted of basalts and tuffs, of which the principal type known is the promontory of Cape Adair, now celebrated because there was witnessed the first landing upon the Antarctic Continent. This abrupt basaltic coast appears to extend without interruption, with altitudes of from 300 to 600 meters, between Cape Adair and Cape Jones.

Beside these cones and coulées of basalt, Ross Sea is besprinkled by a series of archipelagoes and volcanic islands, sometimes notably distant from the shore, as is the case with Franklin Isle (76° latitude south) and Ross Island. These succeed each other from north to south, Coulman Isle, the Possession Isles, Franklin Isles, and Beaufort Isle, and, finally, Ross's Archipelago. The group has been studied close at hand by the *Discovery*, the winter quarters of which were situated at the south point of Ross Island.

It is in Ross Island that rear themselves the two famous cones Erebus (3,938 meters) and Terror (3,278 meters), discovered in 1842 by Ross. Mount Erebus was then in eruption and was emitting flames and smoke in abundance. During the two years' sojourn of the expedition of the *Discovery*, the cone was covered with a perfectly white blanket of snow from base to summit and but little smoke was seen issuing from it. The observers of the *Discovery* have reported that two other cones contribute to the form of Ross Island to which they give a triangular outline, Mount Terra Nova and Mount Bird. The island, situated between 77° 9′ and 77° 49′ south latitude, is about 80 kilometers on each side; the diameter of each of the grand volcanoes is about 35 kilometers. The soundings made in the waters that bathe the island have revealed the curious fact that the depth is greater near the shore than toward the open sea. It is impossible to determine whether this increase of depth, with marked decrease on the side of the open sea, results from the additional weight imposed upon the crust by the colossal accumulations of material or from a depression due to the vacuums which are produced in the depth. The contours of Mount Erebus, the appearance of which on the whole is very massive, indicate three

successive phases of eruption in the history of its formation. The first was much more violent than the others; it gave birth to a cone about 13 kilometers in diameter. The walls of this crater are still standing and form about the present cone a circular wall, a sort of "Somma," about 1,800 meters high. To the second stage of activity belongs the rim of a higher crater (3,350 meters). Certain coulées, bared of snow, can still be distinguished. Finally, the present small crater was built in a symmetric position in the interior of the preceding one. It is from this crater that the vapors now issue. Many other jets of vapor, not visible from the ship, may have been observed by Doctor Wilson. The general appearance of the volcano recalls very closely that of Etna; the dome shape is much more perceptible than in the better known active volcanoes.

II. GLACIATION.

The glaciation of Victoria Land is much less intense and less exclusive than is generally supposed. This, however, is far from meaning that it is mediocre. This glaciation should be studied by and for itself, and in comparison with all that is known in the boreal world, with the possible exception of certain far distant portions of the Arctic region, as the extreme north of Greenland, constitutes a new and original type. The very numerous and beautiful photographs, and above all the panoramic views published in the account of the expedition, present at a glance the full extent of these phenomena.

The type is characterized by features unknown elsewhere. The Piedmont glaciers (which we would call simply "fringing glaciers," or "de rivage") and floating barriers, which Mr. Ferrar classes wrongly, as we believe, with the Piedmont type. It is also characterized by the unusual and inexplicable manner in which the snow is transformed into ice. One can not see directly this transformation. The actual climatic conditions are such that thawing, either partial or local, is exceptional, and all the surfaces were formed either of white granular snow or of compact ice. Even at the head of Ferrar Glacier the transformation of the snow into ice is absolutely abrupt, and along the foot of the grand cascades the ice presents the banded surfaces so characteristic of snow. In the slightly elongated depressions there are local accumulations of snow, but the line separating the granular snow from the glacier ice is always abrupt. If one can not perceive the manner of the transformation, nevertheless one is obliged to recognize the fact that it is accomplished with extraordinary facility. Very little snow suffices to give birth to a glacier, and one is struck with the disproportionate size of the glacial lobes as compared with the extent of

their gathering ground. Numerous glaciers are formed with insignificant reservoirs of snow. Nay, more; such a glacier, cut off from its feeding ground by the gradual cessation of the glacial phenomena, continues, nevertheless, to give rise to the ice slabs, which represent nothing more than lobes no longer supplied with snow, and without doubt deprived of motion. This observation will suffice to show the difficulty of comparisons with familiar glacial forms, such as those of the Alps or Norway. An appearance purely superficial and fallacious has led Mr. Ferrar to group certain glaciers of the Cathedral rocks and the Kukri Hills, which border the Ferrar Glacier, among the Alpine glaciers. Certainly their régime, their physiology, if we may so call it, is not Alpine. Finally, one general trait seems to us to characterize the glacier, properly called, of Victoria Land. It is the surprising contradiction which exists between the very marked external appearance of glaciation and, on the other hand, the slowness of its evolution, which seems to-day to reach the point of almost complete stagnation. To be sure, the observers of the *Discovery* have not made many measurements because of the great distance of their winter quarters from them. Nevertheless, Mr. Ferrar gives some interesting estimates. The south arm, the meridional feeder of the Glacier Ferrar, beyond question does not advance into the east fork at a rate greater than 6 English feet a month. The Blue Glacier, one of the independent glaciers which cover the gneissic foothills, advances at a rate of less than 4 English feet a year. The fact that the crevasses of the Ferrar Glacier remain always covered with snow is explained by these insignificant figures, as is also the fact that neither the Ferrar or Blue glaciers cause any marked disturbance in the fringe of coast ice.

Really, then, one would have ground for saying that the glaciers of Victoria Land are inactive; that they have no motion. What is a rate of 6 centimeters, or one-fourth of a centimeter a day, compared with the figures to which the lowest of the Alpine glaciers have accustomed us? It is difficult, too, after the facts to which the glaciers of our own mountains or of the boreal world have accustomed us, to imagine a glacial covering of such magnitude as shown by the photographs of the Ferrar Glacier, or above all those of the Royal Society Range. From base to summit, except for rocky surfaces of little extent, the mountains of this range are buried beneath snow and ice; only the surfaces turned toward the east and the south seem notably free (particularly the slope south of the Kukri Hills). There is therefore every external appearance of intensity of glaciation, and at the same time stagnation, almost complete rigidity of this frozen cuirasse. That at some point these masses of ice are in a state of tension the following observation proves: In the midst of the amphitheater of the Ferrar Glacier

networks of tiny crevasses are formed, with loud explosions, as soon as the mountains cast their shadow on the ice. The detonations sometimes last for an hour and a half, and crevasses of 50 meters length, traversing the surface of masses of ice 30 centimeters thick, have been seen produced by the blow of an iron rod. The glaciers of Victoria Land are thus in a state of equilibrium, or rather or inertia, quite without counterpart and wholly unexpected for these latitudes. But though this glaciation may appear to be highly developed, yet it is nevertheless in a marked state of recession. The Antartic no more escapes the law of glaciary decrease, the proofs of which have been accumulated in the last years over the entire globe, than do the latitudes of Grahams Land, as reported by the expeditions of the *Belgica* and by Nordenskjöld. The north fork of the Ferrar Glacier no longer reaches MacMurdo Sound; the glacier has retreated far toward the interior of the land, leaving in its place a valley bed about 15 kilometers long, encumbered with morainic materials, and in which occur, not far from the actual extremity, three constantly frozen glacial lakes. More striking yet seems the retreat in the system of glaciers formerly dependent from Snow Valley. This valley occupies the depression which separated the Royal Society Range from the gneissic foothills; it served as the gathering grounds for a series of glaciers, the sole remnant of which is now the Blue Glacier. All the other emissaries of Snow Valley are to-day cut off by cross melting from their reservoirs of supply. They exist, nevertheless, in the state of ice slabs. Thus, one counts a symmetrical succession of seven ice slabs in the ravines which descend precipitously from the gneissic foothills toward the MacMurdo Sound.

Without seeking the cause of such retreat, which seems to be general, and which is also observed, as will be noted later, in the Ross Barrier, certain reasons present themselves at the outset to one who seeks the explanation of the indolent glacial régime which we have just described. First of all is the natural dryness of the climate of Victoria Land. This climatic trait is clearly brought out by certain geological observations; the insignificance of the rôle of water in effecting erosion and the persistence in place of their formation of certain salts, as sulphate of soda and carbonate of lime, due to the chemical decomposition of the rocks. A white powder sometimes covers the surface of the rocks, and there is found on the floating ice heaps 2 feet in height and from 4 to 5 feet in diameter, composed entirely of glauber salt, due to the progressive freezing out of the salt as the water congeals. To this dryness of climate, which is attested also by the small quantity of annual snowfall, is added the action of the wind, which does not content itself with the slow work of polishing, drilling, and chiseling the rocks, as in ordinary desert phenomena;

it does with the snow what the desert wind does with the sand and the loess; it reduces it to an impalpable powder which it drives about unceasingly, darkening the atmosphere and forming dunes of it, which it then destroys and drives bodily into the sea. Thus it happened that a sledge party was held up six days and a half on the edge of the inland ice by a tempest howling at the rate of 80 kilometers an hour and so charged with snow dust that objects 10 meters away could not be distinguished. One will appreciate much better the extent to which such a storm can retard the rate of growth of the Victorian glaciers when it is known that a day without a driving snow is an exception.

Mr. Ferrar, as well as Mr. J. Gunnar Andersson of the Nordenskjöld expedition, attributes to the wind a good share in the diminution of the antarctic glaciation. We believe, nevertheless, that there must be a much more general cause. Nothing indicates, indeed, that this action of violent winds carrying to the sea a notable part of the fallen snow is not a very ancient and fundamental phenomenon of the antarctic climate. It has by no means prevented glacial phenomena from attaining proportions which have elsewhere no counterpart. This local peculiarity would also not account for the singular concordance of the retreat of the antarctic glaciers with the diminution of glaciers all over the earth.

The observations that we have just summed up are applicable on the whole to the only group of glaciers which have been thoroughly studied on the antarctic continent—that of the great Glacier Ferrar and its satellite or its analogous Koettlitz, Snow Valley, and Blue Glacier. It is the principal merit of Mr. Ferrar to have studied carefully, from the glacialist's point of view, a portion of the long range of coast which is presented by Victoria Land for a distance of 1,300 kilometers.

It seems that the Ferrar glacier is a type frequently reproduced. The abrupt wall of Victoria Land is dissected by a large number of inlets, of valleys both broad and deep, into which run at a singularly low level glaciers uniformly emissaries of the inland ice. According to Mr. Scott very few of these emissaries could possibly be active. He divides them into two classes, living emissaries and dead glaciers. For a distance of 11 degrees of latitude from Cape Adare to Mount Longstaff, Mr. Scott recognizes only four active glaciers serving as a channel of discharge for the inland ice. The first probably empties into Lady Newnes Bay; the second issues at about 75° latitude south; finally, the last two observed during the trip toward the south probably filled the two large valleys of the Barne and Shackelton inlets. The Ferrar glacier, on the other hand, seemed to him a type, gigantic, of the dying glaciers. Its ancient limits have been recognized up to a height of 900 to 1,200 meters. It is

notable in this connection that Mr. Scott declares the inland ice which is maintained over vast reaches at an altitude of 2,300 meters, has likewise diminished from 120 to 150 meters. It is, then, permissible to make the following hypothesis: The inland ice of Victoria Land, which still offers to-day such grandiose proportions, can not escape on the side of the chain of mountains which raises its formidable wall up on its eastern coast. This acts as a dam which it has been able to override easily only at a period of very intense glaciation, when the fields of snow attained a much higher level. Its natural flow probably follows another direction, and it is doubtless on the side of Wilkes Land on the Clarie and Adelia coast that one must seek for the principal discharge of the inland ice of Victoria Land.

As has elsewhere been mentioned, the Clarie coast, that barrier of continuous ice over a distance of 20 leagues with a height of from 38 to 42 meters, as depicted by Dumont d'Urville, seems the exact equivalent of Ross's great barrier. Everything leads to the belief that between this Clarie coast and Cape North, which is at present the recognized terminal of the Admiralty (?) Range to the northwest, other barriers of the same kind, the probable end of the Victorian inland ice, will some day be revealed.

These ideas have been suggested by the following observation: The counter proof of the great glacial activity in the antarctic regions as in Greenland, is the icebergs. Now, Mr. Ferrar expressly states that very few of these come from the ruptures in the cliffs of Victoria Land so far yet known. In the space of sixteen months the Blue glacier has not furnished a single one, and the contributions of the Ferrar glaciers is without doubt negligible. Feeble also is the supply of the local glaciers which fringe the banks or encircle the islands, and to which Mr. Ferrar, using a term invented by Mr. I. C. Russell, applies the name "Piedmont Glaciers of the Continent," or "stranded glaciers." There scarcely can result from them anything except secondary or irregular icebergs. In fact, the great majority of the antarctic icebergs come from what Mr. Ferrar calls the "piedmonts afloat" (floating glaciers), and which we shall call by their old name of "glacier barriers." We can not, indeed, subscribe to the designation proposed and employed by the English geologist for the formation of the extraordinary glaciers. It seems to us that it is out of a pure desire for symmetry and classification that he feels himself obliged to class the Ross Barrier among the Piedmont glaciers. Moreover, we still know very little of the famous barrier, though the explorers of the *Discovery* have trod its fields of snow, and Captain Scott recognized it toward the south for more than 4 degrees of latitude. We are entirely ignorant of its origin, and we do not even know whether it constitutes a true piedmont, that

is, whether it comes down from a back country of mountains. The difference is too great between these immense sheets of ice, prolonged for hundreds of kilometers and the thin fringes of ice at the most from 2 to 3 kilometers broad which constitute ordinary piedmont glaciers. This difference lies not only in the dimensions, but in the mode of conduct. The rapid movement of glacial masses, which we have vainly looked for in the continental glaciers, is indeed realized in the Ross Barrier, the measurements of Lieutenant Barne, taken at the approach of Minna Bluff, having furnished a figure of advancement amounting to 608 yards (555 meters) in thirteen and one-half months, or about 1.35 meters as a mean per day. This is, however, a very slow rate compared with that of the great glaciers of Greenland, the Karajak and the Jakobshavn, the maximum progress of which is not less than 18 to 20 meters per day. But one could hardly expect a movement of such rapidity from a sheet of ice which presents to the sea a front of more than 800 kilometers, and which appears due to the confluence and the union of several large glaciers in a wide and shallow bay. Supposing the movement of the original glaciers to be very rapid, it must be continued at a notably slower rate in this enormous outspread sheet which is pushed outward after the manner of a delta. Admitting, with Mr. Ferrar, that the Ross Barrier does originate through the union of several fjords of ice, one will at once see the entire difference between a glacier of this type and the ordinary "piedmont."

Ross Barrier has been studied with care by the *Discovery*. A rigorous following out of its edge was undertaken, a matter made easy by steam navigation, and which Ross found impossible of accomplishment, the imperfection of navigation by sail alone compelling him to estimate many of the heights from a distance. The Barrier is, in fact, neither as high nor as regular in outline as described by Ross. Captain Scott describes it as 21 meters in height at the beginning and for some distance. On January 23, 1902, a height of 62 meters was registered, successive measurements giving on the 24th, 72, 24, and finally 15 meters; one on the 25th, 9 meters, and later 24 meters, when it fell abruptly to 4.50 meters. On January 28 measurements of 17 to 45 meters were recorded, and on the 29th as low as 1.20 to 1.50 meters. It is, therefore, not a uniform wall of ice, and the height of 45 meters attributed to it is simply a mean. The great differences in altitude are productive of equally striking difference in appearance. At times this change indicated that one portion has been longer exposed to atmospheric agencies than another. Much of the time, however, the changes are so gradual as to escape notice when viewed from a distance, the higher portion seeming simply nearer. In Balloon Bay the height was but 3 meters, but on the other hand where it

abuts against the northeast flank of Edward VII Land the higher parts reach the extraordinary altitude of 84 meters.

The most surprising feature in the reports brought by the *Discovery* concerning Ross Barrier relate to its floating character. Sir John Murray has confessed that while difficult to believe, and while he could not make up his mind that all was floating, he could but admit that the border over an extent of 30 to 40 miles was actually in this condition. The facts brought out by Captain Scott seem nevertheless conclusive. At first sight, there can scarcely be a doubt that its terminal edge from Mount Terror to Balloon Bay (longitude 163° west from Greenwich), where the *Discovery* penetrated it, and which seems to mark the lower limits of Edward VII Land, mean depths of 360 to 550 meters were reached by soundings at the foot of the Barrier. The ice cliff has a height of scarcely 45 meters above the surface of the water. It is composed of porous ice which can scarcely be submerged for more than six-sevenths of its mass, probably 250 meters or more. It follows, therefore, that it is separated from the sea bottom by 100 to 300 meters of water. Another decisive argument is that the ice cliff partakes gently of the movements of the sea. During their stay in the eastern channel, to which reference has been made, it was ascertained that the ice rose and fell with the vessel. At the east of Mount Terror and White Island there is developed a formidable zone of crevasses, which attains its maximum at Cape Crozier, where the Barrier is crushed against Ross Island and forms five gigantic pressure ridges oriented north and south and continuing for a distance of over 50 kilometers at the least. One recognizes in this chaos a line of fracture of the Barrier in connection with the tides (tide cracks), and resulting from a differential movement of the glacial walls. Along Victoria Land to the extreme south the immense glaciers of Shackleton and Barne inlets tend by their movement to push the barriers away from the land. There results from this a region of chaos; the surface of the sheet undulates in long ridges, is rifted with crevasses and with veritable chasms encumbered with a confusion of glacial débris and of new material fallen from the littoral heights which extend between the barriers and the land. But at 10 miles from the coast all of the inequalities disappear and the monotonous surface of the great snow plain without ridge or crevasse extends until lost to view. Captain Scott thinks that no mass of ice reposing on the firm land could be deprived of irregularities to this extent.[a]

[a] This last argument, nevertheless, seems to us not irrefutable. The Malaspina Glacier (St. Elias chain) extends to the foot of the mountains upon a low alluvial beach. This, too, constitutes a monotonous plain of snow of considerable size (35 to 40 kilometers) without crevasses, of which the line of the

In the same way great networks of crevasses are developed over 15 to 30 kilometers in the offing of Minna Bluff and White Island. There, regularity and parallelism are so striking that one can not believe in the existence of a terrestrial base, which would certainly bring about irregularities of tension in the mass. Finally, and this is more important, the long voyage of Captain Scott was effected on a horizontal plane; the corrected reading of the aneroids leaves no doubt on this subject. The only indication of a rise in level appeared at the end of the journey; but they were then quite near land, at the entrance of the Shackleton Inlet, and this rise might be foreseen. It is remarkable that no trace of foreign matter could be seen inclosed in the ice along the front of the barrier and no rock débris on the surface except in very close proximity with the land; yet this débris may be rare because of the chasms or gulfs referred to, which prevent the blocks from remaining on the surface of the sheet. Only where the ice rests directly on the shore, as at Minna Bluff or toward the Black Island, are there developed enormous moraines attaining a height of 15 meters, and the elongated faisceau of which ends in the bottom of the McMurdo Sound. These moraines, covering a surface of floating ice, have one singular feature; they are composed of a series of cones of débris which are connected with one another, following the direction of the glaciary movement. In these moraines are found blocks of more than a meter in diameter, but erosion reduces these quickly into masses of coarse sand which the wind scatters and which, because of their dark color favoring the fusion of the ice, gives rise to little streams which are indirectly the cause of the cutting up of the glacial front of MacMurdo Sound into an intricate notched zone, difficult for the sledges to traverse.

The great tabular antarctic icebergs can only come, Mr. Ferrar expressly states, from formations analogous to Ross Barrier—that is, from floating barriers. That is to say, that this class of glaciers is universally distributed throughout the Antarctic Zone, since the tabular icebergs are met with in great numbers in all oceanic regions around the southern ice cap. And, in fact, one can compare with it the west ice, that tongue of floating ice observed by the scientists of the *Gauss* to the west of their winter quarters, and also the terrace of partly submerged ice pointed out by Otto Nordenskjöld as belonging to King Oscar Land and prolonging the continent toward the east. It is probable that similar glacial formations, submerged in relatively shallow seas and of small extent, have accompanied the glacial epochs in Europe—the Irish Sea, the North Sea, the Baltic; perhaps

horizon is rigorously horizontal. One can refer in this connection to the great panoramic view of Victoria Sella, published in F. de Fillippi, "La Spedizione di il Principe," Luigi Amedeo di Savola al Monte Sant'Elia, 1897, Milano, Hoepli, 1900.

a great part of the Norwegian continental plateau. Certainly the whole of Barents Sea must have been covered with glacial sheets of this type. Although these are hypotheses, the observations of the *Discovery* authorize the conclusions; it is this which assures them a high general bearing.

Like the other glaciers of this part of the antarctic world, the Ross barrier is in a retrograde condition. It has receded an average of 24 kilometers from the positions which were fixed by James Ross, but the retreat is in places equal to 35 and even to 50 kilometers. If one sums up the annual advances of the glacial masses during sixty years, an estimate is reached of the enormous surface of icebergs which must have been detached from the barrier during this lapse of time. Captain Scott thinks that the barrier must have occupied positions much more northerly, that the retreat has been very rapid, and it is by this ancient extension that can be explained the many remnants of glacial sheets still adhering to certain points of Victoria Land. Thus Lady Newnes Bay is filled with one of these remnants which the existing conditions of glaciation do not explain. The surface of it forms long undulations and its mass is probably floating. Of the same class are perhaps the barriers Drygalski (75° 30′ south latitude) and Nordenskjöld (76° 30′ south latitude), of which it is not known whether they are glacial lobes or the fragments of ancient barriers.

The ancient barrier then probably advanced to the height of Cape Adare. Captain Scott thinks that at first it rested on the bottom of Ross Sea and aided in leveling it. Then, the quantity of ice diminishing, it probably became floating and commenced to break up and retreat rapidly. It is not, then, beyond our concern to know the composition of the bottoms of the Ross Sea. It has been determined that on the site of the former front observed by Ross the bottom is formed of a yellow, tenacious, and consistent clay containing tests of foraminifera, frustules of diatoms, and spicules of sponges. There is likewise clay 10 degrees farther north near the Balleny Isles. The bottom of the Ross Sea is composed of mud resulting from the pulverization of rocks by the great glaciers of the south Victoria Land.

Face to face with the grand development, in the main, of the glacial phenomena of terrestrial origin one is surprised at the slight power and duration of the marine ice. This trait fixes the physiognomy of Victoria Land. The fields of ice may reach great horizontal dimensions, but their thickness in Ross Sea never exceeds 6 English feet (1.80 meters). The hummocks never exceed 3 feet in MacMurdo Sound, and Mr. Ferrar asserts that the direct increase of the ice can scarcely exceed 8 feet, since it breaks up, he thinks, each summer. The cause of this mediocrity of the sea ice is thought to have been doubtless the temperature of the water of Ross Sea,

high enough to melt the ice fields from the under surface; finally the pressure which the fringing glaciers of the coast never ceased to exert upon the ice fields. The sea ice is thus broken by a slow, almost imperceptible movement which tends to push it out to sea and which Mr. Ferrar calls "creep." It thus finds itself in proper condition to undergo destruction by the swell of the sea during the summer months.

In general, the fringe of ice which encircles the coast is of land origin and comes from the accumulation of snow. There are, nevertheless, examples of ice bunches of purely marine origin, veritable "ice feet," in the class of the great arctic "ice feet," but much more restricted in size, rarely attaining a thickness of more than 6 feet. Mr. Ferrar cites an example of this in Granite Harbor. This kind of a fringe acts toward the land in a conservative rôle, retarding erosion by impeding the direct action of heavy surf and in cementing the loose débris and transforming it into a talus protecting the cliffs.

III. METEOROLOGY.

The data brought back by the *Discovery* relative to the climate of Victoria Land are of equal interest with the geological or glacial observations. The winter station, so favorable to long excursions, commended itself first by its advanced polar situation (77° 50′ 50″ south latitude and 166° 44′ 45″ longitude east from Greenwich). The selection was, moreover, very fortunate because in the midst of the large MacMurdo Sound, surrounded by a circle of low hills, largely bare, the observations would convey a better idea of the true climate of the region and would not be vitiated by foehn phenomena or by the excessive protection of the high hills. Moreover, it was possible to observe with great precision the direction of the currents of the upper air by the behavior of the column of smoke from Mount Erebus.

Below are given some of the mean monthly temperatures, deducted from the bihoral observations covering a period of two years (February, 1902–February, 1904):

	Degrees centigrade.
January	— 4.4
February	— 9.6
March	—16.8
April	—24.5
May	—25.9
June	—26.1
July	—26.0
August	—27.0
September	—26.3
October	—22.0
November	—10.2
December	— 4.1
Annual	—18.5

All the minimum extremes occurred during the winter of 1903, ranging between −47° and −50°. The lowest figure was observed September 20, 1903, at 2 a. m., −50.2° C. On the other hand, the greatest extreme of summer never exceeded +3.8° to 5.5° C. (in December); but this transitory maximum would give a false impression of the temperature of this "beautiful" season. In reality during the two years of winter quarters there were noted only five days of a mean higher than 0° C. and this did not exceed 1.5° C. The highest monthly mean effectively observed was that of December, 1902, and this did not rise higher than −3.2°. Finally, if one sums up the summer months of 1902–3 and 1903–4 there is reached for the six months the incredible figure of −6.3°.

On account of this low temperature there is no precipitation in the form of rain, but always of snow. This fact strongly impressed Mr. W. H. Dines as one difficult of explanation, unless it is due to the fact of the extraordinary dryness of the air and the intensity—unexpected in a region completely covered by ice—of the rate of evaporation. Otherwise the temperature during the summer would rise at least as far as the freezing point of water, as it does in the arctic regions, where the sunshine is, however, less brilliant. But the hygrometric observations show a relative humidity along the coast of Victoria Land comparable with the more arid regions of the globe. This aridity is accompanied during December with a very intense sunshine; it is, in fact, almost as strong as at Madras in June, and the extremes of temperature between sunset and sunrise are from 47° to 66° C. It is not rare, especially in December, to see the sun shine in a clear sky for several days. For a period of twelve consecutive days the sun has been known to shine with but a totality of five hours of cloudiness. Consecutively, all glacial surfaces soiled by dirt or near-dark-colored rocks melt rapidly in the sun. In the southern part of Victoria Land there are frequently found beds of sand and gravel, the result of years of concentration, embedded in the cliffs, remnants of ancient glaciers. These beds of old ice, the last witnesses of a much greater glacial sheet, are in summer subject to very intense ablation, both by evaporation and by melting. Thus an immense solar radiation accompanies the very low temperatures of summer, a significant fact which throws some light upon the problem of glacial epochs in this boreal hemisphere.

One is struck, on the other hand, by this uniformity of the winter mean, which for a period of eight months was between −22° C. and −27° C. These low temperatures—and they are not extremely low—are maintained constantly at approximately the same figure. One would have expected effectively colder temperatures between July and September. The winter in the Arctic is, from this point of view, the most severe. The *Fram* noted uniformily, during a period

of three years, temperatures in the neighborhood of —35° C. between December and April. One can, perhaps, discover in this less severe antarctic winter the effect of a more intense atmospheric circulation. In reality these temperatures are extremely variable in detail. All changes in the condition of the atmosphere, changes of pressure or of wind, the transition from wind to calm, or vice versa, are in Victoria Land reflected by the temperature.

The periods of great cold always occur during periods of calm. The south wind, for some inexplicable reason, is relatively warm. In the midst of this intense cold of midwinter "one would see always appear as an oasis of heat." From another standpoint the station of the *Discovery* was, for little known reason, much less cold than the region round about, notably Cape Armitage, or Ross Island and Cape Crozier.

The amount of precipitation was from necessity measured by means of stakes, since all fell as snow; but in case of a storm it was not possible to say whether the snow actually fell from the clouds or was merely drifted by the winds. All exact observation was therefore impossible. There is nevertheless reason for thinking, judging from the constant height of the snow about the measuring stakes, that the actual amount of fall was slight.

On the other hand, the observations made on the rate of evaporation show surprising results. During the five winter months the rate of evaporation in MacMurdo Sound was, notwithstanding the low temperature, almost double the mean values observed at Cambridge Square (London) in a temperature 30° higher.

One asks how, in the presence of immense surfaces of ice and snow undergoing evaporation, so dry an atmosphere can exist. Mr. Dines thinks that Ross Barrier forms an anticyclonal zone, in which the beds of air are submitted to a continual descending current. From this point of view the atmospheric pressure observed, without clearly proving an anticyclonal zone, does not disprove the hypothesis. The barometric pressure was in fact much higher than at Cape Adare (71° south latitude) and at the station of the *Gauss* (66° south latitude).[a]

The decrease in pressure noted in going south, in the austral regions, does not persist indefinitely. The values calculated by Mr. Hann

[a] Here are the figures, reduced to metric measurements:

	Winter.	Spring.	Summer.	Autumn.	Annual.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Discovery	743.3	739.9	744.9	747.5	743.9
Cape Adare	738.4	730.4	742.8	740.6	738.0
Gauss	739.1	734.0	742.2	741.3	739.1

for 70° south are too low, much more so for 78° south; and Mr. R. H. Curtis, who discusses the observations, agrees with Mr. Shaw in thinking that at the South Pole or in its vicinity there exists without doubt an anticyclonal area in accordance with a pole of cold, comparable to that of Siberia, and on the circumference of which is developed a regular circulation of east winds.

It is indeed principally from the East that the wind blows into MacMurdo Sound, then from east-northeast and from the northeast. In correlation with this dominant direction of the wind the ocean currents in front of the Barrier are also directed from east to west. The winds from the north and southeast are less frequent; those from the south are rare, but the notable fact is the complete absence of west winds. The layer of air submitted to this régime is thin and scarcely exceeds 2,000 meters in thickness; the higher clouds and the smoke of Erebus showed in the higher atmospheric layers (about 4,000 meters) a direction of the wind diametrically opposite, that is, from west and southwest. On his excursion into the inland ice of Victoria Land, Captain Scott observed also that the east winds are at those heights replaced by west and southwest winds. It is a question what becomes of the masses of air rapidly brought in by the east wind, which scarcely goes beyond the mountainous edge of Victoria Land, and to what is due the absolute lack of the usual West winds on the inland-ice. Scott does not attempt to explain the ever-warm character of the south winds. We should be inclined to see in it the effect of a phenomenon of foehn sprung from winds which take their origin on the plateaus of the inland ice and the direction of which was probably originally southwest, but which underwent in consequence of their whirling movement a deviation of such nature as to transform them into south-north wind.

The wind has an extraordinary tendency to blow in squalls and on the other hand quickly dies down to a calm. In spite of the dramatic descriptions of the storms which exposed the expedition to such danger and ills, and which so obscured the atmosphere that two officers were lost within 30 meters of the ship, Mr. Curtis is not impressed by the extreme swiftness of the wind, which amounts to only 16 to 17 kilometers an hour. It is much less than at Valencia (Ireland) or on the Scilly Isles, where it reaches 25 kilometers. In spite of the long duration of certain storms the greater part of them are short. (There were 23 in 1902, and 33 in 1903.) They are especially frequent in winter and autumn, and have a tendency to dislocate the pack ice of MacMurdo Sound very early. To conclude, they are less frequent and less terrible than on the west coast of Great Britain. But the squalls are so furious and the driving snow which accompanies them so painful, that one is naturally tempted, according to Mr. Curtis, to exaggerate their force. In the course of these storms

it is often impossible to stand up in order to reach the near-by observatories.

The violence and duration of the east winds result in clearing the snow and ice from the slopes which are constantly exposed to it. The contrast is striking, as shown by the photographs in the Album, between the south and west slopes of Mount Terror, ordinarily sheltered and consequently entirely covered with snow, and the east and northeast face of Ross Island toward Cape Crozier, where the east wind, whirling tempestuously and tirelessly, lays bare the rock. The same contrasts appear in the Royal Society Range and on the various slopes of the Ferrar Glacier. Thus at certain points the wind, as Messrs. J. G. Andersson and O. Nordenskjöld have maintained, is violent enough to check glaciation. But we think that the retreat of Ross Barrier and of glaciation in general is much more attributable to the increasing dryness of the air, the intensity of evaporation, and the smallness as well as the uncontrolled nature of the snowfall.

IV. FLORA AND FAUNA.

In such climatic conditions terrestrial vegetation is almost entirely banished. A few mosses and lichens form the sum total. The *Discovery* brought back several specimens of mosses gleaned in Granite Harbor and on the lower slopes of Mounts Erebus and Terror. They are the most southern species known, having been gathered near 78° south latitude. Five of the seven gathered were already known from the Graham Archipelago from the Strait of Gerlach and bear witness to the uniformity of the antarctic polar flora. Mr. J. Cardet adds further "the greater part bears traces of the bitter struggle for existence to which they are subjected. All form extremely compact tufts, in order to be able to resist the pressure of beds of snow. The *Bryum argenteum*, a cosmopolitan species, presents itself here in so stunted a form that the longest stems measured did not exceed a length of 3 millimeters and the largest leaves reached only a length of 0.35 millimeters." The other species also show signs of degeneracy: deformed leaves, sick-looking stems, almost complete impossibility of ripening or even of developing a sporogone except in extraordinary circumstances.

As representative of terrestrial fauna, one can as yet cite only a single insect gathered in a tuft of moss from Granite Harbor. It is a blue Poduride of the group collemboles, of which representatives had already been found, belonging to a different family, in Robertson Bay, near Cape Adare. This minute jumping insect, the form of which reminds us of our Courtilieres, is, up to this time, the only terrestrial animal known on the continent of Victoria Land.

A sensation was one day created by the discovery of great imprints in the snow which at first suggested some large terrestrial animal; but they were soon recognized as traces of the webbed feet of the giant petrel (*Ossifraga gigantia*).

In reality, all the truly antarctic fauna are dependent on the sea and are limited to the floating pack-ice or to the coast glaciers.

The marine feeding grounds of Ross Bay seem to superabourd in diatoms. This at least is what we are led to believe by the extreme richness of the fauna which the more or less ephemeral pack covering conceals. Of their richness the naturalists of the *Discovery* had direct proofs through the fishery which was carried on constantly in spite of the covering of pack-ice, and also indirect proofs in the continual presence of seals and in the contents of their stomachs. A world of animal life thrives under the pack-ice; there are first, on the sea bottom, innumerable hordes of voracious amphipods belonging to the species *Orchomenopsis Rossi* of which a single dip of the net brought up from 10,000 to 30,000; the living fish used as bait were often devoured by them, leaving but the skeleton behind.

Mr. Walker thinks that numbers of seals which perish by asphyxiation under the pack-ice are devoured by these amphipods. An abundant fauna of Crustacea, Schizopods of the family of the *Euphausia*, move about with the fish and the cephalopods in the intermediary waters. The *Euphausia cristallorophias*, of which the expedition brought back 10,000 specimens, is the most common species under the ice; it is upon this species that the Manchots feed. It was not easy to procure fish owing to the seals, which move about constantly under the ice, having adopted the custom of robbing the nets. Nevertheless, the expedition brought back a certain number of specimens, mostly very small, belonging to the genera *Notothenia*, already studied at length by the Belgica, *Trematomus*, and *Bathydraco*. It is interesting to note that the seals procured for the expedition two very large fish, one of which was more than a meter long and 18 kilograms in weight. The fish of the cold seas being ordinarily very small, this detail attests the zoological richness of these waters. It should be noted that the waters of MacMurdo Sound are constantly renewed by currents and that their temperature scarcely varies more than 1° C. in the course of the year, oscillating between —2° C. and —1.1°. We do not dwell on the numerous animal species that swarm in these waters of relatively medium temperature—Hydroides, Pycnogonides, and various sponges. They are the subjects of detailed description in the collection of the *Discovery*, but of interest to naturalists more than to geographers.

There is reason for dwelling longer on the higher fauna which flourishes in this sea, cold but swarming with life, and which adds its characteristic tone to the marine or littoral pastures of Victoria

Land or of Ross Barrier. This fauna is distributed in a fairly uniform fashion over the whole circumference of Antarctide. One slight difference separates the population of birds or of seals which animate the American antarctic lands explored by De Gerlache, Nordenskjöld, Charcot, and Bruce from the dominant species of Victoria Land. Thus, Charcot and Racovitza point out the Manchot papou as very abundant in the north of Graham Land, while they have not seen, or very rarely observed, the Imperial Manchot (*Aptenodytes Forsteri*). The Manchot d'Adelie (*Pygoscelis Adeliæ*), on the other hand, appears in great number over all the explored region of Antarctide, in spite of the immense area of dispersion which this fact implies. This is a condition which is not new in polar geography; the number of species is small, but the area of distribution vast, and the number of individuals considerable.

The particular work of the *Discovery*, thanks to the talents of observation of Dr. E. A. Wilson and to the aid which Messrs. Royds and Skelton, among others, lent him, seems to us to have been above all to determine the zones of habitat, the habits and the manner of feeding of the principal antarctic mammiferes and birds. One can henceforth, it seems, distinguish three successive zones.

First, the free zone of the South Ocean, to the north of the pack ice; there reign sea birds with tireless wings, and unterrified by the tempest, belonging to the petrel or albatross family, from the great albatross and the black albatross to the cape pigeon and the gray "Fulmar" of the south. In the Magellan Isles or in the archipelago of the South Ocean (Macquarie Islands visited by the *Discovery*, Auckland, Campbell, etc.), flourish the king penguin (*Aptenodytes patagonica*), the "royal penguin" (*Catarrhactes Schlegeli*), and divers seals of the genus *Otarie*, Hooker's sea lion (*Arctocephalus Hookeri*), and the sea elephant (*Macrorhinus leoninus*), a gigantic species which attains a length of 6 to 9 meters but which the whalers have almost exterminated. A sea elephant, apparently a stray, was taken by the expedition in Ross Sea.

The pack ice, 300 kilometers wide, which separates the South Ocean from Ross Sea, marks the entrance upon the scene of new animal associations. The pack is never deserted. On the contrary, it is the place of assembly of species, attracted by the rich fauna of fish, of cephalopods, of Crustacea, which swarm in its openings, while great voracious whales live at the expense of the hunters themselves. It is the zone, says Doctor Wilson, where the naturalist must ever be on his guard, day and night; if he lose an occasion, many species will never again present themselves to his notice in the south. The ice pack is, moreover, a place where they may in security frolic and bask in the sunshine. There appear the snow petrel (*Pagodroma nivea*) in molting plumage, the great petrel (*Ossifraga gigantea*), the

antarctic petrel (*Thalassœca antarctica*), and the first skua gulls (*Megalestris antarctica*); two species of penguins (Adelia and Imperial) not yet fully developed, and living on the abundant banks of *Euphausia superba*, to which also refer for his nutrition the white seal or crab-eater (*Lobodon carcinophagus*), of which the dentition is disposed after the manner of a seine. The Ross seal (*Ommatophoca rossi*), with molars atrophid for want of use, lives at the expense of the cephalopods. Besides roam all round a horde of carnivorous animals carrying terror among the lowly fishermen, the sea leopard (*Stenorhincus*) with redoubtable dentition, in the stomach of which Ross found 28 pounds of fish, and the naturalists of the *Discovery* found an imperial penguin, entire. Finally, at the end of this carnivorous series, the troops, swift and numerous, of orcas or epaulards (*Orca gladiator*) swallowing indiscriminately penguins and seals in which it inspires terror. The crab-eating seal, the most abundant on the ice pack, shows frequent scars, indicative of fights with the orca.

Upon the ice pack which fringes the shore of Victoria Land, the fauna is less varied, but this struggle for existence is also less severe. Toward the border, nearest the open water, the herd of manchots in October install their strange dwellings, of which Mr. Wilson, after the explorers of Cape Adare, gives a picturesque description. It is there that they breed, commonly in low places, sometimes upon rather high hills but within easy reach of permanent or periodic openings in the ice pack, feeding zealously their young, in spite of the ravages which the sea gulls make in their ranks. In these rookeries thousands and thousands of penguins frisk and strive among themselves with great noise and amidst an insupportable odor.

Messrs. Wilson and Royds have determined as a result of heroic visits pursued under trying atmospheric conditions toward the colony of Cape Crozier, 50 miles from the ship, that two animals in particular are in habitat and custom symbolic of the peculiarly severe climate of Victoria Land; these are the Weddell seal (*Leptonychotes weddelli*) and the imperial manchot or penguin. The Weddell seal, credulous and trustful, for it knows no enemies in the compact ice where it ordinarily stays, lives upon the fish that swarm beneath the ice. It remains even in winter digging itself holes in the sea ice, and spending the coldest seasons in the water. During the polar night its grunt was heard as it swam beneath the ship. Its body is almost never scarred like that of the crab-eater, for the orca can with difficulty reach it. The Weddell seal is little disturbed by the presence of men; thus it furnished an easy and abundant prey to help out the menus of the expedition.

On the other hand, the naturalists of the *Discovery* recognized and studied on Cape Crozier the first colony of the imperial manchot (penguins) that has been described. They collected eggs and a few

of the young of this magnificient bird, which measures from 1 to 1.2 meters, and weighs from 30 to 40 kilograms. This bird it appears breeds on the ice, at the foot of Ross Barrier, in the heart of winter, and as early as the month of July. It builds no nests but places its eggs on the dorsal surface of its feet and covers them with a fold of the skin of its abdomen. The different members of the colony while fighting over the eggs and the young bring about among them an enormous mortality, equal to 77 per cent. A few weeks after the hatching the manchot trusts itself to the drift ice and is borne away to the north with its young. The description of this singular animal, so well adapted to the strange antarctic life, is entirely new.

In brief, the expedition of the *Discovery* has, thanks to the particularly happy choice of winter quarters, made a substantial addition to our knowledge of Victoria Land.

Indeed, it would seem that there was left to future expeditions only the task of gleaning, except so far as concerns the making of collections of marine animals, where the field of discovery is yet enormous.

Author's additional note, May 31, 1910.—The extraordinary results obtained since the publication of this article, by the expedition of Sir E. H. Shackleton, the determination of the south magnetic pole, the ascent of Mount Erebus, and, above all, the discovery of a high frozen plateau, 3,000 to 3,500 meters in altitude, around the Antarctic Pole, have shown that we have been too modest in our prophecies. We can say without reserve that the most extensive remaining field for discovery lies in the mysterious southern world. It is perhaps the last terrestrial region where we can now expect sensational discoveries in pure geography.

SOME RESULTS OF THE BRITISH ANTARCTIC EXPEDITION, 1907–9.[a]

[With 6 plates and 3 maps.]

By E. H. Shackleton, C. V. O.

The British Antarctic expedition, 1907–9, left Port Lyttelton, New Zealand, on January 1, 1908, for the south. In this article I will not attempt to deal in detail with the preliminary arrangements and with the equipment. The amount of money at my disposal had been limited, and economies had been necessary in various directions; but I had been able to get together a small body of well-qualified men, and we were fully equipped as far as food, clothing, sledges, etc., were concerned. We had a motor car, ponies, and dogs for haulage purposes. The generosity of the admiralty in lending the expedition a number of instruments enabled me to make the scientific equipment fairly complete. The *Nimrod*, in which the journey to the winter quarters on the Antarctic Continent had to be undertaken, was certainly small for the work, and left Lyttelton with scarcely 3 feet of freeboard, a somewhat serious matter in view of the fact that very heavy weather had to be faced. On the other hand, the ship was very sturdy, well suited to endure rough treatment in the ice.

The shore party consisted of fifteen men, my companions being as follows:

Lieut. J. B. Adams, R. N. R., meteorologist.

Bertram Armytage, in charge of ponies.

Sir Philip Brocklehurst, assistant geologist.

Prof. T. W. Edgeworth David, F. R. S., geologist.

Bernard Day, electrician and motor expert.

Ernest Joyce, in charge of general stores, dogs, sledges, and zoological collections.

Dr. A. F. Mackay, surgeon.

Dr. Eric Marshall, surgeon, cartographer.

G. E. Marston, artist.

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[a] Reprinted by permission from The Geographical Journal, London, vol. 34, No. 5, November, 1909.

Douglas Mawson, mineralogist and petrologist.
James Murray, biologist.
Raymond Priestley, geologist.
William Roberts, cook.
Frank Wild, in charge of provisions.

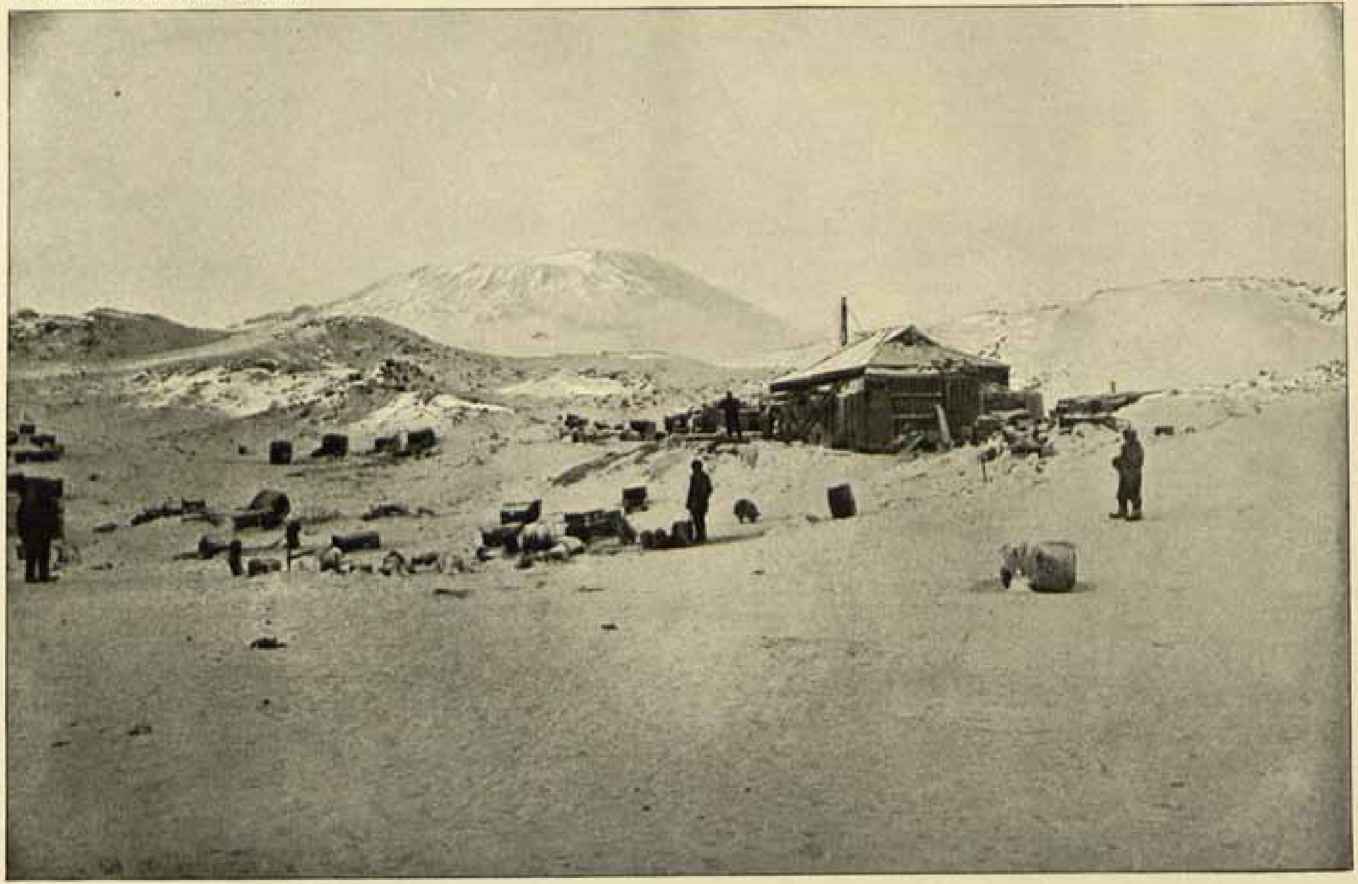
Professor David, of Sydney University, joined the expedition at the last moment, and the services of such an experienced scientific man were invaluable. Douglas Mawson was lecturer in mineralogy and petrology at the Adelaide University. James Murray had been biologist on the Scottish Lake survey, and had made a special study of microscopic zoology, a circumstance that led to most important discoveries in the frozen lakes of Ross Island. Joyce and Wild, like myself, had served on the National Antarctic Expedition.

My original intention was to winter on King Edward VII Land, a part of the Antarctic Continent at present quite unknown. The *Nimrod* was towed to the Antarctic circle, a distance of 1,500 miles, in order that her small supply of coal might be conserved, and we were soon in the belt of ice that guards the approach to the Ross Sea. The navigation of the ice was not more than usually difficult, and on January 16 we entered the Ross Sea in 178° 58′ E. long. (approximate). Keeping a southwesterly course, we sighted the Great Ice Barrier on January 23, and proceeded to skirt the ice edge in an easterly direction toward Barrier Inlet (Balloon Bight), the spot selected by me as the site for the winter quarters. I knew that the inlet was practically the beginning of King Edward VII Land, and that it would be an easy matter for the ship, in the following summer, to reach us there, whereas the land sighted by the *Discovery* expedition might be unattainable if the season were adverse. In 165° E. long., near the point where Borchgrevink landed in 1900, we sighted beyond 6 or 7 miles of flat ice, steep-rounded cliffs, having the appearance of ice-covered land. We could not stop to investigate.

The plan proved impracticable, for we found that Barrier Inlet had disappeared. Many miles of the Barrier edge had calved away, and instead of the narrow bight there was a wide bay joining up with Borchgrevink's Inlet, and forming a depression that we called the Bay of Whales. We accordingly made an attempt to reach King Edward VII Land, but here again we were unsuccessful. The way was barred by heavy consolidated pack, into which bergs were frozen, and this ice stretched for to the north. The season was advancing, the *Nimrod* was leaking, as a result of severe gales on the journey south, and I decided that we had better proceed direct to McMurdo Sound and establish the winter quarters there. The *Nimrod* entered the sound on January 29, and was brought up by fast ice 20 miles from Hut Point, the spot at which the *Discovery* expedition

KOONYA TOWING NIMROD.

NIMROD OFF CAPE ROYDS.



WINTER QUARTERS, CAPE ROYDS.

wintered in 1902 and 1903. The ice showed no signs of breaking out, and on February 3 we proceeded to land stores and erect a hut on Cape Royds, the spot selected under pressure of circumstances, for the winter quarters of the expedition. On February 22 the *Nimrod* went north again, leaving the shore party at Cape Royds. The ship was to return the following summer.

The first work of importance undertaken after the winter quarters had been established was the ascent of Mount Erebus. This active volcano, which has an altitude of over 13,000 feet, was of particular interest from the geological and meteorological standpoint, and though the ascent was likely to prove difficult, it seemed that the attempt should be made. A party of six set out from the winter quarters on March 5, and on the morning of March 10 five of the men stood on the edge of the active crater, the sixth having been left at the last camp with frost-bitten feet. The scientific results of the journey were both interesting and important. The party found that the height of the active crater is 13,350 feet above sea level, the figures being calculated from aneroid levels and hypsometer readings, in conjunction with simultaneous readings of the barometer at the winter quarters. It was noted that the moraines left at the period of greater glaciation ascend the western slopes of Mount Erebus to a height of fully 1,000 feet above sea level. As the adjacent portion of McMurdo Sound is at least 1,800 feet deep, the ice sheet at its maximum development must have had a thickness of not less than 2,800 feet. Two distinctive features of the geological structure of Mount Erebus were the ice fumaroles, and the vast quantities of large and perfect felspar crystals. Unique ice mounds have been formed in the cup of the second crater, from which rises the present active cone, by the condensation of vapor round the orifices of fumaroles. Only under conditions of extremely low temperature could such structures come into existence. The felspar crystals, found in enormous quantities mixed with snow and fragments of pumice in the second crater, were from 2 to 3 inches in length, and very many were perfect in form. The fluid lava which had surrounded them had been blown away by the force of the explosions which had ejected them from the crater. The valuable meteorological observations made can not be stated within the scope of this article.

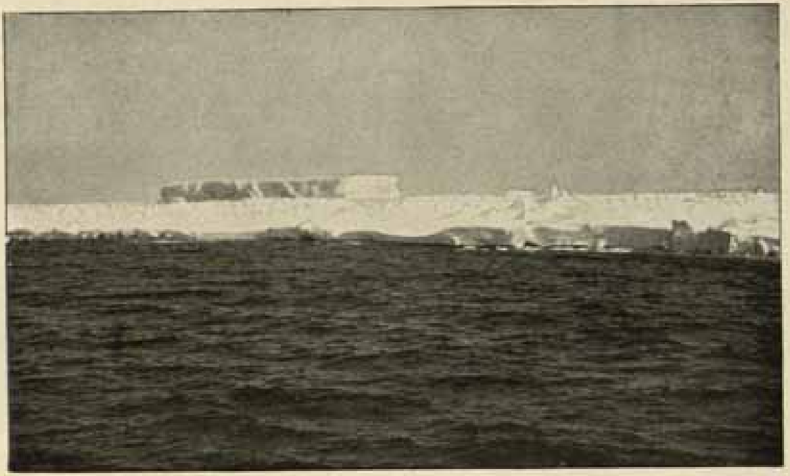
The most important event of the winter months was the discovery by the biologist of microscopical life in the frozen lakes of the Cape Royds district. Investigations showed that algæ grew at the bottom of the lakes, which are frozen during the greater part of the year, and in some cases thaw completely only in exceptionally warm seasons. The microscope showed that rotifers, water bears, and other forms of minute animal life existed on the weed. A shaft was sunk through 15 feet of ice to the bottom of a lake which did not thaw during the

two summers that we spent at Cape Royds, and on weed found under the ice there were living rotifers of several kinds. Other rotifers were found on weed melted out of solid ice. It seemed obvious that the microscopic animals were able to live at a temperature at least as low as 40° below zero Fahrenheit, and experiments verified this conclusion. The animals were not killed by that temperature, though all the natural functions were suspended, including the bearing of young among the viviparous species. They were alternately frozen and thawed weekly for a long period, and took no harm. They were dried and frozen, thawed and moistened, and still they lived. They lived in brine so salt that it froze only at a temperature of about zero Fahrenheit, and many of them survived the test of being dried and placed in a bottle, which was then immersed in boiling water. Some of the weed carrying the animals was dried and conveyed to London, being subjected to tropical temperatures on the way. It was moistened in London, and the animals were found to be still living. They survived a final test of immersion in frozen gas at a temperature of −81° C. The whole subject is one of extraordinary interest to biologists, and the scientific memoirs of the expedition will embody the results of all Murray's observations and experiments.

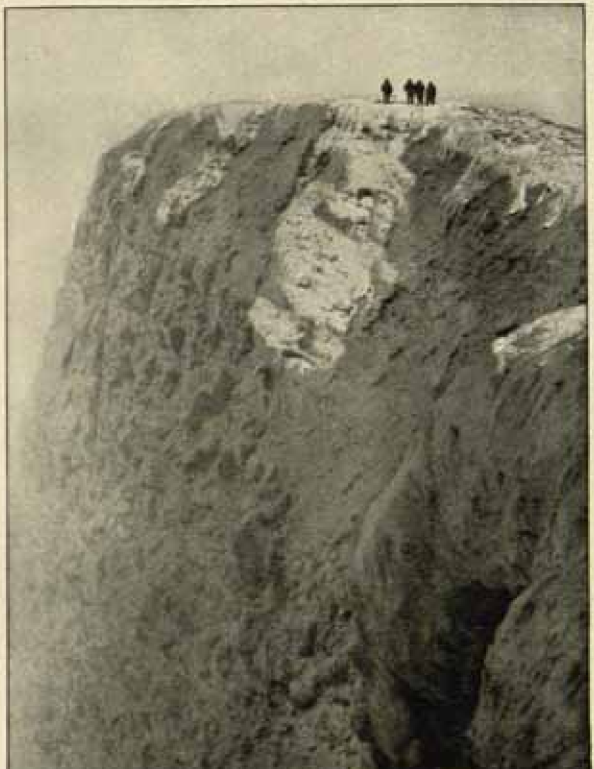
Early in the spring of 1908 we began to make arrangements for the sledging journeys. One party, led by myself, was to go south toward the geographical pole; Professor David was to take a second party north, and attempt to attain the south magnetic pole; and a third party was to undertake geological work in the mountains west of McMurdo Sound, with the special object of discovering fossils. The motor car had not proved a success. The petrol engine ran well, even at low minus temperatures, and on the sea ice the car could travel fast and far, but soft snow, such as was encountered on the Barrier surface, formed an effective bar to its progress. We had left New Zealand with ten ponies, imported from the sub-Arctic regions of northern Manchuria, and landed eight of the animals at Cape Royds in fairly good condition.

Unfortunately, four were lost early in the winter, so that only four were left available for the sledging work. We had dogs, bred from the Eskimo dogs used by the Newnes-Borchgrevink Expedition, but after the experience of the *Discovery* Expedition I had little confidence in these animals. I pinned my faith on the ponies for the southern journey. Experiments showed that they could haul easily 650 pounds each, this including the weight of the sledge (60 pounds), and that they traveled well on bad surfaces, thus realizing the hopes I had based on reports of their performances in their native country.

I made a preliminary journey on to the Barrier before the return of the sun, taking with me Professor David and Armytage, in order to get an idea of the surface to be encountered. We experienced



HEAVY PACK ICE.



THE TOP OF EREBUS.

CURIOUS ICE FORMATION.

VIEW OF LAND WHERE COAL WAS FOUND.

very low temperature, below −57° F., and we only stayed out for a few days. By means of a series of sledging journeys from Cape Royds, we established a depot of stores at Hut Point, and on September 22 a party started out to lay a depot on the Barrier beyond Minna Bluff in readiness for the southern journey. The temperature got down to —59° F., with blizzard winds, and the petroleum for the cookers was practically frozen at times, while off Minna Bluff we got among crevasses.

On October 6 we laid the depot in latitude 79° 36′ S., longitude 168° E., a distance of 120 miles from the winter quarters. We reached the hut again on October 13. In the meantime, Professor David, Douglas Mawson, and Doctor Mackay had started on their journey to the south magnetic pole. I did not see them again until March 1, 1909.

The southern party was to consist of Adams, Marshall, Wild, and myself. I decided to take provisions and oil for ninety-one days, the daily allowance of food, as long as full rations were given, to be 34 ounces. The allowance was made up as follows:

	Ounces.
Pemmican	7.5
Emergency ration	1.5
Biscuit	16.0
Cheese or chocolate	2.0
Cocoa	0.7
Plasmon	1.0
Sugar	4.3
Quaker oats	1.0
	34.0

Tea, salt, and pepper were used in addition. The total weight of the provisions taken was 773 pounds 8 ounces. Each pony was to draw an 11-foot sledge. In regard to our own clothing, we made a radical reduction in weight as compared with previous expeditions. We wore Burberry windproof gaberdine over Jaeger woolen undergarments, and used furs only for the hands and feet and for the sleeping bags. I am satisfied that we could not have traveled as far as we did in the time at our disposal had we worn the usual heavy garments. The other articles of our equipment were along the lines laid down by other polar explorers, weight having been reduced to the minimum in each case. The scientific equipment included a 3-inch theodolite with stand, three chronometer watches, three pocket compasses, one hypsometer, eight thermometers, one case surveying instruments, two prismatic compasses, one sextant with artificial horizon, and camera with plates. The food for the ponies consisted of maize and Maujee ration, with a little Australian

compressed fodder, 900 pounds in all, the allowance for each pony being 10 pounds per day.

The southern party left the winter quarters on October 29 accompanied by a supporting party of six men. Progress at first was slow, heavy weather and crevassed ice being encountered; and it was not until November 15 that we reached the depot laid out on the spring journey, the supporting party having left us some days previously. The ponies were pulling well, and I was feeling very satisfied with the change from the dogs used when I accompanied Captain Scott on his southern journey in 1902. The surface was soft, but we were able to move south at the rate of about 15 miles each day. Our course lay farther from the land than the course followed by the previous expedition, as is shown on the accompanying chart. Good marches were made in the days that followed, and on November 26 we camped in latitude 82° 18½′ S., longitude 168° E., having passed the "farthest south" record. New land had come within our range of vision by this time, owing to the fact that we were far out from the base of the mountains, and I had noted with some anxiety that the coast trended south-southeast, thus threatening to cross our path and obstruct the way to the pole. We could see great snowclad mountains rising beyond Mount Longstaff, and also far inland to the north of Mount Markham. On November 26 we opened out Shackleton Inlet, and looking up it sighted a great chain of mountains, while to the west of Cape Wilson appeared another chain of sharp peaks, about 10,000 feet high, stretching away to the north beyond Snow Cape, and continuing the land on which Mount A. Markham lies. The first pony had been killed on November 21, when we were south of the eighty-first parallel, and we had left a depot of pony meat and ordinary stores to provide for the return march. We started at once to use pony meat as part of the daily ration, and soon found that scraps of raw, frozen meat were of assistance on the march in maintaining our strength and cooling our parched throats. A second pony was shot on November 28, and a third on December 1, by which time we were closing in on the land, and it had become apparent that we would have to find a way over the mountains if we were to continue the southern march. We were still sighting new land ahead, and the coast line had a more distinct easterly trend. We camped on December 2 in latitude 83° 28′ S., longitude 171° 30′ E., opposite a red granite mountain about 3,000 feet in height. On the following day we climbed this mountain, and from its summit saw an enormous glacier, stretching almost due south, flanked by huge mountains, and issuing on to the Barrier south of our camp. We decided at once that we had better ascend the glacier, and on the following day made our way, with two sledges and the last pony, on to its surface.

We encountered difficulties at once, for the snow slopes, by means of which we gained the glacier surface, gave way to blue ice, with numberless cracks and crevasses, many of them razor-edged. Traveling on this surface in finesko was slow and painful work. On December 5 Marshall and Adams, who were ahead looking for a route, reported that at a point close to the granite cliffs, a bird, brown in color, with a white line under each wing, had flown over their heads. They were sure it was not a skua gull, the only bird likely to have been attracted by the last dead pony. It was a curious incident to occur in latitude 83° 40′ S. We left the fourth depot close to the foot of the glacier, at the foot of a wonderful granite cliff, polished by the winds and snows of ages. On December 6 we took six hours to pass about 600 yards of severely crevassed ice, over which all our gear had to be relayed, and on the following day we lost the last pony, which fell into a crevasse disguised, like so many others, by a treacherous snow lid. Wild was leading the pony with one sledge, while Adams, Marshall, and myself went on ahead with the other sledge and pioneered a practical path. We had passed over a snow-covered crevasse without noticing it, but the greater weight of the pony broke through the lid, and the animal dropped through, probably to a depth of several hundred feet. Happily, the swingle-tree snapped with a sudden strain, and Wild and the sledge were saved. This accident left us with two sledges and a weight of about 250 pounds per man to haul. Our altitude at this time was about 1,700 feet above sea level.

During the days that followed we made steady progress up the glacier, experiencing constant difficulty with the crevasses. We hauled well ahead of the sledges, so that when one of us dropped through a snow lid the harness would support him until he could be hauled up again. We had many painful falls as a result of having no footgear suitable for the ice climbing, and any future travelers would do well to take boots with spikes. A special form would have to be devised, on account of the low temperature rendering impracticable the use of ordinary mountaineering boots. New land appeared day after day, and we were able to make small geological collections and to take some photographs. The rocks were sedimentary, the lines of stratification often showing clearly on the mountain sides, and we made two geological discoveries of the first importance. In latitude 85° S., Wild, who had climbed the slope of a mountain in order to look ahead, found coal, six seams ranging from 4 inches to 7 or 8 feet in thickness, with sandstone intervening. Close to this point I found a piece of sandstone showing an impression, and microscopic investigation has shown that this was fossil coniferous wood.

The glacier proved to be about 130 miles in length, rising to an altitude of over 9,000 feet. Christmas Day, 1908, found us in latitude

85° 55′ S., a plateau with icefalls appearing to the south. Much glaciated land trended to the southeast, apparently ending in a high mountain shaped like a keep. The land to the west had been left behind. It was evident that we were still below the plateau level, and though we were getting free of the crevasses, we were hindered by much soft snow. The level was rising in a series of steep ridges about 7 miles apart. We had started to reduce rations before leaving the Barrier surface, and by Christmas Day were marching on very short commons. Our temperature was 2° subnormal, but otherwise we were well and fit.

On December 31 we camped in latitude 86° 54′ S. We had not yet reached the plateau level, for slopes still lay ahead, and our altitude was about 10,000 feet. We had three weeks' food on a reduced ration, and were 186 geographical miles from the pole. The land had been left behind, and we were traveling over a white expanse of snow, still with rising slopes ahead. We were weakening from the combined effects of short food, low temperature, high altitude, and heavy work. We were able to march on the first six days of January, and on the night of January 6 camped in latitude 88° 7′ S. We had increased the daily ration, for it had become evident that vitality could not be maintained on the amount of food we had been taking. I had been forced to abandon the hope of reaching the pole, and we were concentrating our efforts on getting within 100 miles of the goal.

A fierce blizzard blew on January 7 and 8, and made any march impossible. We lay in our sleeping bags, frequently attacked by frostbite. The wind ceased at 1 a. m. on January 9, and at 4 a. m. we started south, leaving the camp standing, and taking only instruments, food, and the flag. At 9 a. m., after five hours' marching over a fairly hard surface, we calculated we were in latitude 88° 23′ S., and we hoisted the flag. The snow plain stretched southward to the horizon without a break.

The homeward march was rendered difficult by shortage of food and attacks of dysentery, due to the meat from one of the ponies. We picked up a depot left on the plateau on January 4, and made rapid progress to the north. The blizzard winds from the south, which had hampered us on the outward journey, now proved of assistance, for we made a sail from the floor cloth of a tent and traveled fast with our one remaining sledge. On January 19 we covered a distance of 29 miles down the glacier. On January 16 we ran out of food when 16 miles from the glacier depot, and we marched for thirty-one hours with only a little tea and chocolate. We were able to reach the depot in an exhausted condition. We left the glacier and reached the Barrier surface on January 28, but Wild was attacked by dysentery, and a little later we all suffered. The trouble was evidently due to the meat from one pony, and as the frozen flesh

CAMP ON SOUTHERN JOURNEY.

CAMP ON SOUTHERN JOURNEY.

PROFESSOR DAVID, DOUGLAS MAYSON, AND DOCTOR MACKAY AT THE SOUTH MAGNETIC POLE.

SOUTHERN PARTY AFTER THEIR RETURN.

could not have become tainted in the usual way, we assumed that it was due to the toxin of exhaustion, the animal having been killed when very weary.

We were assisted on the southward march over the Barrier by snow mounds erected on the outward journey, and we picked up the depots without any difficulty, reaching each with our food bags empty. We could not march at all on February 4, owing to acute dysentery, but we were able to continue on the following days, and on February 23 we reached a depot, laid out off Minna Bluff in readiness for our return, by a party from the winter quarters. We were all safe on board the *Nimrod* on March 4.

The latitude observations made on the southern journey were taken with the theodolite, as were all the bearings, angles, and azimuths. Variation was ascertained by means of a compass attached to the theodolite, and the steering compasses were checked accordingly. At noon each day the prismatic compasses were placed in the true meridian and checked against the theodolite compass and the steering compasses. The last latitude observation on the outward journey was taken in 87° 22′ S., and the remainder of the distance toward the south was calculated by sledge meter and dead reckoning. The accuracy of the sledge meter had been proved by the fact that the daily record of distance traveled agreed roughly with the observations for position. We took only one observation on the return journey, on January 31, and then found that our position had been accurately recorded by the sledge meter.

The results of the southern journey may be summarized briefly. We found that a chain of great mountains stretched north by east from Mount Markham as far as the eighty-sixth parallel, and that other ranges ran toward the southwest, south, and southeast between the eighty-fourth and the eighty-sixth parallels. We ascended one of the largest glaciers in the world on to a high plateau, which in all probability is a continuation of the Victoria Land plateau. The geographical pole almost certainly lies on this plateau, at an altitude of between 10,000 and 11,000 feet above sea level. The discovery of coal and fossil wood has a very important bearing on the question of the past geological history of the Antarctic Continent.

The northern party consisted of Professor David, Doctor Mackay, and Douglas Mawson. The three men left Cape Royds on October 5, and traveled on the sea ice along the coast as far as the Drygalski Barrier tongue. They had neither dogs nor ponies, and as they could not haul the whole of their load at one time they had to relay their two sledges, thus covering the ground three times. They reached the Drygalski tongue on November 30, and from that point struck inland in a northwest direction, with a lightened load, toward the south magnetic pole. They crossed the Drygalski Glacier with

very great difficulty, a fortnight being occupied in gaining 20 miles over steep ice ridges and crevasses, and twice failed in attempts to climb on to the inland plateau, first by means of the Mount Nansen Glacier, and then up the Bellingshausen Glacier. Finally, they succeeded in finding a path up a small tributary glacier to the south of Mount Larsen and gained the plateau. Then came a painful march over the plateau, which gradually rose to an altitude of over 7,000 feet, in the face of blizzards, broad undulations, and high sastrugi. On January 16, 1909, the party reached latitude 72° 25′ S., longitude 155° 16′ E., the approximate position of the magnetic pole as calculated from the observations taken by Mawson with the Lloyd-Creak dip circle. The journey back to the coast had to be made by forced marches, for the party knew that the sea ice would have broken out and that their hope of safety depended largely on the *Nimrod*, which was to cruise along the coast as far as Cape Washington early in January. They reached the Drygalski Barrier tongue on January 3, and on the following morning, by a happy combination of circumstances, were picked up by the ship, which was on its way back to the winter quarters after a fruitless search along the coast. The party did very useful geographical work in the course of its journey, for Mawson triangulated the coast of Victoria Land from McMurdo Sound to the Drygalski Barrier, and many new peaks, glaciers, and tongues were discovered, as well as two small islands. Professor David studied the geological conditions with good results.

The western party consisted of Armytage, Priestley, and Brocklehurst, and it first proceeded by the Ferrar Glacier as far as the Solitary Rocks, with the special object of searching for fossils in the Beacon sandstone formations. Priestly made a thorough geological search of the neighborhood, but without success so far as fossils were concerned. The party descended the glacier with the object of joining the northern party, according to my instructions, but the junction was not effected owing to the delays that had overtaken Professor David and his companions. Priestley was able to work at the Stranded Moraines and in Dry Valley. The party was picked up by the *Nimrod* on January 25, after narrowly escaping disaster on a drifting ice floe.

All the members of the expedition were aboard the *Nimrod* on March 4, 1909, and we proceeded north under steam at once, for the season was advancing and the sea ice had commenced to form. We were off Cape Adare on March 6, and I made an attempt to push on west of Cape North, with the object of securing knowledge of the coast line. The pack ice, which was thickening rapidly and threatened to imprison the ship, prevented the *Nimrod* going as far as I had hoped, but we got to longitude 166° 14′ E., latitude 69° 47′ S.,

and on the morning of March 8, from that position, we saw a new coast line stretching first to the southward, and then to the west for a distance of over 45 miles. We took angles and bearings and sketched the outline. Then we went north, and on March 22 reached New Zealand.

The geological work of the expedition was carried on by Prof. T. W. Edgeworth David and Raymond Priestley. I have already mentioned matters connected with the Great Ice Barrier. Their conclusions in regard to other points are summarized as follows:

(1) Throughout the whole of the region of Antarctica, examined by us for 16 degrees of latitude, there is evidence of a recent great diminution in the glaciation. In McMurdo Sound this arm of the sea, now free from land ice, was formerly filled by a branch of the Great Ice Barrier, whose surface rose fully 1,000 feet above sea level, and the Barrier ice in this sound, in areas from which the ice has retreated, was formerly about 3,000 feet in thickness.

(2) The snowfall at Cape Royds from February, 1908, to February, 1909, was equal to about 9½ inches of rain.

(3) The névé-fields of Antarctica are probably of no great thickness.

(4) The southern and western sides of the sector of Antarctica south of Australia is a plateau from 7,000 to 10,000 feet high, which may possibly extend across the south pole to Coats's Land and Graham's Land.

(5) Ross Sea is probably a great subsidence area.

(6) The Beacon sandstone formation, which extends for at least 1,100 miles from north to south in Antarctica, contains coniferous wood associated with coal seams. It is probably of Paleozoic age.

(7) Limestones, pisolitic in places, in 85° 25′ S., and 7,000 feet above sea level, contain obscure casts of radiolaria.

Radiolaria, in a fair state of preservation, occur in black cherts amongst the erratics at Cape Royds. They appear to belong to the same formation as the limestone. These radiolaria appear to be of older Paleozoic age.

(8) The succession of lavas at Erebus appears to have been first trachytes, then kenytes, then olivine basalts. Erebus is, however, still erupting kenyte.

(9) Peat deposits, formed of fungus, are now forming on the bottoms of some of the Antarctic glacial lakes near 77° and 78° S.

(10) Raised benches of recent origin extend at Ross Island to a height of at least 160 feet above sea level.

The fossil in Beacon sandstone found by the southern party in latitude 85° S. is described as follows by Mr. E. J. Goddard, B. Sc., Macleay Research Fellow of the Linnæan Society, New South Wales:

Longitudinal sections of the included dark masses give a homogeneous banded appearance of a distinctly organic nature. The banded appearance is due to the

vascular nature of the organic elements composing the mass. The whole structure recalls to one's mind the appearance given by longitudinal sections of the xylem portion of the vascular area of a gymnosperm, such as *Pinus*. Only the xylem area is represented in the specimen, no traces of medullary, cortical, or phloem tissue being visible. Medullary rays are present, as shown in the microphotograph.

The xylem itself is composed of a homogeneous mass of vessels, tracheidal in nature, no differentiation as regards the vascular elements being present. In places one may readily make out in longitudinal sections dark opaque bands of much greater size individually than the tracheides. These, in all probability, represent resin passages belonging to the xylem. It would seem, further, that these masses might be considered as being nothing more than an aggregation of material similar in nature to that of the walls, and due to changes under the process of petrifaction. This, however, is opposed by the fact that they occur even in these small sections fairly commonly and at the same time are all of exactly the same size as regards width. At all events, they represent some definite structure, and in all probability resin passages.

The walls of the tracheides themselves, seen under the high power of the microscope, appear to be pitted; but the preservation is by no means good enough to warrant any remarks on this, beyond that in the common wall of adjacent tracheides occur clear spaces of the same relative importance as the bordered pits of such a gymnosperm as *Pinus*. These clear spaces occur regularly along the length of the tracheides, and stand out strongly against the dark color of the walls in their preserved condition.

The nature of the xylem itself leads to the conclusion that it is a portion of a gymnospermous plant, resembling strongly in nature the same portion of a coniferous plant.

The meteorological observations taken during our stay in the Antarctic have yet to be studied, and only tentative conclusions have, so far, been reached. Systematic observations were taken during the voyages of the *Nimrod* between New Zealand and MacMurdo Sound, and at Cape Royds observations were recorded at intervals of two hours from March, 1908, to February, 1909. During this period no rain fell. The lowest temperature definitely recorded was −57° F. near White Island on the Great Ice Barrier on August 14, 1908. We were able to secure interesting observations of the upper currents of the air at Ross Island. Reporting on this subject, Professor David and Lieutenant Adams state:

At Mount Erebus our winter quarters were situated in an exceptionally favored position for observing the upper currents of the atmosphere. Not only had we the great cone of Erebus to serve as a graduated scale against which we could read off the heights of the various air currents as portrayed by the movements of the clouds belonging to them, but we also had the magnificent steam column in the mountain itself, which, by its swaying from side to side, indicated exactly the direction of movement of the higher atmosphere. Moreover, during violent eruptions like that of January 14, 1908, the steam column rose to an altitude of over 20,000 feet above sea level. Under these circumstances it penetrated far above the level of a current of air from the pole northward, so that its summit came well within the sweep of the higher wind blowing in a southerly direction, the result being that the steam cloud in this

region was dragged over powerfully toward the southeast. On such occasions one usually saw evidence of two high-level currents, the one coming from a northerly direction, its under limit being about 15,000 feet above sea level, and the other, or middle current, from a southerly quarter, usually blowing toward the east-northeast, having its upper limit at 15,000 feet normally, while its lower limit was between 6,000 and 7,000 feet above sea level. While these two currents were blowing strongly, there would frequently be a surface current blowing gently from the north. This would bring up very dense masses of cumulus cloud from off Ross Sea. The cumulus would drift up to the 6,000 or 7,000 feet level on the northwest slopes of Erebus, and then the tops of the cumulus would be cut off by the lower edge of the northward-flowing middle current. Wisps of fleecy cloud would be swept along to the east-northeast, torn from the tops of these cumulus clouds by the middle current. Our observations showed that during blizzards the whole atmosphere from sea level up to at least 11,000 feet moves near Cape Royds from southeast to northwest, and the speed of movement is from 40 up to over 60 miles an hour. After and during the blizzard the middle air current, normally blowing from the west-southwest, is temporarily abolished, being absorbed by the immense outrushing air stream of the southeast blizzard. During a blizzard the air was generally so thick with snow that we were unable to see the top of Erebus. At the end of a blizzard the air current over Erebus became suddenly reversed, the steam cloud swinging round from the south to the north. After a time, following on the conclusion of a blizzard, a high-level current was seen to be floating the cirrus clouds from the southeast toward the northwest, and the steam of Erebus would stream out toward the northwest. We could not account for this high-level southeasterly current. It looked like a reversal of the usual upper wind, and it appears to be a fact new to meteorological science.

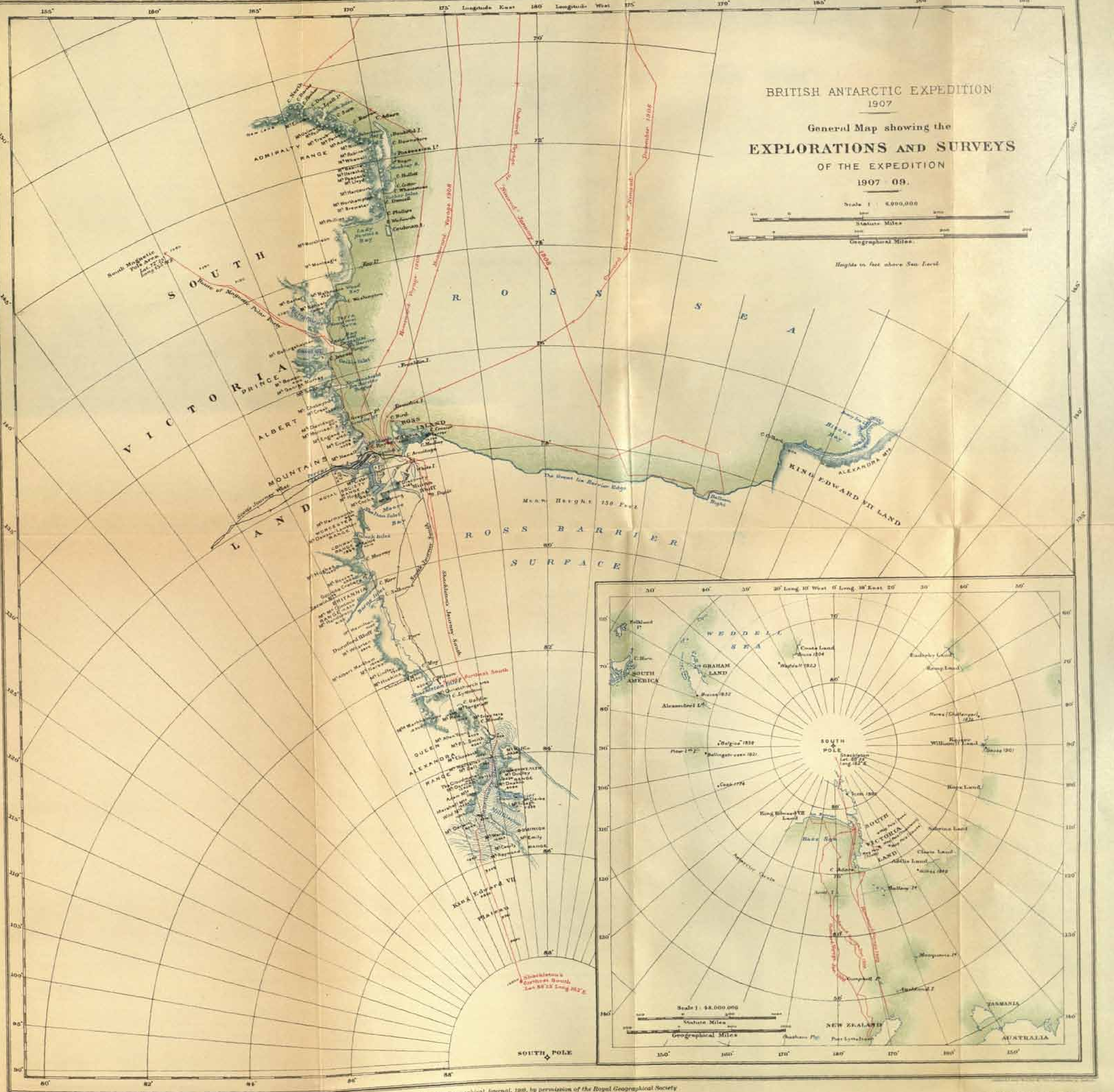
In this article I can only indicate the scientific results of the expedition, as apart from the new geographical knowledge secured. We were able to throw some additional light on the problem presented by the Great Ice Barrier. The disappearance of Balloon Bight shows clearly that the recession noted since the days of Sir James Ross continues, and suggests that very large portions of the Barrier edge may occasionally "calve off." The trend of the mountains discovered on the southern journey indicates that the Barrier is bounded by mountains which run eastward along the eighty-sixth parallel, about 300 miles from the sea edge. The great glacier up which we marched to the polar plateau shows that the Barrier is fed to some extent from the highlands of the interior. It would seem, however, that in the main the Barrier is formed of superimposed layers of snow, and some interesting observations were secured in this connection. We formed the opinion that at Cape Royds the annual snowfall is equal to about 9.5 inches of rain. The southern depot party, in January, 1909, found depot A, left by Captain Scott in 1902 on the Barrier off Minna Bluff. A careful examination showed that the depot had been moving bodily to the east-northeast at the rate of a little over 500 yards a year, while there had been an accumulation of about 13 inches of hard snow above the depot during each year. A determination of the density of the snow showed that the snowfall on

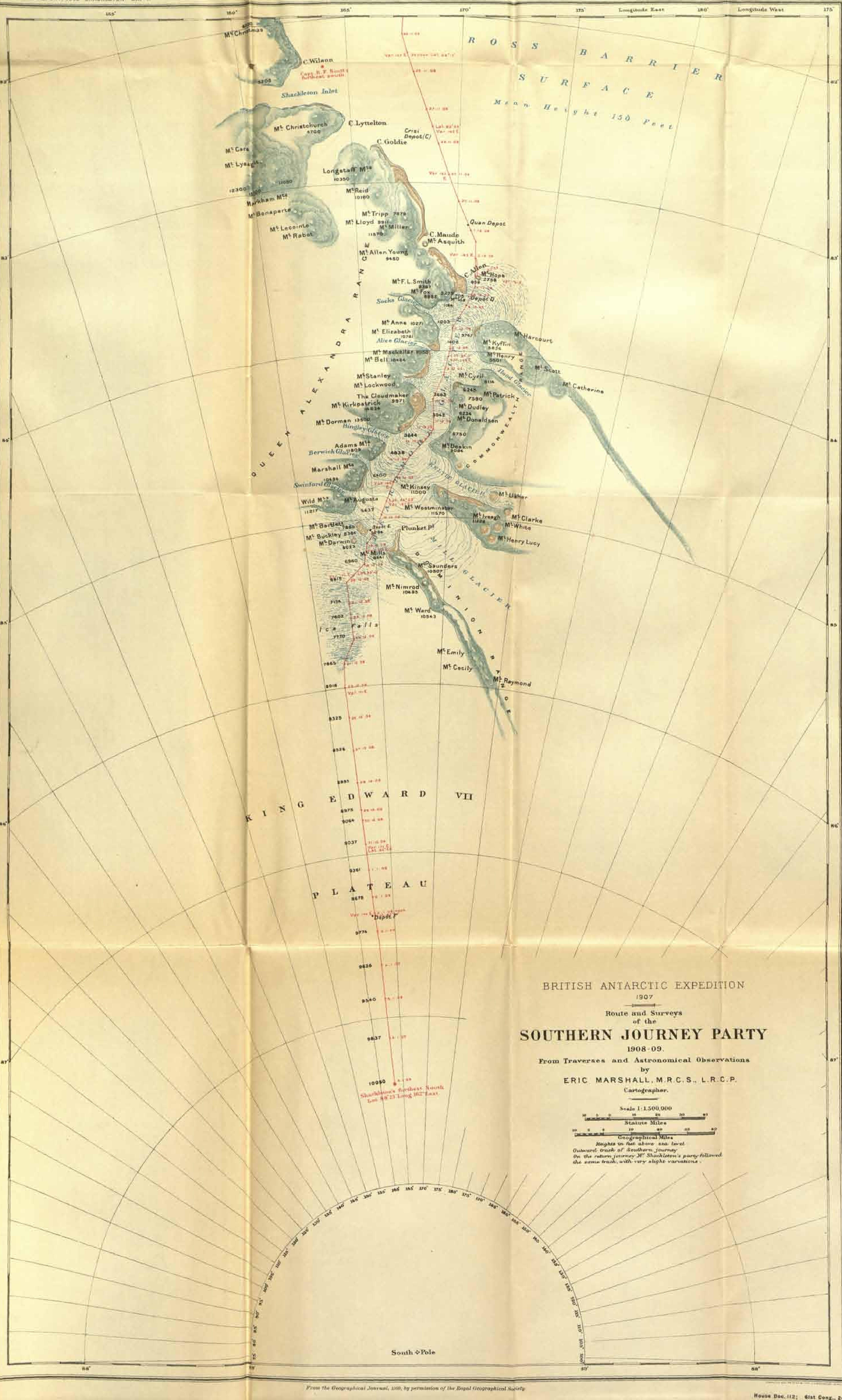
that part of the Barrier had been equal to about 7.5 inches of rain per year. If it is assumed that the rate of accumulation of solid snow over the Barrier is 12 inches of consolidated snow per year, then it follows, since the Barrier extends south for about 300 miles, and is moving northward at the rate of about one-third of a mile per year, that a layer of snow deposited 300 miles inland will be covered by a depth of 900 feet of snow when it reaches the Barrier edge nine hundred years later. This theory suggests that the Barrier is an accumulation of snow rather than of glacier ice, and was supported by the evidence of bergs which were examined by the expedition. The typical antarctic berg is formed of consolidated snow. The question of what becomes of the ice from the inland glaciers remains unanswered. The Barrier is certainly afloat at its northern edge, and perhaps the ice, weighed down by superimposed snow, is thawed away by the sea water. Some true icebergs are found in the Antarctic.

The expedition made a special study of meteorological optics, and some very interesting observations were made, and will be dealt with by the scientific members in the memoirs. The curious "earth shadows" were observed in a variety of forms. Some of them seemed clearly to have a relation to the relative positions of Mount Erebus and the sun. Other forms were not so easily explained. In the spring, when the sun was low in the northern sky, we saw above us six parallel earth-shadow beams, directed from the sun.

The scientific memoirs of the expedition will deal in detail with geology, biology, meteorology, magnetism, physics, chemistry, and mineralogy, tides and currents, optics, and other scientific subjects. We were a small party, and of necessity a considerable part of our time was occupied in the necessary routine duties incidental to daily life in the Antarctic, but we tried to cover all the ground possible in the various branches of scientific knowledge. It is probable that most of the volumes containing our scientific records and conclusions will be published within the next twelve or eighteen months.

The last stage of the expedition was a search by the *Nimrod* for some of the charted southern islands the existence of which is doubtful. The ship sailed over the positions assigned to the Royal Company Island, Emerald Island, the Nimrod Islands, and Dougherty Islands, without having sighted land.


BRITISH ANTARCTIC EXPEDITION
1907
General Map showing the
EXPLORATIONS AND SURVEYS
OF THE EXPEDITION
1907 09.
Statute Miles
Geographical Miles
Heights in feet above Sea Level
SOUTH VICTORIA LAND
PRINCE ALBERT MOUNTAINS
ADMIRALTY RANGE
ROSS SEA
ROSS ISLAND
ROSS BARRIER SURFACE
The Great Ice Barrier Edge
KING EDWARD VII LAND
ALEXANDRA MTS
QUEEN ALEXANDRA RANGE
King Edward VII Plateau
Shackleton's Farthest South
SOUTH POLE
WEDDELL SEA
GRAHAM LAND
SOUTH AMERICA
Coats Land
Enderby Land
Kemp Land
Kaiser Wilhelm II Land
Knox Land
Sabrina Land
Clarie Land
Adelie Land
Balleny Is
Macquarie I
Campbell I
Auckland I
NEW ZEALAND
TASMANIA
AUSTRALIA
Alexander I Land
Peter I Id



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From the Geographical Journal, 1909, by permission of the Royal Geographical Society.

THE OCEANOGRAPHY OF THE SEA OF GREENLAND.[a]

[With 2 plates.]

(A résumé of the observations made during the expedition of the *Belgica*, in 1905.)

By D. Damas.

In 1905 the Duc d'Orleans undertook what has proved to be a fortunate cruise to Spitzbergen and northeast Greenland upon the *Belgica*, commanded by M. A. de Gerlache. The oceanographic observations made during the cruise by the commandant and M. Koefoed, working in connection with the Norwegian Bureau of Fisheries, form a valuable contribution to our still very imperfect knowledge of the ocean comprised between these two great polar lands.

The region explored by the *Belgica* in 1905 constitutes a special basin and merits the name Sea of Greenland, which has recently been given to it. It is situated between Spitzbergen and Bear Island on the east and Greenland on the west. To the south it opens out into the Sea of Norway a little below 70° north latitude; its meridional limit is therefore the least well defined. The ancient volcano Jan-Mayen, which raises itself between Greenland and Norway, alone indicates the conventional limit of the basin. The general form of the Sea of Greenland is plainly triangular. Measured along the seventy-first parallel of north latitude its assumed base is more than 780 marine miles in length. Its borders on the east and west converge toward the north.

This form is revealed better if one considers the relief of the oceanic basin (fig. 1). Opposite Spitzbergen, and particularly opposite Greenland, there extends a large continental platform. If we set the isobar of 1,500 meters as the limit of the base of this coastal platform it will be seen that the central basin has a maximum depth, so far as known, of 3,630 meters, and constitutes a special depression separated from the analogous basin of the Sea of Norway by the low divide which carries the island of Jan-Mayen and which unites eastern Greenland with Bear Island.

[a] Translated by permission from La Géographie, Paris, vol. 19, No. 6, June 15, 1909.

The apex of the triangle unites the Sea of Greenland with the polar basin.

This region comprised between Greenland and Spitzbergen constitutes the outlet of the ice from the polar basin, and at the same time affords a passage toward the north of the farthermost branch of the Gulf Stream. This Atlantic current, which warms the western coast of Spitzbergen, passes around the northwest angle of this archipelago and loses itself in the Arctic basin, as Nansen has demonstrated. The oceanographic régime of the basin depends then, first of all, on the topographic conditions existing in the northern part of the Sea of Greenland. This region is in general blocked by ice,

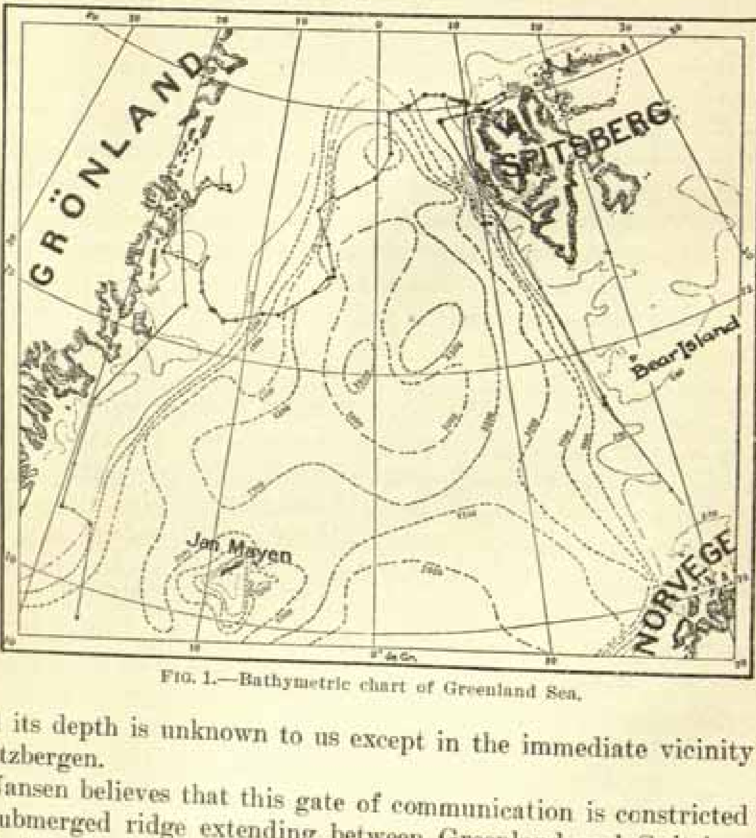

Fig. 1.—Bathymetric chart of Greenland Sea.

and its depth is unknown to us except in the immediate vicinity of Spitzbergen.

Nansen believes that this gate of communication is constricted by a submerged ridge extending between Greenland and Spitzbergen, and rising to within 800 meters of the surface.

The origin of this hypothesis is curious; first of all, it has a hydrographic foundation. Nansen has shown that in the polar basin proper, the deeper lying water has a density of 1.02825, while the samples collected by Amundsen in the Sea of Greenland yielded, for the water from the depths of the basin, values a little less (about 1.02811). Nansen concludes from this that if the waters have not the

same density it is because they can not admix freely. It follows, then, that there exists a barrier preventing the free circulation between the profound depths of the two oceanic basins.

The possibility of establishing a similar hypothesis rests upon the extreme exactitude of modern oceanographic research. Thanks to an exceptionally perfect outfit, to which Nansen himself greatly contributed, it is possible to determine the temperature and the density of waters at all depths with a precision impossible ten years ago. On board the *Belgica* the temperatures were measured with the aid of Richter's thermometers to within an approximation of 0.02 of a degree. In numerous instances two thermometers were employed simultaneously, and in more than 75 per cent of the cases the difference between the two readings, after a correction varying for each instrument, was less than 0.01 of a degree. The salinity has been determined by titration of the chlorine down to nearly 0.02 per cent.[a] For waters from the profound depths the method has been controlled by hydrostatic pressure. After this manner the density could be calculated for all the depths as far as the fifth decimal place. A difference apparently so slight as that admitted by Nansen, 1.02825 against 1.02811, is then an accurate indication of the composition and origin of the bodies of water.

Accepting the fact that the southeast part of the Greenland Sea is well explored, the problems which presented themselves to the expedition were these:

First. To begin at the northeast angle of Spitzbergen and course toward the northwest in order to cut across the hypothetical barrier of Nansen by a line of soundings.

Second. To come back as far as possible into the midst of the ice of the polar current.

Third. To reach the coast of Greenland in order to make, as nearly as possible, a cross section of the body of water which covers the continental platform.

The labors relative to the expedition are now finished and will appear shortly. They constitute an important volume of more than 500 pages, accompanied by 80 plates, maps, and diagrams, comprising the following memoirs:

Succinct account of the voyage and extracts of the itinerary by A. de Gerlache.

Meteorology: Synoptic maps of the weather for July and August, 1905, by M. Dan La Cour.

Geology: Submarine sediments collected in the Greenland Sea by M O. B. Böggild.

Botany: Plants collected on the northeast coast of Greenland, by C. H. Ostenfeld.

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[a] This method has been the object of adverse criticism in France. Helland-Hansen and Koefoed question if this method will permit a sufficiently precise determination.

Oceanography and biology: Journal of stations, by MM. H. Broch, A. de Gerlache, B. Helland-Hansen, and E. Koefoed.

Hydrography, by B. Helland-Hansen and E. Koefoed.

Plankton of the Sea of Greenland, by MM. D. Damas and E. Koefoed, with notes upon Radiolaria, by M. E. Jörgensen.

Medusæ, by M. C. Hartlaub.

Fishes, by M. E. Koefoed.

Deep-water invertebrates, by J. Grieg.

It will doubtless be of interest to review briefly the results obtained. We shall attempt this while limiting ourselves to the important geographical problems that the expedition had proposed to solve. We omit, then, reference to a great part of the zoological material collected, notably that obtained in the course of the dredging carried on near Spitzbergen and in the offing of the east coast of Greenland; also the botanical and meteorological results of the expedition.

Let us review briefly the route of the expedition. This is shown in figure 1; the route of the *Belgica* is indicated by the principal observation stations, omitting the "diverse routes" inevitable in a voyage traversing the ice fields. After some preliminary stations near Spitzbergen, the *Belgica* sailed on July 7, 1905, from the Isle of Amsterdam, and bore first toward the northwest. The route being obstructed by pack ice, the course was soon turned back toward the south. In so doing one of the principal purposes of the expedition was lost. It remained then to push as far as possible toward Greenland. One can see by the course on the chart that at different times the *Belgica* pushed toward the west, but each time the polar ice, thick and compact, barred the way. The navigation was relatively easy in the deeper waters, but when the *Belgica* arrived near the edge of the continental platform of Greenland the ice presented an impenetrable barrier. This route, which was accomplished almost entirely to the west of 0° Greenwich, is nevertheless of great interest. It was made appreciably farther to the north and to the west than all previous itineraries, and the soundings have particular value in that in one point they reached the foot of the continental talus (soundings 1,425 meters). Nevertheless, under latitude about 76° north, the *Belgica* succeeded in making her way through the ice, thick and confused, which descends from the North Pole in immense and dangerous fields. The crossing of the polar current made in the course of this cruise was more than 2° north of all those that had preceded it. In proportion and measure as the depth diminished toward the coast the ice became more tractable and soon the polar ice gave way to the ice formed in the neighborhood of the land, which is much easier to navigate. Along the coast of Greenland the *Belgica* was able again to turn toward the north, and gaining the latitude of Terre de France,[a]

[a] The name which the Dépôt des Cartes et Plans of the Danish Marine has substituted for that of "Land of Duc d'Orleans."

attempted again to cross the polar current. The expedition was then at the latitude where the sounding of 1,425 meters mentioned above was accomplished.

This new effort seemed destined to succeed. It brought an interesting first result; the discovery of a bank situated off Greenland (at a depth of 58 to 100 meters) which was later designated as the Bank of the Belgica, and in the center of which, according to Commander de Gerlache, there perhaps rises an island. By this it was established that here the Greenland continental platform is enormously extended, and if one follows upon our chart the line of the 1,500-meter contour which marks the base of this platform, he sees that it extends in a much more northeasterly direction—that is, in the direction of Spitzbergen—than does the coast of Greenland. It is very probable that this is the first appearance of the relief which Nansen supposed to exist.

The crossing of the polar currents having been again rendered impossible by the abundance of ice, and the season being advanced, Commander de Gerlache resolved to turn southward. Laying his course between the land ice and the polar currents, the *Belgica* worked out of the ice and traversed again, and not without difficulty, the polar current at the meridional limit of the Greenland Sea. As is seen, this voyage of the *Belgica* lay wholly to the northwest of all previous expeditions. There may thus be formed a more complete idea of the depths and the hydrographic régime of the Sea of Greenland. This problem had already been touched upon, and particularly by Nansen. In his memoir entitled "Northern Waters" he had shown the results of the studies of all the material collected up to 1905 concerning the Greenland Sea, and particularly the results of the examination of the material that Amundsen had brought together during the trial voyage of the Gjöa. It was especially from a study of these materials that Nansen has been brought to admit the existence of the Spitzbergen-Greenland relief.

It is therefore of great interest to consider the observations of the *Belgica* as a check, confirmatory or otherwise, of the theories and conclusions of Nansen. It is the best proof of their correctness.

What, before all else, characterizes the Sea of Greenland is the presence of a sheet of surface ice in its western part. In winter this sheet is extended toward the east and covers the larger part of the oceanographic region. This extension is due to the freezing of the water in situ; the ice thus formed is composed of horizontal layers and never attains a great thickness. It remains where formed; that is to say, in the midst of the Greenland Ocean, until the beginning of summer, when it begins to melt. Its eastern margin progressively and irregularly retreats toward the west. This ice, born as it were in the Sea of Greenland, is designated under the name of bay ice.

It is of an entirely different nature from the polar ice which is met with in the offing of east Greenland. This is formed of laminæ much thicker, more compressed, and contorted, and originates near the Pole. While the bay ice, relatively stagnant, forms and disappears in the Greenlandic Ocean, the polar ice is carried along by a constant current. It results that the region of the bay ice is relatively navigable, while that of the polar ice constitutes a dangerous barrier. During the greater part of the voyage the *Belgica* penetrated as far as possible into the pack ice (banquise) so that it had polar ice on the starboard and bay ice on the larboard side. The *Belgica* twice crossed the polar ice, and each time with the greatest difficulty. Thanks to a combination of happy circumstances, it was enabled to reach the coast of Greenland.

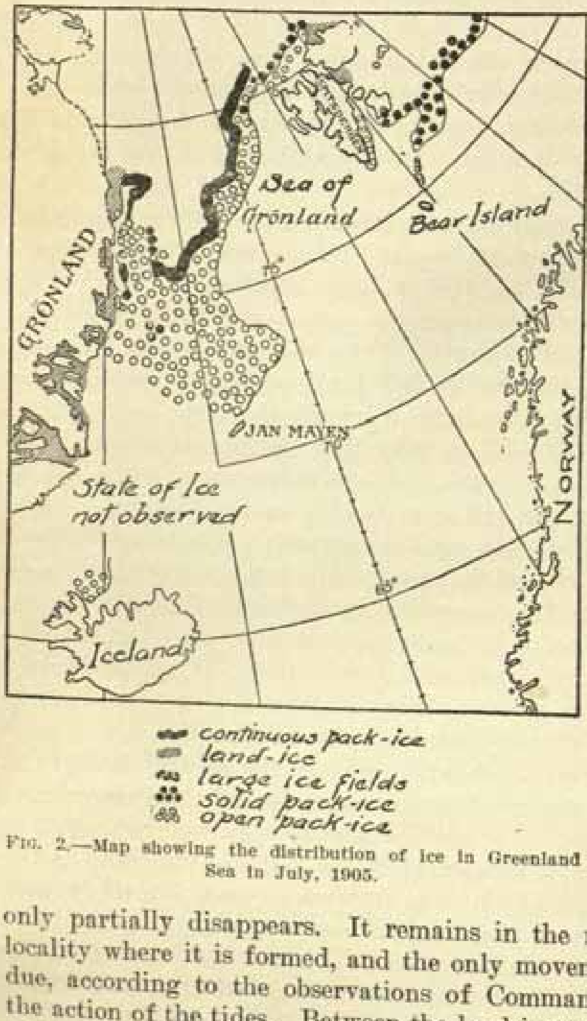
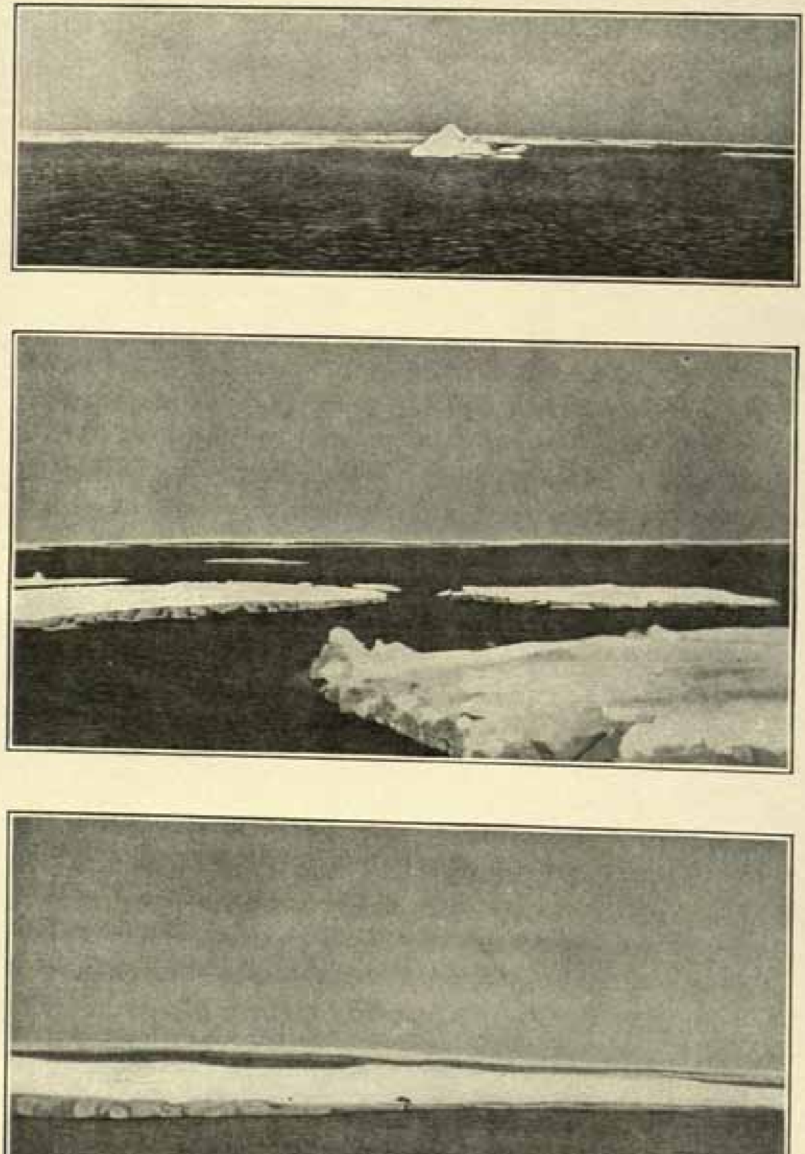


FIG. 2.—Map showing the distribution of ice in Greenland Sea in July, 1905.

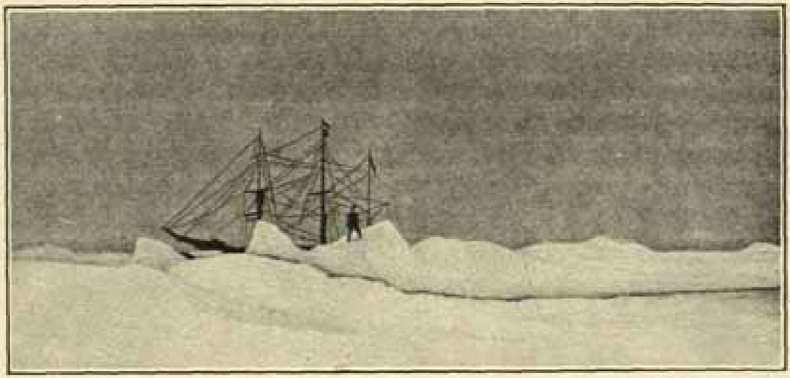
On the other side of the zone of polar ice the *Belgica* found the land ice formed in winter in the fiords and the neighborhood of the Greenland coast. Even in July, this ice only partially disappears. It remains in the neighborhood of the locality where it is formed, and the only movements manifested are due, according to the observations of Commander de Gerlache, to the action of the tides. Between the land ice and the polar ice there exists a zone less encumbered, through the favor of which the expedition was able to ascend as far as the Belgica bank.

These three kinds of ice are very different in origin, distribution, and movement. Thanks to the numerous observations of the *Belgica*

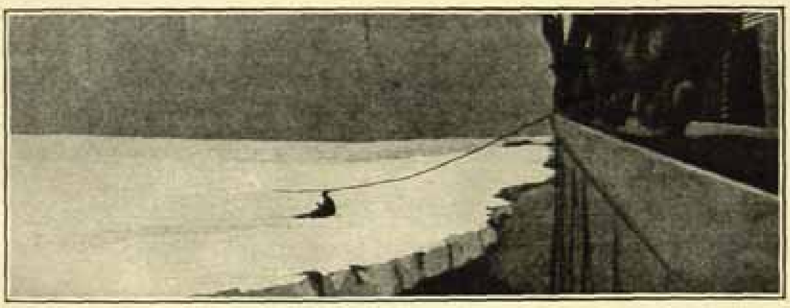


BAY ICE IN GREENLAND SEA.

(From photographs by Doctor Récamier.)



THE BELGICA IN A FIELD OF POLAR ICE.



EDGE OF LAND ICE, WEST OF GREENLAND.

and those of Norwegian sealers, it has become possible to construct for the summer of 1905 very complete maps showing the condition of the ice in the Greenland Sea. As an illustration we give here the maps for the months of July and August (figs. 2 and 3). They enable us to determine some of the chief laws of ice distribution. The land ice is attached on the west to the Greenland coast. Its exterior limits exceed but little the shallow depths of the continental plateau. The eastern limit of the polar ice corresponds rather closely with the isobar of 1,500 meters which marks the base of the continental talus slope; that is to say, the field which it covers is enormously expanded toward the north and gradually narrows to the south until, at the height of the second crossing of the *Belgica*, the zone has scarcely, according to observations of Commander de Gerlache, an extent of more than 2 or 3 kilometers. The distribution of the polar ice on the surface is, then, closely related to the topography of the ocean bottom.

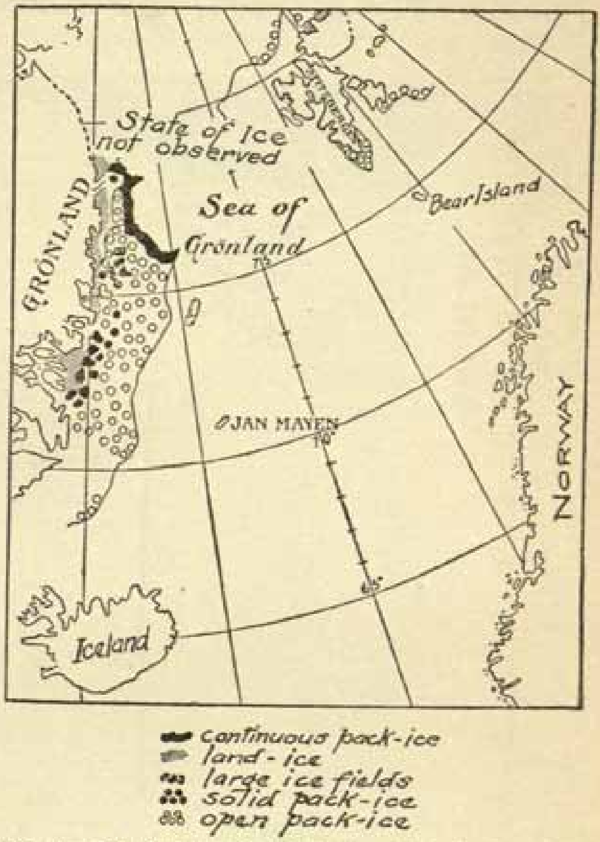


FIG. 3.—Map showing the distribution of ice in Greenland Sea in August, 1905.

The bay ice covers a surface varying with the season. It occupies in general the central or region of most profound depth of the Greenland Sea. Its progressive retreat in summer is irregular. In general it is less rapid immediately to the south of Jan Mayen than farther to the north. There results from this the formation of a gulf sufficiently constant to merit the name of Gulf of Bay Ice, which the Norwegian hunters have given it. It is through pene-

trating into this gulf that the *Belgica* was able to reach the Greenland coast.

Thus, as Nansen has described, and as also shown in the extracts of the journals of the Norwegian sealers published by Wollebaeck in a memoir by Hjort and Knipowitch, the regions of the bay ice—that is, the central region of the Greenland Sea—is the region sought out in the spring by the seals (*Phoca greenlandica*) as a breeding place, that find there an ice of slight thickness, always quiet, and

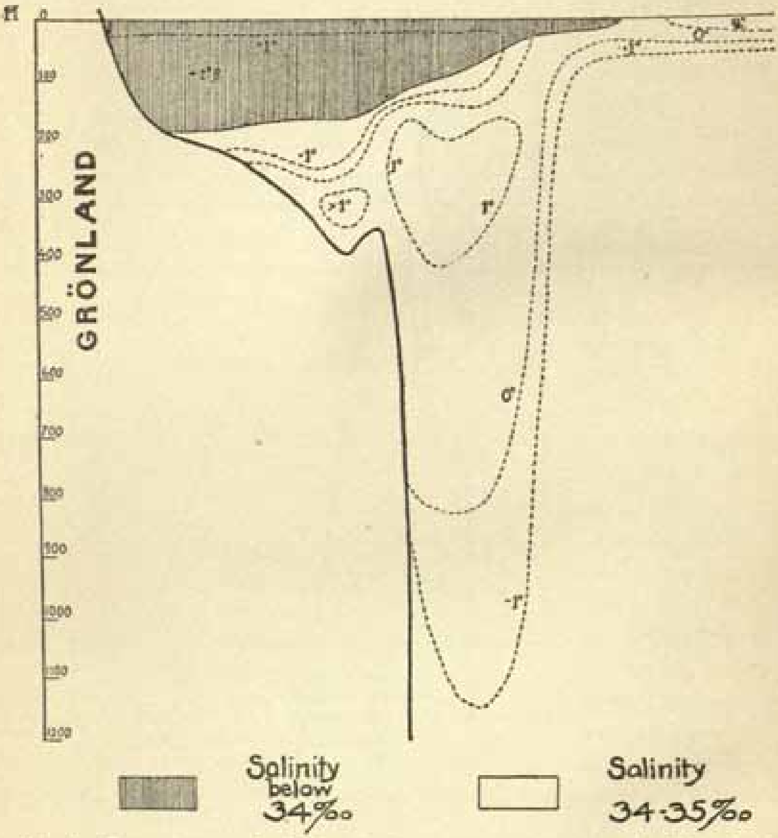


FIG. 4.—Temperature and salinity of polar current off west coast of Greenland.

little frequented by the white bears, all conditions such as can not be found either on the polar ice or near the coast. The sealers concern themselves in their hunts mainly in the Gulf of Bay Ice, which they have learned to know very well.

As has been seen, the ice of the central part of the Sea of Greenland is very characteristic and quite different from that of the polar current. This curious distribution of the various kinds of ice is explained completely by the study of the oceanographic materials brought back by the expedition of the Duc d'Orleans.

To the east is found a region always free of ice. It is kept open by the Atlantic current. This, in flowing between the Shetland and Faroe islands, carries water of a salinity in the neighborhood of 35.2 parts in 1,000 or more, and of a temperature of about 7°. At the latitude of Spitzbergen its temperature has fallen to 5° and even to 2°, and its salinity is lowered as a result of its commingling with the continental waters. In the cut (fig. 5), which extends from the center of the Sea of Greenland to the south of Bear Island, we see the waters of a salinity upward of 35 parts in 1,000 thrown against the

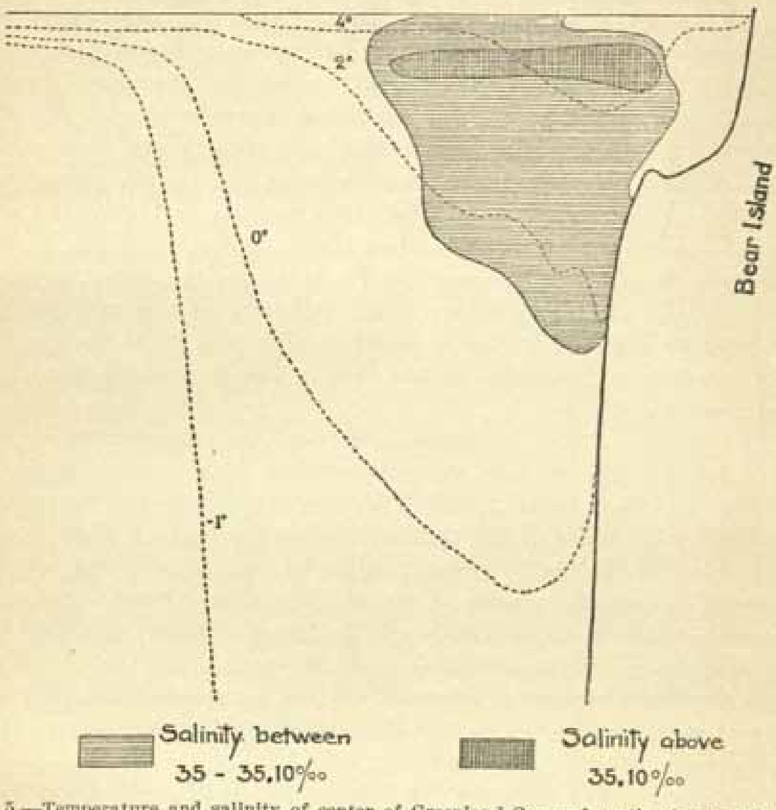


FIG. 5.—Temperature and salinity of center of Greenland Sea and south of Bear Island.

continental talus by the earth's rotation. Their depth in the figure is about 400 meters. The Atlantic current runs along the west coast of Spitzbergen, and in figure 6 we see the same waters at the moment of losing themselves in the polar current. They have then a temperature of about 3.5°. Opposite Spitzbergen the current divides, one portion going toward the west. This is shown in figure 6 under the form of a tongue of water of a positive temperature, which is intercalated between the surface water and that of the depths, the last having a negative temperature.

Along the coast of Greenland the current moves, carrying with it the old polar ice noted above, but the masses of water which come from the north toward the southwest are not limited to the surface. They have a considerable depth and a great complexity, which we will now consider (fig. 4). The vertical distribution of the temperatures is especially characteristic. In summer the ice floats in a water of variable temperature, mostly below 0°, but never going lower than −1°. From the surface as far as the depth of about 100 meters the temperature decreases progressively. At this depth is found a nucleus of very low temperature (as low as −1.8°) which represents the center of the polar current. Beyond this the temperature rises progressively, and between 200 and 400 meters is found a maximum of about +1.2°. It is only below 800 meters that they have observed again a negative temperature which is characteristic of the deep water. This remarkable distribution of temperature is explained very clearly by Helland-Hansen, who agrees in all points with Nansen. The ice carried by the polar current forms in the polar basin, mainly during winter, when the water has a minimum temperature of −1°. In summer the ice melts and the water warms up slowly. This warming makes itself felt only at the surface. The cold temperature of winter is maintained in the great depths; it is this remnant of the polar winter that is found between 20 and 150 meters under the ice.

The region of the maximum intermediate temperature is more remarkable. The waters where it occurs have a relatively high salinity (34.90 parts to 1,000). By this they show an evident relationship with those of the Atlantic current. In fact, these are the last traces of the Gulf Stream, which, when it encounters the polar current, becomes by reason of the density of its waters, intercalated between these and the waters of the great depths. We find then here the waters of the returning Gulf Stream. Whether or not they have made a complete or a partial tour of the polar basin, they were turned aside toward the west at the latitude of Spitzbergen, as shown in figure 6.

We have stated that the Gulf Stream is held against the continental platform of Spitzbergen by the rotation of the earth. The polar current, some 800 meters in depth, is likewise held against that of Greenland; according to the observations of the *Belgica* its outer limit corresponds to the isobar of 1,500 meters, that is to say, it is very broad and quiet in the north, while it contracts and gets much swifter at the south.

These Atlantic and polar waters overlie the waters of the great depths, the mass of which fills all the basins and by far surpasses in volume the superficial waters. The deep-seated waters have a temperature of −1° to −1.4°, and a salinity between 34 and 35 parts per

1,000. They are then at the same time very cold and relatively salt. It should be noted also that their density is 1.02811. These waters can not then be polar waters, properly called.

According to Nansen and Helland-Hansen, they owe their origin to the progressive cooling of the intermediary bed (of Atlantic origin, therefore salt). In winter, in the central part of the Greenland Sea and during the formation of the bay ice, the water becomes cooled at the surface to the freezing point (−1° to −1.8°). At this point it becomes more and more dense, sinks into the depths and becomes the bottom water ("l'eau de fond"). At the time of the melting of the ice in summer the surface waters are slowly warmed up and there is formed at the same time a superficial layer of water only slightly salt, which impedes the penetration of heat into the depths. In the center of the Sea of Greenland there is found, even in summer, a great uniformity in the distribution of temperatures. This is made very clear in figures 4 and 5. The formation of the bottom water in the central region of the Greenland Sea is then in close relation with that of the bay ice. This could not freeze in situ unless the total body of the sea water had a low temperature. The extension of the polar ice is likewise in relation with that of the polar current, and it is evident that the topography of the depths exercises a preponderating influence as much upon the ice as upon the body of water which carries it.

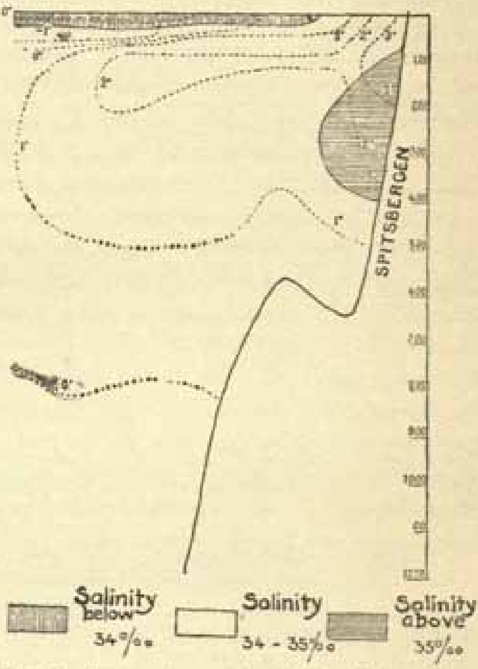


FIG. 6.—Temperature and salinity of the Atlantic current off Spitzbergen.

The polar current which turns toward the south along the western border of the Sea of Greenland, and the Gulf Stream, which flows toward the north along its eastern margin, cause the formation of a cyclonic system peculiar to this basin, the center of which lies in the region of the bay ice above the great depths. This movement, cyclonic in the periphery, brings about an ascension of the water of the depths in the central regions, and the formation of the bay

ice in winter is thus accounted for. It is on this account that the Sea of Greenland appears to us as a special oceanographic basin.

The Sea of Greenland communicates freely with that of Norway on the south. Their hydrographic régime is also identical. Comparison of the results of the *Belgica* with those supplied by the expedition of the *Fram* bring out, on the other hand, some valuable suggestions as to the relations existing between this sea and the polar basin. These are illustrated by the following table, where are summed up briefly the hydrographic conditions in three different localities: (1) In the polar sea, according to Nansen; (2) in the polar current to the east of Greenland, according to the *Belgica;* (3) in the center of the Greenland Sea, according to the observations of Amundsen, as published by Nansen.

SEA OF GREENLAND.

	Polar sea, according to Nansen: *Fram*.	Polar current, according to Helland-Hansen and Koefoed: *Belgica*.	Central region, according to Nansen from observations of Amundsen: *Gjoa*.
	1. Superficial polar beds (0 to 20 or 30 meters).	1. Superficial polar beds (0 to 20 or 30 meters).	1. Superficial beds (0 to 20 or 30 meters).
Ice	Compact; hummocks	Compact; hummocks	Thin (bay ice).
Temperature	Below 0°	Below 0°	Variable in summer.
Salinity	21 to 32 parts in 1,000	21 to 32 parts in 1,000	34.90 parts in 1,000, about.
	2. Cold polar beds (from 20 to 100 meters).	2. Cold polar beds (from 20 to 150 meters).	2. Water of profound depths. From the depths to the surface in winter, attaining a variable level in summer.
Temperature	Minimum, down to −1.9°	Minimum, down to −1.8°	−1° to −1.4°.
Salinity	Less than 34 parts in 1,000	Less than 34 parts in 1,000	In the neighborhood of 34.9 parts in 1,000. Density 1.02811.
	3. Chilled Atlantic beds	3. Chilled Atlantic beds	
	a. Central nucleus down to 400 meters.	a. Central nucleus down to 400 meters.	
Temperature	Maximum, up to +1.2°	Maximum, up to +1.2°	
Salinity	In the neighborhood of 35 parts in 1,000.	In the neighborhood of 35 parts in 1,000.	
	b. Transitional beds (down to 800 meters).	b. Transitional beds (down to 800 meters).	
Temperature	Above 0°	Above 0°	
	4. Bottom water (from 800 meters to bottom).	4. Bottom water (from 800 meters to bottom).	
Temperature	From −0.8° to −0.9°	From 0° to −1°	
Salinity	About 35.1 parts in 1,000	Less than 35 parts in 1,000	
Density	1.02825	1.02811	
	5. Water of depths warmed by contact with bottom.	5. Water of depths rewarmed by contact with bottom.	5. Water of depths rewarmed by contact with bottom.

As may be seen, there is an absolute identity between the oceanographic régime in the two principal regions down to a depth of 800

meters. On the other hand, there is an absolute difference between the central waters and those of the polar current in the Greenland Sea. This fact is evidently explained by the circumstance that down to 800 meters the superficial waters of the polar basin can flow out freely. The deep-lying waters, as has been previously stated by Nansen and as confirmed by the *Belgica*, are different, a fact which can be explained only by the existence of a submarine relief uniting Spitzbergen and Greenland. To the explanation invoked by Nansen in favor of this hypothesis is added then the fact ascertained by the *Belgica* of the identity of the superficial waters, and one must suppose that this relief rises to within nearly 800 meters of the surface.

It is to be noted that this conclusion rests upon the extreme exactitude to which the hydrographic observations of the expedition were carried. Modern oceanography has a second method for determining the zones of influence of marine occurrence. It consists of a study of the distribution of organisms which appear passively under their influence. The knowledge of the plankton has become in the last years the necessary complement of all oceanographic research. This point of view was not neglected during the campaign of 1905 of the *Belgica*. The naturalist of the party, M. E. Koefoed, had employed the best instruments for pelagic fishing, and obtained the first truly representative collection of the floating fauna of the polar current. It had the more value since it comprised not only the catches made horizontally by the aid of instruments of large size dragged at various levels, but also an important number of catches made by the aid of an excellent closing net invented by Nansen. It tells us as a result very exactly the composition of plankton in the Sea of Greenland and concerning the horizontal and vertical range of the principal pelagic organisms.

But before utilizing the zoological facts thus obtained, for geographic study, it is important to determine in what proportion the divers species are influenced by marine currents. In this short résumé we will limit ourselves to describing some of the conclusions of general interest to which the study of the materials collected by the *Belgica* has conducted us. It will appear with a sufficient amount of evidence that the use of the plankton as an indication of the marine currents should be made with extreme care. It is known that various species of animals, belonging to very diverse groups (crustaceans, worms, ctenophores, coelenterates), have been considered as characteristic of polar waters, and the conclusion is reached that their appearance in the lower latitude is indicative of the existence of waters coming from arctic regions. We are, nevertheless, able to state, thanks to the pelagic catches of the *Belgica*, that the composition of the plankton in the Sea of Greenland was

extremely uniform, and that it presented the greatest analogies with that of the Sea of Norway. A great number of species considered as characteristic of arctic waters are found equally in the waters of Atlantic origin which flow toward Spitzbergen. It is understood, moreover, that the slight variations in the salinity and temperatures which are observed in this latitude are not sufficient to produce any essential modification in the composition of the floating fauna.

Now, if we compare the pelagic fauna of the polar basin, as far as it is now known to us, with that of the Sea of Greenland, such as the catches of the *Belgica* show us, and that of the Norwegian Sea explored actively during these last years by the Norwegian steamer *Michael Sars*, and finally with that of the Atlantic, there would appear conspicuously a general law of the distribution of the pelagic organisms. The superficial and intermediate fauna of the Sea of Greenland offers the greatest resemblance to that of the average depths of the Sea of Norway. A considerable number of species of the ice regions are found in the Atlantic, but only at considerable depth. Some are found even in the Tropics, showing thus the cosmopolitan character of the plankton, but here they exist only at great depth. In other words, many of the organisms of the Sea of Greenland are abundant beyond the arctic waters properly called. Some are even universally distributed, but the level which they seek is proportionally as much more remote from the surface as the latitude is lower. Some forms are even known in the vicinity of both poles and frequent the neighborhood of the surface, in the midst of the ice of the Antarctic, as well as in the latitude of Greenland and Spitzbergen. They can be traced for a greater or less distance in the Temperate Zone to depths more or less profound, while they lose themselves in the abysses of the Tropics.

At the same time that the organisms retreat progressively into the basins of the ocean they leave the shores. It results that the same form can frequent the littoral portions in the north and can, as a consequence, serve to characterize the coast water, while it exists in the south only broader and becomes thus an excellent indicator of oceanic waters.

One sees, then, that the distribution of these pelagic organisms can teach us nothing on the subject of the action of marine currents. The existence in the depths of the basin of Skagerak of organisms which are habitually known in arctic latitudes is not due, as some (Cleve and Aurivillius) have stated, to the direct effect of transport by polar currents. It is explained by an entirely different law. The progressive retreat from the surface is occasioned by the more intense action of solar rays.

This example suffices to show that profound biologic study of species ought necessarily to precede its geographic utilization, a

conclusion to which all those have been led who have studied the terrestrial zoological geography. The action of the currents of the Sea of Greenland reveals itself only in the distribution of the three following groups of pelagic organisms.

First. The species which do not breed in the Sea of Greenland, but which are introduced by exotic currents. The most typical are the Atlantic forms transported by the Gulf Stream, of which the influence can be well recognized in this way as far as the latitude of Spitzbergen.

Second. The species which breed only upon the continental platform, but which are transported far and wide and dispersed by the currents. They indicate, consequently, the influence of waters which have been at some time in contact with the coast. These forms appear periodically, and the season of their swarming is often very short. Therefore, one can, by their progressive extension, form an exact idea of the rapidity of the movement of the waters. These coast species (still called néritiques) are different in four parts of the continental platform bordering the Sea of Greenland. There results from it that these may serve as indicators to determine the zone of influence of the coast waters which have touched Norway, Spitzbergen, east coast of Greenland, or the island of Jan Mayen.

Third. Finally, however feeble may be the variations of temperature and salinity of this sea, they do not fail to favor or retard the development of diverse organisms. The waters of different nature which we have recognized above, especially in the upper beds, are then characterized by a special facies of the fauna and floating flora. Thus the polar current carries water of a brown color due to the active development of vegetable plankton, which utilizes the vegetable substances coming from the streams of Siberia and brought by the current which comes from the pole. In the waters of positive temperature the copepods multiply actively and impart to the fauna of the final branches of the Gulf Stream a special character.

In a general way, then, the several currents are recognizable by the life they carry, as well as by the chemical or physical character of their waters.

FROM THE NIGER, BY LAKE CHAD, TO THE NILE.[a]

[With 3 plates.]

By Boyd Alexander,[b] Lieutenant, Rifle Brigade, F.R.G.S.

Before commencing the narrative of my expedition across Africa I should like to make a few remarks on the object and composition of the expedition.

The first work we wished to carry out was a systematic survey of a portion of northern Nigeria. Secondly, to explore Lake Chad and the rivers between the Niger and the Nile, with the idea of demonstrating the wonderful system of waterways that connects the west with the east, and I think this is fairly well shown when I tell you that in the three years which the journey took to complete, the boats were carried for only fourteen days. Together with these primary objects, special attention was to be given to tribal distribution and orthography of native names, and a careful study made of the distribution of the fauna to prove its affinity between the West Coast and the Nile.

The party consisted of my brother officer, Capt. G. B. Gosling, Mr. P. A. Talbot, my brother Capt. Claud Alexander, and myself. With me I took my Portuguese collector, José Lopes. We were fully equipped with survey instruments.

Captain Gosling was active in obtaining zoological collections, Mr. Talbot and my brother were responsible for the Nigerian survey, for which they had special qualifications, while I acted as leader. For the river work we took with us two steel boats, double keeled, 26 feet long and 6 feet wide, drawing $1\frac{1}{2}$ feet for $2\frac{1}{2}$ tons, and made on the Hodgett principle by Forrest Brothers, of Wyvenhoe. It took 24 men to carry each boat, which was in six sections. It would be

[a] Addressed to the Society in the Chemical Lecture Theater, Victoria University of Manchester, on Tuesday, November 3, 1908. Reprinted by permission from The Journal of the Manchester Geographical Society, Manchester, England. Vol. 24, part 4, 1908. A large colored map, not here reproduced, accompanies the original paper, showing the route of the expedition.

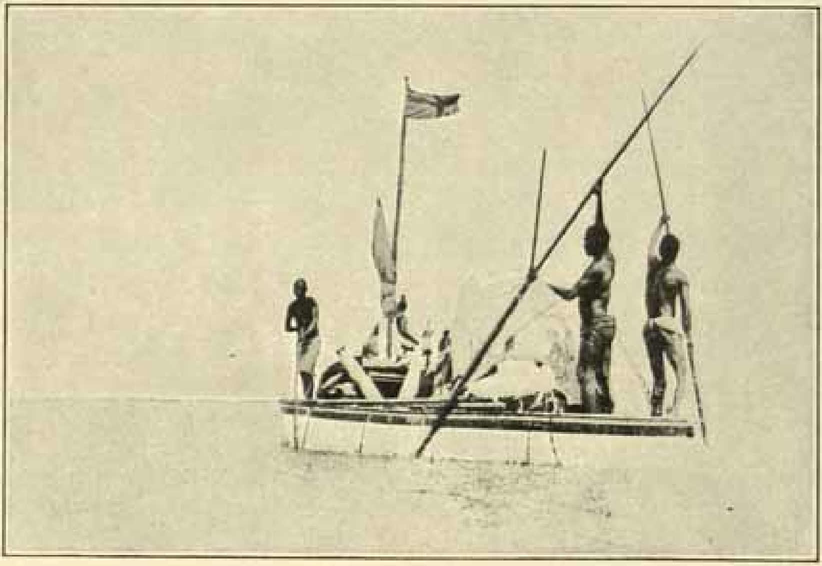
[b] Lieutenant Alexander was killed April 2, 1910, by natives near Abeshr, in Wahdi, French Kongo.

hard to exaggerate their importance. In many places they did the work of bullock transport and carriers, which were impossible to obtain; and it must be remembered that it was necessary at times to support a large number of followers, sometimes 200 in number, who had to be paid and fed. For this purpose a great amount of trade goods were carried, besides provisions, survey instruments, and photographic apparatus.

The expedition left England on February 27, 1904, and arrived at Lokoja on March 24. There it organized and went to Ibi, our first base for the survey work which was to triangulate through the country north to Bauchi and connect that place with our subsequent work in Bornu. The survey party traveled by way of the Murchison Range and passed through the country of the Montoils and Yergums, pagan cannibals who inhabit the hills. The early state of their civilization is shown by the fact that they have not yet evolved as far as the village stage; each hamlet is against each other, each village against the next, and each tribe against its neighbor; the stronger prey upon the weaker, with the result that the former inhabitants have been driven right up to the peaks of the range, where they now lead a precarious existence. They are very hostile to one another, and are continually raiding their supplanters below to get captives. It was astonishing to see how these pagans had irrigated and cultivated their fields, and taken advantage of every available patch of soil on the hillsides. At this point progress was checked by both members of the survey falling ill, which necessitated their traveling to Wase, where there is a post. Here I might mention the Wase rock, an immense mass of igneous rock rising sheer out of the plain. It is about 600 feet high, and was probably the tube of a volcano, of which all the rest have been denuded away.

Having recovered their health, the party proceeded into the Angoss country past Mount Madong. The country was hilly, with numbers of isolated rocks like that of Wase. In these parts they came across an extraordinary amount of mica; the path followed shown with it like silver, and on either hand there were great sheets of it. Beyond the Madong Mountains to the northwest lay a magnificent range with peaks 5,000 feet high. This has been named the Claud Mountains in memory of my brother.

From Bauchi the work of triangulation was carried into the unexplored and interesting country of the Kerri-Kerris. It is only necessary to describe the towns of Gamari and Lewe, as they will be found typical of all the rest. Amid an alluvial plain rises a huge circular mass of chalk with precipitous cliffs stretching sheer up on every side. At the top, 300 to 500 feet above the plain, the mass forms an absolutely level plateau, crowded with villages. In the midst of the plateau again rises a very steep peak of ironstone or laterite,



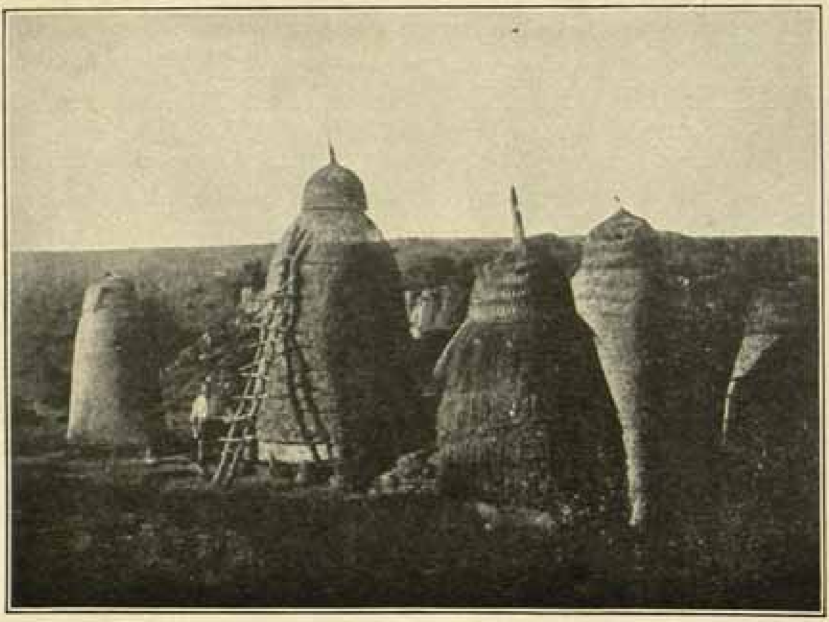
BOAT ON RIVER BENUE.

KERRI KERRI COUNTRY.

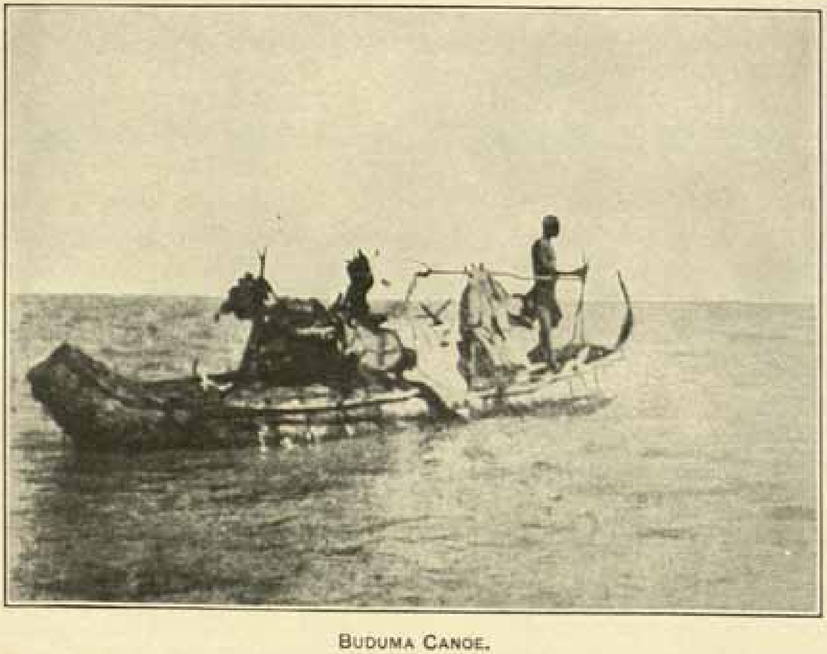
water is so gradual that there are no banks, and except in one or two places the lake can be reached without difficulty, for there is scarcely any marsh, and the land is firm with a sandy soil. We made our first voyage with the object of gaining the Shari mouth, but we found it was impossible to go south; a great barrier of dense marsh lay to our right. Hoping to find an outlet, we followed this belt as close as possible, but were eventually compelled to take a northeasterly course, the marsh giving way to continual low-lying land in the form of bays, in many places unapproachable owing to thick mud. Our prospects the first day were anything but bright, and the impossibility of getting into touch with the Buduma did not improve matters. Toward sundown we sighted a large fleet of canoes engaged in fishing operations. They had not observed us, and under cover of the growing darkness we stole silently along under the lee of a promontory, and came within 500 yards of them. Then a great commotion followed. The canoes were drawn up out of the water, and boats and men disappeared into the reeds. The next day the water to our left became studded with innumerable small sandy islands, overgrown with tall grass, and many strewn with shells. On account of mosquitoes star work was impossible, and consequently latitudes had to be taken during the day.

For several days we toiled along with hardly any progress, the boat often scraping along the thick mud. Our hopes were more than once raised by the sight of what we took to be Buduma settlements on the land to our right, but on approaching these they turned out to be deserted cattle stations, which consisted of reed-built huts very small in circumference, not more than 4 feet high, and the sides toward the prevailing wind always plastered with mud.

By now we found that our provisions had run out, and we were obliged to shoot gulls for food. By the following evening, however, our cartridges were almost finished, and we were forced to make for rats, which abound on the islands, digging them out of their holes and making humble pie of them, and this is how we lived for another six days, ever hoping to find a passage to the east; but, realizing at last the necessity of bringing our trip to a close, we changed our course to west, and after a tedious winding through a network of islands we emerged into open water. This continued for a distance of 15 miles till the Yo mouth was reached, where we encamped on a small island, the site of a Buduma fishing station, which presented a picturesque sight. There was a fleet of some twenty canoes, many full of dried fish, while hanging from frameworks of poles was fish in the process of drying. Their canoes, made of thick bundles of dry reeds tied together and turned up at the prow, are most picturesque. They are generally 18 feet long



KERRI KERRI GRANARIES.



BUDUMA CANOE.

and about 3 feet wide. Lighter canoes are also made, for traveling over shallow water and for escapes from sudden attack.

On December 23 we arrived back at Kaddai and Talbot left for England.

By the middle of February, 1905, Gosling, after elephant hunting near the shore of the lake, left for Kusseri, our next objective, and a week later we started with the two boats once more to try and find a way across the lake to the Shari. We took the direction of the Yo mouth, with the idea of following the influence of its water. We passed an island on the way, where I counted a herd of sixty hippopotami that had been driven to the lake by the falling of the river. Five miles beyond the Yo mouth we struck a northeasterly direction. At a Buduma fishing island I induced two boys to come with me as guides. For 16 miles we found good open water, and then our course lay through a mass of small islands, through which we struggled on for 10 miles, the men often wading and pushing up to their chests in mud. The next morning I found that we were near the east shore of the lake, for there were horsemen to be seen on the land about a mile beyond the island.

My difficulties were increased by the Harmattan wind. It would rise daily at 9 a. m., and by 12 o'clock the sun would be blotted out by a dense, damp mist, through which we had to grope our way, miserably cold. To show how strangely the water shifts with the wind, one morning, in retracing our course of the evening before, we found the water had gone, leaving numbers of fish of enormous size, some 4 feet long, stranded. As I could find no passage southward, and my men were worked out, I decided to retrace my way to Kaddai and refit for another attempt.

On March 2 I took the same course as our first, again determining to find a southwest passage, but the reeds still proved impassable. On the outward journey we came upon a large Buduma fishing fleet. At first they mistook us for other Budumas, whom they considered an easy prey, for it is their habit to plunder one another when they get the chance. Accordingly they closed up ready for attack. But soon they realized their mistake, and the tables were turned. Before we could get up to them, many of the boats burst into flames, and the Budumas, swimming like otters, underneath the water, disappeared into the reeds. Hidden in the boats we found four slave boys, who were the victims of a traffic carried on between the Budumas and Tubus. They were in a shocking condition, and we took them back and released them at Kaddai.

We then determined to try and cut through the reeds. We worked steadily for two days, cutting a distance of about 800 yards, and beyond that I waded a mile, but there was no end to the reeds and "maria" bush.

I then relinquished this, my third attempt, and once more returned to Kaddai. When within half a mile of the shore we found the water had disappeared, and as it was late the men slept in the boats and my bed was put up in 6 inches of water, and that night I slept on the floor of the lake. In the morning the water rose earlier than I did, and I had just time to get out of bed as the lake was getting in.

I then abandoned Kaddai as a starting point and trekked with the boats' sections to Seyurum, a distance of 25 miles, which was the next point to the south where there was open water. This took me a month and a half owing to desertion and sickness.

From Seyurum I made my fourth and last attempt, which necessitated three days' cutting through great belts of reeds, papyrus, and maria bush which extended as far as eye could reach. We were obliged to spend the nights huddled up in the boats. Sleep was out of the question owing to the hordes of mosquitoes. Many of the men preferred to sit up to their necks in water all night.

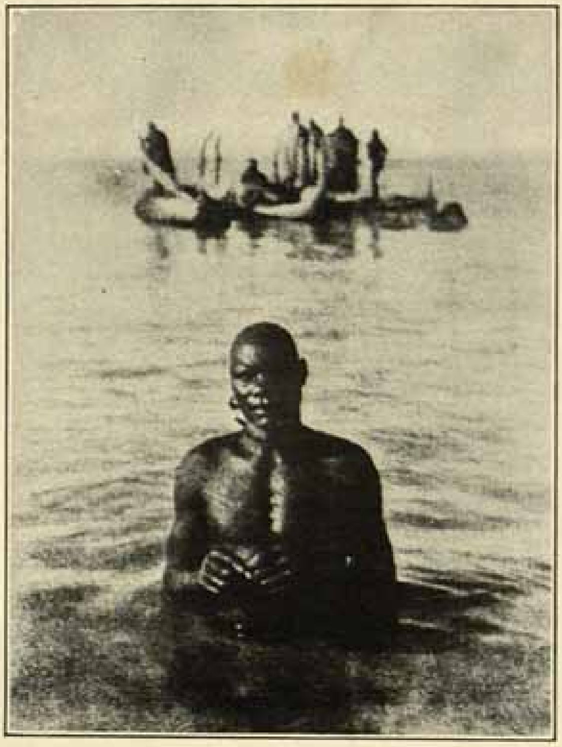
In the course of the work we discovered a gigantic turtle, nearly 100 pounds in weight, with a shell of a pale lemon color. On getting through the reeds, we found 5 feet of water. The aspect of the lake was now quite different from that of the Yo basin. Instead of low islands, there were big island stretches, which formed continual promontories ahead, overlapping one another on either side of our course, with channels sometimes not more than 100 yards wide; at other times forming deep bays as much as 2 miles in width, lined with belts of dark-green maria 10 to 30 feet in height.

Up to this time the Budumas had held severely aloof, but now a Kachella, or chief, of a large fishing fleet we met saluted us, and offered to show us the way to the other side. On the way he took us to his island, Karraragga, where we rested for two days. This island presented a very fertile appearance; the delicate green of young mimosa leaf was a pleasant sight after the sand-swept stretches of Bornu, and large herds of cattle roamed about at will. The Kachella's town consisted of reed huts, conical in shape. Each dwelling had its low round mosquito-proof house covered with close-woven matting.

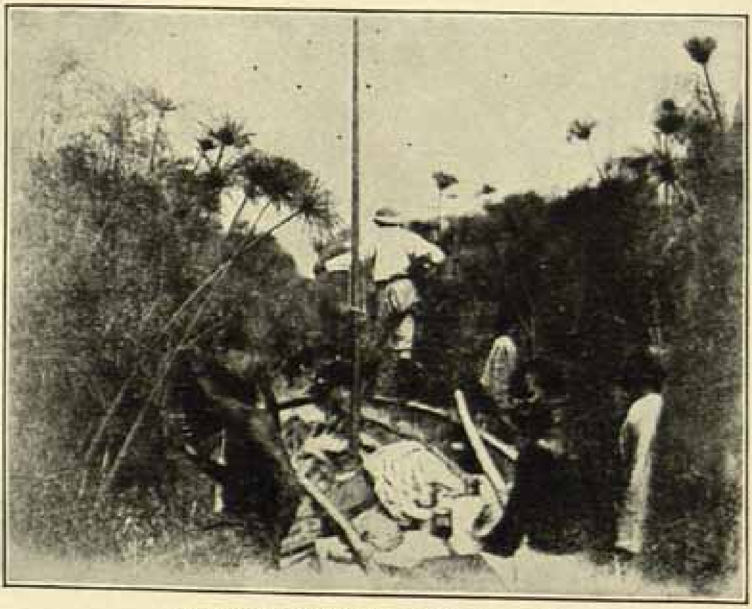
The Buduma men are tall, with well-developed heads. Living as they do on fish, their skins are very sleek and oily. The women are small, and resemble the Kanembus.

On leaving the island I went to Wunnda on the east side of the lake, thence followed the shore to the mouth of the Shari. About 12 miles before reaching the Shari mouth one leaves the great somber maria belts behind and comes out into magnificent open water, and Chad for the first time assumes the grandeur of a lake.

Before leaving Lake Chad I will attempt to give a general idea, based upon the observations I was able to make. As regards the size,



BUDUMA, LAKE CHAD.



CUTTING THROUGH THE REEDS, LAKE CHAD.

I made it considerably less than it was formerly supposed to be. There is an idea that the lake is drying up, but my opinion is that it does not alter very much, and I believe that the supposed greater original area is simply due to inaccurate survey and partly to the fact that the villages on the Bornu side are several miles distant from the lake, which has given the impression that these determined a former shore line. But I think that the sole reason for their position is one of security, for, as there are no containing banks, and the land and water being almost level, the Harmattan, which causes the water to flow 600 yards over the land with an ordinary wind, drives it as far as 2 miles when the wind is strong. Besides, I was told by the King of Kowa, a town situate 11 miles from the lake, that in a great flood twenty years ago the water had reached as far as the town, and in another seven years ago it had risen past it and covered the plain as far as a place called Mongonu. While the floods lasted the Budumas went up in their boats and established a fish market just outside Kowa. Now, on the eastern shore, where there are good banks, and the water is not influenced by the prevailing wind, there are many villages close to the lake.

Another fact that has perhaps created the impression that the lake is decreasing is that chains of islands that once were separate are now more or less joined together by marsh. But I think that this may very likely be due to the silting up of mud and sand against the obstruction of the islands by the opposing influences of the Yo and Shari, the two rivers that feed the lake. In fact, my observations go to show that the lake is practically two lakes, divided by the 15 miles or so of marsh and maria bush that I attempted to cut through, and these form the separate basins of the two rivers. Moreover, a Buduma chief told me that there was no communication between the two parts, and I found that the people on the different sides knew little of each other. This impression is further borne out by the very marked difference in the character of the scenery and the people. On the north the shores are flat and bare, and the surface of the water, which is nowhere more than 4 feet deep, is broken up by small uninhabited islands that are little more than sand flats. The people are neither numerous nor flourishing, and lead a lawless existence. But in the south or Shari basin everything has a more flourishing appearance. The depth of the water is from 5 to 9 feet, and the islands, which form prominent features, are fertile and thickly inhabited. Everywhere the maria tree grows luxuriantly, and its close dark foliage gives a somber character to the scenery. This is the real home of the Buduma, who are a prosperous, enlightened people, gaining their wealth by fish and potash, and counting it in numbers of wives, slaves, and herds of cattle.

Previous to my work on Lake Chad I had the fortune to witness a Tubu raid upon the Mecca caravan. At that time the Yo districts were in a most unsettled state; natives went about fully armed, and only traveled by night, for fear of the Tubus, who were on the warpath. These people are the nomad robbers of the Sahara. Armed with long spears, and mounted on small ponies and camels, they cover long distances, concentrating suddenly when a raid is contemplated, afterwards to scatter and as quickly disappear. Many of the lawless Mobbur are their worthy allies, acting as spies, and sharing a portion of the spoils. While the last great Mecca caravan was traveling through this country, escorted by the Kachella of Yo, it was heavily ambushed near Bulturi. The Mobburs opened the attack by flights of poisoned arrows, while the Tubu horsemen charged on the flanks, cutting off numbers of the flocks of the caravan, which spread over 2 miles of road, and numbered seven hundred people and nearly a thousand cattle. With the loss of twelve men and thirty horses killed, the Kachella, who had eight spear wounds, with his hundred horsemen kept the enemy at bay, and, under the protection of darkness, brought the harassed caravan into Bulturi, where for five days the Tubus hemmed it in. On the fourth day the Kachella managed to get a runner through to me. Accordingly, with all the arrowmen and horsemen I could muster at Yo, I reached Bulturi in time to relieve him. At daybreak we moved out of the town. It was a picturesque sight. Whole families were there, driving their flocks and carrying with them all their worldly belongings, and their children, perched on the backs of bullocks and camels. Among this pilgrimage there traveled pale-faced Fulanis, Hausas from Sokoto, handsome dark-skinned people from Melle and Timbuktu, and many Mallams or priests, turbaned and clothed in white, walked calm and heedless of the danger, incessantly telling their beads. When close to Yo the Tubus were dispersed, for their leader had been killed, and the Kachella's warriors concentrated and advanced past me in a long line toward the town, and then the women and children crowded round the king, asking for news. All night long the hours were broken by the wail of women calling upon their dead men to return.

To go back to the expedition. Ascending the Shari, with fine steep banks and an average width of 500 yards, we traveled through the land of the Kotokos, the giants of the Sudan; and at Gulfei, the big Kotoko chief, some 6 feet 3 inches in height, received us with all his infantry and horsemen.

After leaving Fort Lamy the river has a winding course, with an average width of 800 yards, now and again widening out to a mile. In places the scenery reminds one forcibly of our English woodlands. Throughout its entire course the river flows through a very flat country, much of which is under water during the heavy rains.

Beyond Miltu the flat expanse is for the first time broken by an isolated group of wooded ironstone hills, known as the Togbau, about 300 feet in height, abutting on the left bank of the river. From the top, a vast view of a barren country presents itself, and my mind was at once carried back to a similar occasion, when I viewed the landscape from the top of the Keffi hills in Nigeria, and I could not help being forcibly struck by the contrast of the two scenes. There, as far as the eye could reach, stretched wide fields of yellowing corn, whose surface was often broken by clusters of hamlets where dwelt the happy harvesters, while here on all sides to the distance lay a barren stretch of bush and sand.

From Fort Lamy onward the Shari region is thinly populated. Between Busso and Fort Archambault there are no villages, and the magnificent river flows through a silent land untouched by traffic of any kind, and one can travel for days without meeting a single native canoe. Regarding the natives, those on the right bank belong to the kingdom of the Bagirmi people, who have carried on for years a systematic slave raiding against the Sara tribes, or Kurdi, as they are known to the Bagirmi; inhabiting chiefly the country away on the left bank, where they live in small communities, scattering their huts among their crops as a protection against surprise. They are timid people, but good and industrious farmers, growing chiefly millet and ground nuts; and, what is rare, both men and women work. They may be observed in the fields together, sowing their crops. After the ground has been cleared the man walks along making a dab in the soil at intervals with his native hoe, and the woman follows with the seed, which she places in the hole and covers up with her foot.

Closely allied to these people, both in appearance and customs, are the Kabba-sara, who inhabit the vicinity of the river above Fort Archambault. Beyond the right bank to the east the women of the Kabba-sara insert enormous wooden disks 4 inches in diameter in holes bored in the upper and lower lips, and the face is disfigured to such an extent that it no longer looks human, and the power of speech is reduced to a mumbling. This hideous custom is said to have originated in the mutilations which the women inflicted on themselves to prevent being seized by the sultans of Bagirmi for their harems in the days of slavery. The raids of these Bagirmi sultans, followed by the devastations of Rabeh, have crippled and depopulated to a disastrous extent the whole of the Shari region. This great leader had no less than 60,000 men in the field, who devastated and fed on the land like locusts. Each division of this large army had its foraging ground apportioned to it each day by the leader.

During our journey up the Shari the amount of game we met with was truly wonderful. On different occasions Gosling obtained elephant, giraffe, buffalo, rhino, hartebeest, bushbuck, duiker, water

buck, roan antelope, kob, ostrich, pig, and wild dog. This was accounted for by the fact that the dry season causes all this game to concentrate near the banks of the river.

At Archambault we found it necessary to collect a large supply of grain, for hardly a village lay in front of us, and our next object was the exploration of the Bamingi River, which flows through a deserted country. On August 6 we camped on a sand bank at the junction of the Bamingi and Gribingi rivers. The former is the larger, having a width of some 50 yards at its mouth. This river was still unknown to the explorer, unless we consider the record of a French trader, named Behagle, who attempted to ascend it, but at the rapids, about 4 miles from the mouth, had his boat badly smashed and was compelled to return. He was afterwards hanged by Rabeh at Dikoa. With the exception of these rapids, caused by a reef of rocks across the river, we found the Mamingi excellent for navigation. In August it was at its full, with a depth of 6 to 9 feet and a strong current which made our progress slow.

The river Bamingi has pretty scenery; sometimes the banks rise to a height of 60 feet formed by rocky knolls, and at these points the growth becomes tropical. For 130 miles, the distance we traveled up this river, we found the country uninhabited, and the impressive solitude was only disturbed by the herds of elephant, which at times frequented the gravelly sand banks, and troops of baboons that followed us along the banks, gazing in excited wonder at our boats.

We next ascended the small rivers Gribingi and Nunna, and crossed the Shari-Ubanghi watershed, carrying the boats for four days. Then we descended the Tomi River through a well-watered and undulating region. Here the character of the vegetation changes. Thick belts of forest full of rubber vine hide the streams, and the fauna for the first time belongs to the forest region.

In this part of the country the natives have a barbarously cruel method of hunting elephants. When a herd is located in the dry grass, all the villages turn out with guns and spears and fire the grass all round the herd. The poor beasts make frantic attempts to break through the ring of fire, and are to be seen rushing madly to and fro in their agony, rooting up trees and throwing grass and earth over their scorched backs.

A journey of four days down the Tomi River brought us into the Ubanghi, or "drinker up of little rivers," a great stream some 1,200 yards in width, swelling to a mile at the bends. Its banks are fringed with trees, with undulating grass beyond. On either side chains of gentle rounded hills, about 150 feet in height, and devoid of trees, save in the hollows and ravines, loop sometimes close to the river line and sometimes wind away to a distance of a day's journey. Above the junction of the river Kwango, there are large wooded islands,

some 3 miles long, inhabited by elephant, pig, and the small Congo buffalo. As one journeys on the aspect of the river changes and its course winds past wooded headlands that form a succession of bays. At Mobbai the river appears to be a dividing line between a sterile and fertile land. On the right bank treeless hills, on the left extensive tropical forests, wind along the valleys. From the Tomi to Yakoma there are only two serious rapids, those at Mobbai, and the more formidable Setema rapids.

As regards the inhabitants, space does not permit me to mention more than the Banziris and the Yakomas. They are fine races, especially the Yakomas, whose men are veritable giants, and the finest specimens I have seen anywhere in Africa. All along the river there are thickly populated villages, some over a mile in length, and the appearance of the people strikes one as being extremely healthy and prosperous. The young girls of the Yakoma race deftly weave long plaited cords of black twine into their hair, which, falling over their shoulders to the ground, give the appearance of their possessing luxuriant tresses. The ends are wound on a stick like a big ball of twine that weighs 10 pounds, and is carried under the arm and on the head when at work.

On January 1 we arrived at Yakoma, a large Belgian post at the mouth of the Welle, and the next day we left to ascend the river, whose course has a width of from 800 to 1,000 yards, studded with rocks, and flowing through an ironstone country, where the natives work mines to a depth of 90 feet. A few days later, in a thick mist, we set out to pass the Voro rapids, about three days below Djabbir, the strongest and most dangerous on the Welle, stretching a distance of 3 miles and sometimes a mile wide, cut up by a maze of small rocky islands covered with palm trees and tropical growth, between which the water rushes and tumbles headlong, the foam flying many feet into the air. With great efforts the boats mounted and were driven beyond the rapids.

The violent uses the boats had now been put to had caused splits to appear, and I was at a loss to find a wherewithal to mend them, till I luckily remembered having seen a native woman mending her pots with the wax of wild honey, and it struck me at the time as so interesting that I made a note of it. And now I tried it with unexpected success. Wooden wedges were driven into the cracks and then sealed over with the melted wax. The restoration was complete, and Samson's proverb reversed, for out of sweetness came forth strength.

Except for good water between the Angba hill and Niangara, the entire course of the Welle is cut up by rapids and hidden rocks. The river folk are the Bakango, a numerous people, whose conditions

have greatly improved since the Belgian occupation, for its protection shields them from the raids of the fiercer forest tribes.

It was at Angu that we first heard rumors of the existence of the okapi in the neighborhood, and in the forest, some three days to the southeast of that place, we spent three weeks endeavoring to obtain one. The okapi, or n'dumba as it is very widely known by the natives, is very locally found, and Angu is the only part near the Welle where it is met with. We found its haunts were small streams running through swampy ground, thickly overgrown with a clean-stemmed plant some 6 to 8 feet in height, with large oval shiny leaves bunching at the top, the young shoots of which are an essential food of the okapi. In these localities it roams about singly or in pairs, and, according to the Mobatti hunters, three may occasionally be found together. Gosling, although he got to close quarters with it on three occasions, never saw it, so perfectly concealed was it among these leaves. He says: "During the night the okapi will wander along in the mud and water in search of the young shoots of this plant. Here he may be found feeding as late as 8 a. m., after which he retires to the seclusion of the forest, where he remains until dusk. In the glades and clearings I found his spoor on ground frequented by buffalo and water buck, but this is unusual, for his companions in the forest are more often the elephant, the greater bush buck, and the yellow-backed duiker." At this time José had been following a solitary animal for three successive mornings in the vicinity of a stream. He observed that, on leaving the water, the okapi always took the same course, between two large trees about a hundred yards from the stream. So, with the help of natives, he dug a pit 4½ feet deep between the trees, and then carefully concealed it with branches and leaves. Very early next morning José again approached the stream and heard the noise of the okapi rushing away. Soon there followed a loud thud, for the animal, taking its usual course, had fallen into the pit, and was secured. Owing to the thick leaf and forest, its restless nature, and keen hearing, even the natives find it difficult to track, and are obliged to resort to the method of trapping it in pits. They regard the animal as a mysterious creature, and say that it is always moving and never lies down to sleep. José's observations bear this out, for on several occasions when he heard it feeding it simply paused to take a leaf here and there and then passed on again.

This portion of the journey was the most trying to the health of the party, the long stays in the hot, steaming forest hunting the okapi, and the work on the Welle, which has an evil reputation for being the breeding ground of bilious and blackwater fever, told severely upon our already weakened constitutions, and we were all

attacked by fever. It was at Niangara that the expedition received its last great blow. Gosling was struck down with blackwater, whose deadly attack he laid himself at the mercy of by his refusal, almost to the last, to abandon his labors.

Leaving Niangara with a heavy heart I next ascended the Kibali, which has never before been navigated. On the south bank there is a semicircle of igneous hills, about 500 feet high. In this range there are seams of magnetic ore, and I observed there were many trees on the watershed that had been struck by lightning. The Momvu, who inhabit the hills, told me that when there were blacksmith's villages on their tops many people every year were killed by lightning. At the foot of this range a hut, during a terrific storm, was set on fire, and two of my men were knocked down and stunned; and a few days later a heavy thunderstorm broke from the southeast, with hailstones as big as beans.

Along this river there are many formidable rapids. Among these the Andimanza, which stretch for a distance of 2 miles, present a scene of wild grandeur. The river here swells out to a width of 400 yards, and is broken up by small rock-bound islands which cause tremendous chutes.

The banks of the Kibali are sparsely populated. In the hills south of the river are the Momvu and Mombuttu tribes, still unconquered. They build their frail huts of mud on the great slabs of rock, frequently using the caverns themselves as dwelling places and shelters in time of war, and wherever there is enough earth they grow their maize among the rocks. In these hills I was fortunate enough to obtain from the natives two ancient stone implements. The tribes are ignorant of their origin and believe they are bolts of lightning which strike trees and kill men. The Azandi call them "mangu n'gamba," or "axes of the lightning." They say that these axes may often be discovered by turning up the soil immediately a tree has been struck by lightning; a little later it would be no good, because the stone would have gone back to the clouds in order to strike again. Many natives attribute a mysterious power to them, believing their discovery announces a friend's approaching death.

We next ascended the Ira or Bakwa, which up to now has been considered the main stream of the Kibali, but this is not correct. The N'soro is the true main stream. The Ira is navigable for 12 miles, after which there are many bad rapids.

The whole way we came upon numbers of elephants, which, so unaccustomed to man, allowed us to approach quite close, and it was a pretty sight to see them playing on the banks and bathing in the water.

From here I penetrated by road into the country of the hostile Mombuttu south of the Ira. Here the scenery is grand. A mass of

mountainous hills rolls away, range on range in glorious confusion, their steep sides darkened with trees, save where they are scarred by clefts and sharp angles of bare rock. And below in the deep valleys the courses of innumerable streams are revealed by their coiling coverings of tropical green. From here, where I climbed to a height of 4,000 feet, far away to the eastward on the horizon, I saw for the first time the gray blue of the hills of the Nile.

Finding it impossible to reach the Nile by the river system to the east, owing to impassable rapids and hostile natives, I trekked with the boat to Yei, eight days distant. The rise along this road was so gradual that we were greatly surprised when near Aba suddenly to behold the huge panorama of the Kongo-Nile watershed. Behind us to the south lay the dark green vastness of the Kongo forests, whose monotony was here and there relieved by winding partings in its surface that told the courses of the rivers. On either side and to the north stretched endless plain, with an occasional lonely hill, and far away to the east the sharp peaks of a sierra chain.

On October 13 I arrived at Yei and started to descend the river. At this point it is little more than a rocky mountain stream, 25 yards wide, and some 50 miles from its source in Mount Watti. For the first 20 miles we passed a succession of rapids in terrace formation, rendered more difficult by the obstruction of small green islands. It was laborious progress, sometimes only a mile a day was made, and the boat had to be got past the rapids by the men hanging onto the chain in the water from the stern. Sometimes trees, fallen right across the stream, had to be cut through. At other times, where a passage allowed, we took the risk and shot the rapids. The boat was now in such a battered condition that frequently after the passing of a rapid it had to be drawn out of the water, a fire lit, and the wax melted, and the wedges renewed. After this difficult 20 miles, the river decidedly improved, and a navigable reach of 15 miles brought us to the Azandi village of Kapi. It was at this place I saw the interesting ceremony of the signing of a treaty between the chief and an ancient foe. They met, each surrounded by his followers, and their headman made incisions in the chiefs' arms, and with a feather mingled the blood of one with the other.

From Kapi for 23 miles the river is good, with the exception of two rapids, the second of which was one of the worst, and certainly the most disastrous, we had to encounter. Owing to the tremendous current the men on the chain behind for a moment relaxed, and the boat was driven with terrific force against an overhanging tree. The shock swept off two of the polers, who disappeared into the torrent never to be seen again.

In the open reaches we came across numbers of hippos, and their closely cropped feeding grounds by the riverside afforded us excellent

sites for our camps. They were not always successful in getting out of our way in time. On one occasion, as the boat was coming down at a rapid pace into a pool, we were all thrown together by a tremendous bump, and for a moment all thought we had struck upon a rock. But the rock snorted and plunged out of our way.

For the next 6 miles, up to the station of Wandi, the river is quite unnavigable. In places the boat had to be unloaded and dragged over the rocks, so as to avoid the chutes, which were gigantic. The river in appearance ceases to exist, and the water pours itself as best it may over the slabs of rock with which the whole length and breadth are strewn. In this distance there are at least six big rapids. At one we had a very narrow escape of being smashed up. We had been going in smooth water for a time and the men were all in the boat poling when suddenly the current became strong and the boat was carried helplessly along, each second nearing the steep. The poles were quite useless to check the increasing impetus of the boat. In spite of the heroic efforts of the men the boat swung round, and the next instant crashed heavily against a large dead limb of a tree, where it stuck. But for this there would have been nothing to hope for.

The tsetse fly, the species that carries the germ of sleeping sickness, was very much in evidence about Wandi, and I saw two cases of the disease. Further on it became still worse, and close to Amadi I came across two villages that were wiped out by it and the chief of another was brought to me in a dying condition. The same scourge carried off one of my boys, who died just before we reached the Nile.

For 100 miles after leaving Wandi there are nothing but rapids the whole way, and the one 6 miles from that place is the biggest we had yet seen and presented a splendid spectacle. Here the river is 300 yards across, and a great volume of water sweeps foaming over steep rocks, past islands covered with beautiful palm trees, which are the resort of dog-faced baboons. In the neighborhood of Raffai appear small hills of not more than 400 feet. These are inhabited by the Miza people, a tribe that struck me as rather original. The men, who are smooth-skinned and gentle, adorn themselves with bead ornaments and girdles of beautiful design, while the women affect a masculine severity of costume, fruit stones taking the place of beads. At Avurra the Yei becomes a splendid river, with an average width of 60 yards, and the country throughout is well populated.

It was now December, and the river was rapidly emptying itself; in places there was hardly enough depth to clear the keel of the boat, and it became a race between us and the water. To hasten our pace we threw away all our belongings with a light heart, for our spirits were high, as we had said good-bye to the rocks. For about 90 miles, to near its mouth, the Yei flows through a flat fertile country, where large herds of cattle and sheep roam at will. Often along the

sloping banks one sees the brilliant green of young tobacco plantations. This is the land of the Dinkas, who, on our first appearance, ran away, but later, gaining confidence, flocked down to the river and lined the banks in hundreds. All naked and with their bodies painted a ghastly white, they shouted and danced and threw their long spears into the air. So we made 60 miles, then trees, flocks, and men gradually disappeared, and the river wound alone through a vast empty plain. It widened and slackened, and the impression came over me that it was nearing its journey's end. Eagerly we craned our necks for a sight of the Nile, but this reward was still withheld; nothing but marshland as far as the horizon met our gaze. We followed the river till it lost itself in a lake surrounded by dense reed and sudd. We crossed the lake with irresistible recollections of Chad, and then found ourselves stopped by the barrier of marsh and sudd which choked our passage to the Nile. I then trekked 38 miles with the boat sections to Gaba Shambi, on the Nile. Thus we had reached the goal that we had set ourselves, and here our journey was brought to an end, which, in distance, had extended over some 5,000 miles, and in time occupied just three years.

MESOPOTAMIA: PAST, PRESENT, AND FUTURE.[a]

[With 4 plates and 1 map.]

By Sir William Willcocks, K. C. M. G.

"Out of Eden came a river which watered a garden, and from thence it was parted and became four heads." Plans and levels in hand, starting from the spot where Jewish tradition placed "the gates of Paradise," I have followed the traces of the four rivers of the early chapters of Genesis. Appointed by the new Turkish Government to engage engineers and survey and level the rivers and canals of the Tigris-Euphrates delta, and devise projects for the rehabilitation of the country, I first set myself the task of mastering the ancient systems of irrigation, improving on them when I could, and adopting them when I could find no better substitute. I started with the Garden of Eden.

The Euphrates enters its delta a few miles below Hit, at the gates of Babylonia, where Cyrus the Younger's army, accompanied by the ten thousand, left the deserts and entered the alluvial plains which terminate at the Persian Gulf. What the gates of Babylonia were to one descending the Euphrates, the gates of Paradise were to the early livers in the Babylonian plains.

Upstream of Hit, past Anah, the river is to-day a series of very indifferent cataracts, where the current turns giant water wheels which lift water and irrigate the narrow valley to the edge of the desert. Garden succeeds garden, orchards and date groves lie between fields of cotton, and life and prosperity are before us wherever the water can reach. I do not think it possible to imagine anything more like a practical paradise than the country near Anah. Every tree and crop must have been familiar to Adam except the cotton crop. Though to-day, owing to the degradation of the cataracts, a degradation whose steady progress was noticed by the writers of the Augustan age, water wheels are necessary to irrigate the gardens; it is easy, indeed, to imagine the condition of the river when the

[a] Read at the Royal Geographical Society, November 15, 1909. Reprinted by permission from The Geographical Journal, London, vol. 35, No. 1, January, 1910.

cataracts were such as we see on the Nile, and water could be led off from above a rapid and utilized for irrigating, with free flow, gardens situated a little downstream and above the reach of the highest floods. Such was the Garden of Eden, and its site must have been near an outcrop of hard rock like we see at Anah, where, in coming down the river, we first meet the date palm, which even to-day is a tree of life to the whole Arab world.

Below Hit no place can be found for a garden without lifting apparatus and protective dikes, because otherwise any garden irrigated in the time of low supply would be inundated in flood, and if irrigated in flood would be left high and dry in the time of low supply.

Downstream of the garden the river was parted and became four heads. The first was Pison, represented to-day by the many-armed depressions of Habbania and Abu Dibis between Ramadi and Nejef, which are not inaptly described, from the point of view of a dweller in Babylonia, as encompassing the whole land of Havilah which lay between the frontier of Egypt and Assyria.

The second river was Gihon, the modern Hindia, the Chebar of Ezekiel, who lies buried on its banks, the Ahava of Ezra, the Pallacopus of Alexander, and the Nahr Kufa of the early khalifs. It is represented as encompassing the whole land of Kis or Kutha or Cush, the father of Nimrod, the beginning of whose kingdom was Erech and Akkad and Calneh and Babylon. The ancient town of Kutha lay on the Nahr Kutha, which was in all probability the main stream of the Euphrates in the earliest times, and on whose banks were situated Kutha, Nil, Niffur, Erech, and Tel Senkere, which date from days long prior to Babylon, the capital of Khammurabi, founded on the Babylonian branch when the other had silted up.

The third river was Hiddekel, the modern Sakhlawia branch, some 250 feet wide and 25 feet deep to-day, running like a mill race into the wide Akkar Kuf depression, and flowing out of it into the Tigris at Bagdad. If let alone, the Sakhlawia would be capable of carrying more than half the waters of the Euphrates, and rendering the country between the two rivers uncultivable. In ancient times it was undoubtedly a second head to the Tigris, and from the point of view of a dweller in Babylonia, it was accurately described as "that it is that goeth in front of Assyria."

And the fourth river was Euphrates. No definition was necessary. It was the river of Babylon itself.

Just as the Babylonian colonists carried the name Tigris with them to Nineveh, so doubtless, in times after the most ancient, they gave the name of the river of Babylon to the great stream on whose banks was situated the cradle of the race. From source to mouth one river became the Euphrates, and the other the Tigris.

The Tigris enters its delta at Beled, south of Samarra, over the ruins of one of the most interesting works of antiquity. In ancient days some giant, local tradition says Nimrod, closed the channel of the Tigris by an earthen dam and turned the river over the hard conglomerate, forcing it to flow at a high level and irrigate the whole country. Coursing down over rapids, the Tigris became navigable at Opis; and from there past the modern Baghdad and on to Kut it kept within the channel of to-day. From Kut on to Ur of the Chaldees, past Tel Lo, the ancient Tigris followed the line of the modern Hai or Garraf branch. The country past Amara and Gurna on the modern Tigris was an immense sheet of fresh water known as the Susiana Lake. The levels of the country prove this beyond the question of a doubt.

The junction of the Tigris and Euphrates was at Ur of the Chaldees; and from there the joint waters of the two rivers flowed past the modern Zobeir and down the Bubian channel of the Khor Abdalla. The 3-fathom line depicted on the British admiralty charts clearly shows the ancient mouth of the river north of Koweit. The Khor Abdalla has two heads, one represents the joint waters of the ancient Tigris and Euphrates, and the other the mouth of the ancient Karun.

The Karun River has played no small part in the formation of the Tigris-Euphrates delta. While the Tigris and Euphrates have left all their deposit behind in the Babylonian, Chaldean, and Susiana marshes, the Karun has always hurried down from the Persian hills and carried its silt-laden waters into the Persian Gulf or into the joint stream of the two other rivers. It has been the sole factor in forming the comparatively high-lying land which stretches from Basra eastward. This tongue of land protects the Tigris-Euphrates swamps from the inroads of sea-water, and keeps them fresh. The Basra bar is formed almost entirely of Karun mud. The Tigris and Euphrates mud lies far away to the west.

The ruins of all the more ancient cities lie near the junction of the Euphrates and the ancient Tigris at Ur of the Chaldees. The two rivers had left their deposits in the extensive marshes higher up their course, and the earliest settlers had to do with opaque water, rich in chemical matter, but free of silt, which would have necessitated the presence of many hands to keep their canals clear. A comparatively small population could begin and continue the development of the country, and it was not until the inhabitants became really numerous that the silt-laden waters higher up the rivers were taken in hand.

The lands in the marshes so reclaimed and cultivated became extraordinarily productive, as we see to-day. They were valuable enough to be protected from floods by immense dikes running along

the banks of the rivers, which can be followed to-day for miles upon miles, with a width never under 100 feet.

The great value of water free of silt for the early development of the country is the first serious lesson I have learned from an examination of the ancient systems of irrigation, and you will see later on how we propose to utilize this knowledge.

The Tigris and Euphrates carry in flood during a few days every year over four times as much silt as the Nile. Irrigation with such water will be no easy task even to-day. It was terribly difficult in the old days when they had no cement, and were ignorant of every kind of weir or barrage, except an earthen dam completely shutting off the waters and causing convulsions among the people living lower down.

While the development of the country was confined to the low-lying lands blessed with water clear of silt, everything in the delta went on smoothly enough. Pressure of population made the work of development advance into the parts where there was no clear water, and then the difficulties began. In the language of Genesis, the world became full of violence. A strong central government only could have dealt with the question, and there was no strong government. Now the Euphrates and Tigris floods come down with extraordinary force, and both rivers, but especially the Euphrates, overflow their banks in a way a dweller in the Nile Valley could have no knowledge of. Joseph's famine would have been impossible in the Tigris-Euphrates delta. Noah's flood would have found no place in Egypt.

As men crowded up the two rivers, the necessity of protecting themselves from the floods and at the same time keeping their canals free of silt, compelled the early more powerful communities to resort to the only kind of regulation they knew of, and that was the bold one of bodily shutting off the waters of certain of the branches by earthen dams. Judging from the levels, I should say that the first head to be shut off was that of the Hiddekel, or the modern Sakhlawia. Until this was closed nothing could be done with the upper half of the delta. The struggle between the different communities, and the terrible consequences which might result, intimidated the more thoughtful members of the community, of whom Noah was one, and he prepared for the worst. He built an ark of the poplar wood so common in the Euphrates Valley, and pitched it inside and out with bitumen from Hib, just as the boats and corracles on the Euphrates are pitched to-day. A settler probably in the lower part of the delta south of Kerbela, where the deserts, moreover, are strangely degraded and low, he felt the full force of the inundation. A massive earthen dyke was thrown across the head of the Sakhlawia, the flood discharge of the Euphrates was doubled, and instead of

the waters rising 16 feet, as in an ordinary inundation, they rose 15 cubits, or 24 feet, and not only was the cultivated land under water, but the deserts themselves were submerged. To men living in the Euphrates Valley and in the valley of the Nile, the word "jebel" does not represent a hill, but the desert. In the English translation the word "mountain" represents something those people never saw. In the Arabic translation it is properly called the "jebel." A rise of water of 15 cubits could put no hill, leave alone a mountain, under water.

While traveling in Upper Egypt I have often been asked by the less-informed sheikhs whether England was irrigated by basins or by water courses. On my replying that England had no irrigation at all, the remark has invariably been, "Then, how do the people live in the 'jebel?'"—pronounced "gebel" in Egypt. As director-general of land-tax adjustment in Egypt I was once valuing the lands in a large basin, in the middle of which was a small desert mound some 2 acres in extent and 4 feet high. On my suggesting that we might ignore so insignificant a patch of land, I was told that you could not tax the "gebel." Mentioning these facts to Colonel Ramsay, the British resident at Baghdad, and to Mr. Van Ess, the Basra missionary, who were traveling with me, and just then on a steamer in the Nejef marshes, we agreed to test the matter on the Euphrates. Approaching Shinafia we saw the low degraded desert on the horizon, and asked our boatmen what that was. They immediately replied, "the jebel." It was no more like a hill than Ludgate Hill is like a mountain.

Floating off in all probability from near Kerbela, where one of the shrines of the patriarch very properly stands to-day, and driven by the current and the wind, both steady from the north, the ark drifted southward and wandered long in Chaldean marshes. Finally it touched land, probably somewhere near Ur of the Chaldees, on the edge of the desert. I say Ur of the Chaldees, because it is here that we find Terah, the father of Abraham and the representative of the patriarch's family. I think readers of the Bible will agree with me that the representatives of the patriarchal families were a stationary kind of people in place and habits. It was the Cains and Tubalcains who moved about, undertaking new pursuits and making discoveries. The fact that Abraham, the friend of God, should have wished to move made him a marked man, and earned him his name of Hebrew.

Ararat was the name of the desert mound where the ark rested; and when the families of the younger sons of the patriarch moved off and made new settlements, they gave the name of Ararat to the highest mountain they knew in honor of the spot where the ark

rested. This Armenian Ararat could no more have been the Ararat where the ark rested than New York be York.

As I have tried to depict these early events, everything has been looked at from the point of view of the dweller in the Babylonian or Chaldean plain. And this in accord with the opinion of the time. My friend, the Reverend Professor Sayce, has shown me a copy of a Chaldean map of Abraham's time, in which the earth lies round Babylon as a center.

In following the history of the delta the second lesson we have learned is the necessity of controlling the floods of the Euphrates if any serious development of the country is to be undertaken.

The dwellers in the Euphrates delta, tired of anarchy and confusion, gladly welcomed any strong man ready to produce order and method in a country which could not exist without order and method; and they found their "mighty one" in the person of Nimrod, according to Genesis, or Khummurabi, according to the tablets. The dwellers in the delta to-day are in the same position. I have seen eight hundred armed peasants, all Arabs, volunteer to help the government troops to keep order. Every Arab family, like that of Isaac, has some of its sons after the peaceable Jacob and some after the Beduin Esau. In Mesopotamia to-day the would-be agriculturists have little chance, for whenever they desire to settle, down comes a mighty flood and converts them into wanderers. Let the floods be controlled and the irrigation works begin operating, and it will be seen that those on the side of order are more numerous than those against it, and moreover far more earnest.

This dispute between the agriculturists on the one hand and the shepherds on the other is as old as the feud between Cain and Abel. About May 5 this year, when the flood was at its highest, I was riding up the left bank of the Euphrates from Ramadi to Hit, and counted over 50 flocks of sheep of about 200 each, or 10,000 sheep in all, walking into the valley from the desert. The appearance of the shepherds made the agriculturists alert, and on my way down the river in a boat the next day I heard two shots fired quickly, one after the other, and in an instant the cultivated plain was covered with men on horseback and on foot rushing to the spot, some with spades and some with guns. They were prepared to fight the Beduin shepherds or the flood. Meeting one of the head sheikhs I asked him why they could not arrange to let some of the land be inundated and some put under wheat and barley. He said that they could not agree among themselves, but would be pleased to see some order and method instead of the eternal feud. He added that if working rules were laid down, the agriculturists were sufficiently numerous to insist on their being respected.

All the early kings who did anything worth recording have left memorials of the canals they constructed, to which they gave names strangely similar to the "Kanatir il Khairia," or "Bridge of Blessings," which the Egyptians apply to-day to the first barrage constructed on the Nile.

As population increased we hear of reservoirs for storing water for perennial irrigation, especially for the important Arakhtu canal, which came down from Sippara and irrigated Babylon.

It is recorded of Cyrus the Great that he, too, utilized his army for digging numerous canals from the Gyndes or Dyala. Many of these canals are in use to-day.

Herodotus gives a picturesque and glowing description of Babylonia in B. C. 480.

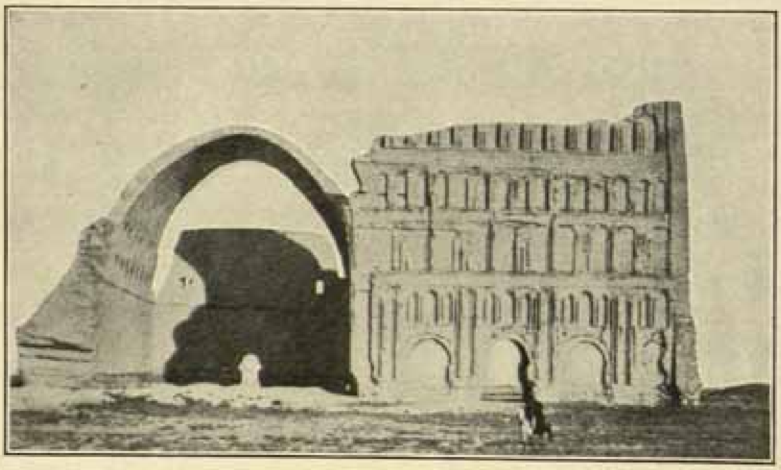
Some fifty years later Xenophon, as becomes a disciple of Socrates, gives an exact description of the country as he saw it. Book in hand, I have followed his march in the delta from "the Gates" to Opis, and I here give my impressions. Cyrus the Younger's army entered the delta at the Gates already described, and crossed the valley of the Sakhlawia by the great earthen embankment which from all antiquity stretched from desert to desert and kept the Euphrates within its own valley. Cyrus anticipated the reopening of the branch by Artaxerxes, who had dug a new canal down the valley of the Sakhlawia, trusting to the steep slope to soon scour out an impassable barrier to his brother's army. Hurrying along the dike, the army of Cyrus entered the desert plateau of 110 square miles in extent which lies between Feluja and Bagdad, and over which Artaxerxes's army advanced under thick desert dust which looked like a white cloud. Xenophon saw the first of the four canals, known in the times of the Khalifs as the Issa, the Sarsar, the Malik, and the Kutha, which leave the Euphrates south of this desert plateau. The first is in very deep digging in the desert. He saw no more, and spoke from hearsay of the rest, for he is wrong in every particular—a circumstance rare with him. Mind, he does not say that he saw them. The canals are not the same size, they are by no means the same distance apart, and they do not run from the Tigris to the Euphrates. In this reach the Euphrates is 25 feet higher than the Tigris. The battle of Cunaxa could not have been fought south of the desert plateau, as the country was intersected by four large canals and countless deep-water courses, and was, moreover, heavily irrigated. Armies accompanied by large bodies of cavalry, chariots, and baggage wagons could not have moved at all, leave alone maneuvered and fought. After the battle the ten thousand retreated in a northwesterly direction, with the rising sun on their right hand, and were entangled in the water courses fed by the new canal just dug by Artaxerxes and now opened. North of Tel Safêra there are no dikes or trenches going north-

ward. The Median wall, I think, stretched from Tel Safêra to Akkar Kûf, and from there to Coche, on the Nahr Melcha, opposite Ctesiphon. It protected Babylonia from the Assyrians first, and then from the Medes in the pre-Persian days; it took the place of the Sakhlawia branch, which, as already twice stated, was closed from the earliest times. Artaxerxes opened his canal in August, during the time of low supply, or there would have been a catastrophe.

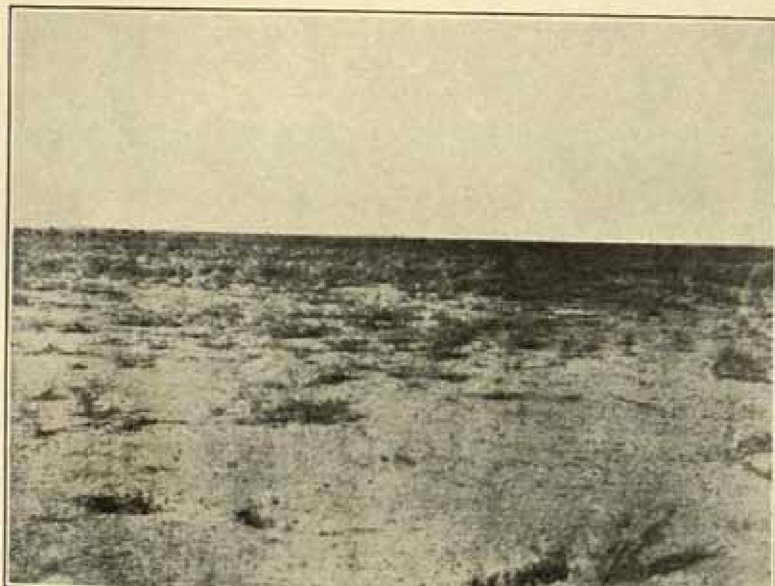
Keeping south of the Median wall, the ten thousand crossed over to the north at some point west of Akkar Kûf, and winding their way round the Akkar Kûf depression, crossed two canals, both coming from the Tigris near Nimrod's dam. The latter was the Izhaki canal, on whose east bank was Sitaki, not far from the modern Kazimain. They crossed the Tigris by a bridge of boats with the same number of boats that the Baghdad bridge had a few years ago, before it was replaced by the present one of larger boats. From here they had to leave the river, as the country was heavily irrigated by the numerous canals, into which Cyrus the Great had led the Dyala. The troops with the transport wagons had to follow the road, which doubtless then, as now, went to Bakuba, and so the distance covered was 50 per cent in excess of the bee line which commentators ordinarily measure along. At Opis they crossed the Physcus, or Adhaim River by a bridge 100 feet long, and entered desert country. At Manjur, which Capt. Felix Jones, of the Indian navy, unerringly stated to be the site of Opis, the Adhaim River flowed into the ancient Tigris before the river burst into its present channel. Immediately to the north of this point we leave the alluvium of the Tigris, and enter the unirrigable marls which Xenophon called deserts.

Alexander's historians give a vivid description of the irrigation of the country and the difficulty the Babylonians had in closing their canals in flood and clearing them in low supply. They described the closing of the canals in flood as by far the more difficult operation. Alexander entered into the work with all his energy and genius, and to-day we can only admire the judgment with which he treated the Hindia branch or the Pallacopus, and the promptitude with which he acted. The whole of the waters of the two rivers was used for irrigation in all but the flood season, and Alexander had to remove the earthen barrages thrown across the Tigris before his fleet could sail up the river from the sea.

In the time of the Sassanian kings of Persia, in the early centuries of the Christian era, the delta probably saw its greatest prosperity. The gigantic Nahrwan Canal, 400 feet wide and 15 feet deep, irrigated all the country to the east of the Tigris, and the Dijail irrigated that to the west. The Euphrates gave off the four canals already mentioned by Xenophon, and canals fed by the Babylonian branch from near Babylon irrigated the country right up to the ancient



NAUSHERWAN'S PALACE, CTESIPHON.



UNIRRIGATED MESOPOTAMIA.

Tigris, or the modern Hai branch. Ammianus Marcellinus, who traversed the whole length of the delta in the fifth century of our era, describes the country as a forest of verdure from end to end.

The centers of development varied from period to period. While during the earliest times Tel Lo, Senkere, and Ur of the Chaldees were the heart of the country; Sippara and Babylon took their place in Babylonian times; and Opis and Ctesiphon in that of the Persians.

In the seventh century of our era the Arabs overthrew the Persian Government, and substituted Kufa, Wasit, and Basra, as capitals in place of the earlier cities. These soon gave place to Baghdad, which till to-day has remained the most important town in the delta. Baghdad saw its greatest days about A. D. 800, in the reign of Harun-el-Rashid. Under the Arabs the prosperity of the country steadily declined, but the final blow was given by the Mongols under Zengis Khan and the Tartars under Timur, in the thirteenth and fourteenth centuries. Previous disasters had drenched the country in water; it was now drenched in blood. In the anarchy and confusion which ensued all the great works of antiquity were swept away one after another, until not a single one remains to-day. Nimrod's earthen dam on the Tigris was breached, and the level of the water in the river fell some 25 feet, leaving the great Nahrwan and Dijail canals dry and waterless. Both banks of the Tigris in the upper part of the delta became a desert. The Tigris, lower down its course, fared no better. Near Kut the river breached its left bank and wasted itself in the marshes on the Persian frontier, while the ancient channel past Wasit and Tel Lo received a limited supply of water only in flood time. The ancient dike across the Sakhlawia branch of the Euphrates was breached, and Western Baghdad with its irrigation system was wiped out. All the canals taking water from the Euphrates, which had come down from a remote antiquity, the Issa, Sarsar, Melcha, Kutha, Araktu, Surat, Nil, and Nars, silted up and ceased running; and finally, in our day the Euphrates of Babylon has dwindled into an insignificant stream, and the whole of the waters of the river are flowing through the Nejef marshes. The Tigris and Euphrates, left to themselves, have deserted the highlands which they irrigated in old days, and are now traversing the lowlands and marshes along the extreme east and west of the delta.

Things would have been far more desperate than they actually are had not a new crop been introduced into the country which has permitted of large areas of swamp being turned into valuable fields. When rice first appeared in the delta no one can tell, but it is the most valuable crop in the country to-day after the date crop.

The delta of the two rivers has an area of some 12,000,000 acres, of which about 9,000,000 are desert and 2,500,000 acres fresh-water swamp. In the upper parts of the delta there are stretches of culti-

vation along the river banks in places and along a number of small canals; but in the lower part of the delta there are magnificent reaches of date groves and gardens interspersed with clover and cereals, and large areas under rice in flood.

We have seen that the earliest settlers in the delta clustered round the reaches of the rivers where the water was free of silt. It is the same to-day. This water, though free of sand, is opaque in color, and retains the rich chemical ingredients so necessary for agriculture. It is totally different from the dark-looking, transparent water which has stagnated in the marshes.

The rainfall is on the average about 8 inches per annum. The whole of the rain falls in winter, and there have been years in succession when the total fall has not exceeded 4 inches. Of such tracts President Roosevelt, in his first message to Congress, has well said, "In the arid region it is water, not land, which measures production." We therefore turn to the amount of water in the two rivers. The Euphrates has a high flood of 120,000 cubic feet per second and a low supply of 10,000 cubic feet. The corresponding figures for the Tigris are 180,000 and 10,000.

The rivers are in flood in March, April, and May, while August and September are the months of low supply. We may, without the aid of reservoirs, count on 6,000,000 acres of winter crops and 3,000,000 acres of summer crops. We shall have wheat, barley, and beans in winter, and cotton, Indian corn, and rice in summer. To-day, if the winter rains are above the average, large areas of land are put under barley, for the deserts of Mesopotamia are not deserts like those of Egypt, but in great part steppes capable of supporting millions of sheep. The date palm is at home everywhere in the delta, while the Basra groves are credited with 10,000,000 trees. Dates and wheat are considered as growing wild at Anah.

The winter is severe and the summer is very hot and prolonged. Live stock of every kind is abundant and of superb quality. Old Mahomed Pasha il Daghistani has 200 Arab mares in his studs at Azazia, on the Tigris. Live stock will always be one of the principal exports of the country.

The delta is strangely flat. Baghdad, removed some 500 miles from the sea, is only 115 feet above sea level. Opposite Baghdad the Euphrates is 25 feet higher than the Tigris. Between the two rivers runs a regular valley, across which are carried the giant banks of the ancient canals like miniature hills.

The waters of the two rivers and the soil of the country are yellow in color and very different from the black soil of Egypt. The percentage of lime in water and soil is as high as 15, and consequently the soil is far more friable than the stiff clay of the Nile Valley. The chemical analysis of soil and water testify to their richness.

BASRA CREEK.

(Photograph by Percy L. Loraine.)

SOUTH ROAD IN BAGHDAD.

Beginning at Beled, the delta first consists of bare plains of clay with the silt banks of countless canals, showing what a desperate fight the wretched agriculturists made for existence when the dams were carried away and the level of the water fell. We then have alternate stretches of level country covered with a thorny leguminous plant, which dies down in winter, and the same bare plains which we met in the north. Near the rivers are jungles of licorice plant and the same leguminous thorn. On the rivers themselves, but especially on the Euphrates, wherever there is a foreshore, there is a luxuriant growth of poplars and sometimes of willows. On the upper Euphrates, and as one approaches Babylon, we have great stretches of salted land interposed with bare plains and low sand drifts. All this land is capable of easy leveling and reclamation. The presence of 15 per cent lime in the soil renders reclamation very easy compared with similar work in the dense clays of Egypt. One is never far away from the giant banks of old canals and ruins of ancient towns. As one goes south the salted land increases in area, and then the marshes begin with their stretches of rice. On the lower Euphrates and on the Basra River are luxuriant date groves and gardens mingled with wheat and clover. The lower Euphrates, past Nasrie and Suk es Shayûk, is a veritable garden surrounded with water.

The junction of the Tigris and Euphrates is no longer at Kurna, where it had been for 500 or 600 years, but at Garmat Ali, near Basra.

Such is Mesopotamia to-day. From what has been already said, it will not be difficult to gather that the first works before the hydraulic engineer are the protection of the country from floods, and the provision of water as free of silt as possible. The levels and surveys of the twelve engineers who are working for me in Baghdad, with a devotion worthy of the task they have undertaken, have shown that we can do both. We have already submitted to the Government a project for escaping the excess waters of the Euphrates down the depressions of the ancient Pison, the first of the four rivers of Genesis. An expenditure of £350,000 should suffice for the work, and it should take three years to carry out. I am under and not over the mark when I say that the cultivated area will be doubled and the yield of wheat trebled along the Euphrates the day this work is completed. The cultivators to-day are afraid to sow anything like the crop they could put in; and, moreover, they count on losing everything every third year. If Noah had been an hydraulic engineer, he would have constructed the Pison River escape instead of an ark, and saved not only his family but his country as well. This escape has been approved of by the Turkish Government, and the necessary funds have been assigned for beginning it immediately. Its effect will be far-reaching.

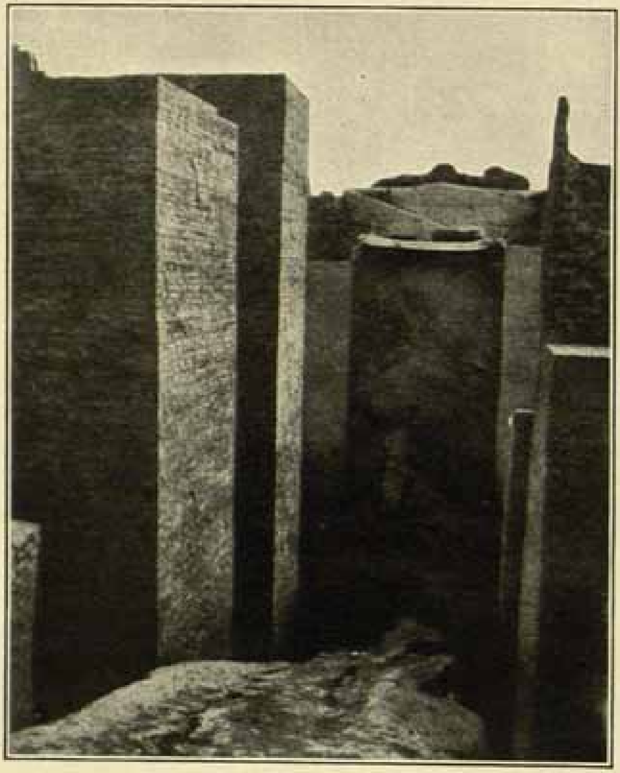
The surveys and levels are now in hand for a project for the great central canal of the delta, which will irrigate 3,000,000 acres of the best land in Mesopotamia, and carry water free of silt. Northwest of Baghdad, between the Tigris and the Euphrates, lies a strange depression known as the Akkar Kuf Lake. It has an area of 40 square miles at extreme low water, and 300 square miles when full. Its level is 35 feet below that of the Euphrates, and 10 below that of the Tigris. Into this depression runs the Sakhlawia branch of the Euphrates, the ancient Hiddekel, or the third of the rivers of Genesis, with a channel 250 feet wide and 25 feet deep at the head, which splits up into some twenty small channels as it enters the western side of the lake. The head of the Sakhlawia branch will be provided with two powerful regulators to control the supply leaving the Euphrates. On the Euphrates downstream of the branch will be a barrage to control the river itself. These works will insure our supply from the side of the Euphrates.

On the Tigris we propose to construct at Beled, near the site of Nimrod's dam, a weir for controlling the river. This work will be above the Tigris rapids, where the water is 60 feet higher than that of Lake Akkar Kuf. From the upstream side of this weir we shall construct a canal to irrigate the rich lands north of Baghdad, with an escape into the lake. The escape will keep the canal free of silt, and feed the lake with Tigris water. We shall thus have all the water we need from both rivers, entering the lake at its western and northern sides.

From the southeastern end of the lake, near Baghdad, will start a canal which will run along the right bank of the Tigris and finally tail into the Hai branch or ancient Tigris near its head. In the days to come this canal will irrigate 6,000,000 acres, but not now. The excessive silt of some fifteen days per annum, which does all the mischief, will be decanted in the lake, and so will all the silt we do not need. At certain stages of the flood, when the river water is not heavily charged with silt, it will be possible to take in supplies at different points of the canal. All these details will come later. We are now concerned with broad issues.

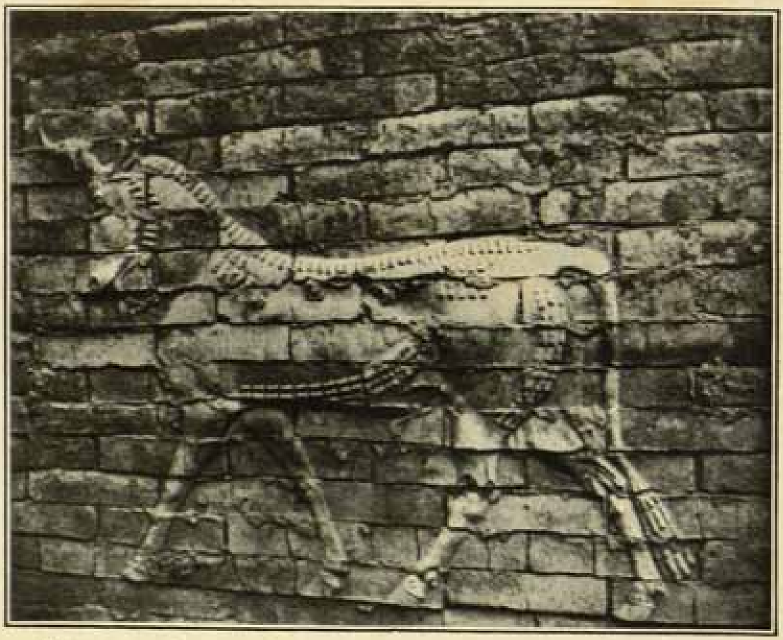
The left bank of this canal, which I shall submit to the authorities to be called after the name of the first constitutional sovereign of Turkey, will act as a dike for protecting the country from the Tigris floods, and will, moreover, carry a railway to transport the abundant harvests of the country. We shall again see Sippara, Kutha, Nil, Niffur, Erech, Tel Senkere, and Tel Lo important centers of life and prosperity.

Dealing with water free of silt, it will not be necessary to complete the whole length of the canal before we can begin sending down our supplies, as we should have had to do with muddy water. We shall



THE GATE OF ISTAR AT BABYLON.

RUINS AT BABYLON.



BULL ON THE GATE OF ISTAR AT NEBUCHADNEZZAR'S PALACE AT BABYLON.

first complete some 30 miles, and immediately use the water for irrigation in this reach while we are digging the second reach of 30 miles. In this way we shall waste no time.

The works should, I think, be carried out on the following principles. The Government should undertake the construction and maintenance of the barrages on the rivers, the main feeder canals, the main drains, the navigation works if any, the flood escapes, and the flood embankments. In this way the control of the rivers and their supplies would be in the hands of the authorities. All minor canals, drains, and masonry works of every kind should be left to the agricultural community and to interested parties. In return for constructing and maintaining these works they would receive title deeds for the lands they irrigated. I had at first thought of recommending the Chenab system of irrigation works, but acquaintance with the people has taught me that all details should be left to the agriculturists themselves. They have their own ideas, and will be far happier working on their own lines, many of which have come down from the remotest antiquity, and are well worthy of preservation.

I have shown how the country can be protected from floods, and how a beginning can be made with the irrigation of 3,000,000 acres of land capable of producing annually 1,000,000 tons of wheat, and 2,000,000 hundredweight of cotton. It now remains to consider how we are going to get this produce to the markets where it will be sold, and how we are going to dispose of the millions of sheep and hundreds of thousands of cattle which the delta will contain.

Every merchant and man of business I have talked with in Baghdad is convinced of one thing, and that is that the backward state of the country is due in great part to the fact that while communication is open by river with the east, it is to the west that the whole produce of the country wants to find a way. In this direction there is no outlet. The principal products of Mesopotamia to-day—sheep, cows, buffaloes, wool, liquorice, wheat, barley, and rice—have their markets in the eastern Mediterranean and in Europe, and all the imports the country stands in need of could come most readily from Europe. What is wanted, therefore, is a cheap railway connecting Baghdad with the Mediterranean by the shortest and cheapest line possible. Such a railway would have its outlet on the Mediterranean coast near Tyre and Sidon. These centers of commerce did not place themselves by accident where we find them to-day. They fulfilled the requirements of the trade of western Asia. Haifa and Beirut, to the immediate south and north of Tyre and Sidon, are the modern representatives of these old Phœnician cities. They are connected by railway with Damascus. Very shortly Tripoli, to the north of Beirut, will be connected by railway with Homs, on the Damascus-Aleppo Railway.

Any railway going east from Damascus or Homs must pass through Palmyra, founded by Solomon in Israel's great days, and the capital of Zenobia in later times. From Palmyra will diverge the railways of the future, which will either go north to Thapsacus on the Euphrates, another creation of King Solomon, or to Der Zor of the Khalifs, or eastward to Abu Kemal near Salahia, a creation of Saladin's. The Damascus-Baghdad Railway will pass through Palmyra, Abu-Kimal, Hit, and Baghdad. At Abu Kemal the railway will tap only part of the upper Euphrates Valley capable of great development. In the center of this tract is situated the rising town of Meyadin, on the site of the ancient Rehoboth. At Hit we have the terminus of free navigation on the Euphrates and the future port of the river. Rivers whose waters are used up in irrigation have their ports where they begin to be navigable.

The Euphrates upstream of Hit, up to El Kaim past Anah, has a narrow valley, but the current is sufficiently strong to turn large water wheels, which irrigate the country up to the edge of the desert. Upstream of Suk-es-Shayûk this is the only tract on either of the rivers which enjoys perennial irrigation without having to lift the water by means of oxen or pumps. For the area cultivated the population is very dense and the crops excellent. We can here form an idea of what the country will be when perennial irrigation with free flow is available over extensive areas.

From El Kaim near Abu Kemal right up to Meskene opposite Aleppo, the current is incapable of turning water wheels, and the cultivation is confined to the areas flooded by the river or irrigated by lifting machinery. From Abu Kemal to Der Zor past Meyadin the valley is very broad, and, judging from the ruins of towns and villages, must have been at one time well cultivated. To-day the cultivation is confined to the water's edge. From above Der Zor to Meskene past Rakka, the summer residence of Harun-el-Rashid, the valley contracts and the ground is covered with dense jungle, which supports very many buffaloes, sheep, and camels. Occasionally one meets a patch of rich cultivation, as at Meskene, where an Englishman had erected many water wheels and was preparing to put up a 20-horsepower engine and pump.

The desert at Hit is flat, and only some 50 to 100 feet above the level of the Euphrates Valley. This height gradually increases until at Meskene it is from 300 to 400 feet. For some miles on either side of the valley the desert is broken up into ravines; but as one leaves the river the desert becomes flat, and was described by Xenophon as being level like the sea. The farther north one goes the more undulating becomes the desert, but south of Der Zor the undulations are insignificant. Here and there one meets a wady finding its way to the Euphrates Valley. Gypsum is the ordinary rock, and there

are considerable outcrops of limestone, while immense areas are covered with pebbles, and are known as haswa to the Arabs.

During the winter months the deserts are covered with grass and the hollows are sown with barley. This refers to the country past Hit. The rainfall increases as one goes northward, and by the time one reaches Meskene the whole country is capable of producing barley with the aid of the rainfall.

The total length of the railway from Damascus to Baghdad will be 550 miles, which could be constructed for £2,200,000. This allows £4,000 per mile along an easy alignment, while Nigeria is being developed by railways traversing more difficult country at £3,000 per mile. According to the Beduins and the Turkish officers who annually escort the sheep from Abu Kemal to Damascus, water is sufficiently evenly distributed to allow of hundreds of thousands of sheep traveling from the Euphrates delta to Damascus.

In addition to the transport of the exports and imports of the Tigris-Euphrates delta, the railway from Baghdad to Damascus will be the highway for the merchandise of Persia and for all the Moslem pilgrims of central Asia to the holy cities of Islam. It will carry all the materials and fuel needed for the future irrigation works of the delta, and when continued along the bank of the great central canal to Basra, it will be the shortest route possible between east and west, and will one day be carrying the mails between Europe and India.

Though zealously advocating the direct railway connecting the Tigris-Euphrates delta with the Mediterranean, as without it the development of the country will not be possible, my hopes are centered in the delta itself, where it is my ambition to see the works carried out which we are planning to-day. I know that in these western countries of Europe, where rainfall is timely and abundant, and where ruin and disaster can not overtake a country in a day, we are apt to imagine that works of restoration must also take long years to bear any fruit. But in the arid regions of the earth it is not so. There the withdrawal of water turns a garden into a desert in a few weeks; its restoration touches the country as with a magician's wand. In her long history of many thousands of years Babylonia has again and again been submerged, but she has always risen with an energy and thoroughness rivaling the very completeness and suddenness of her fall. She has never failed to respond to those who have striven to raise her. Again it seems that the time has come for this land, long wasted with misery, to rise from the very dust and take her place by the side of her ancient rival, the land of Egypt. The works we are proposing are drawn on sure and truthful lines, and the day they are carried out, the two great rivers will hasten to respond, and Babylonia will yet once again see her waste places becoming inhabited and the desert blossoming like the rose.

Postscript, May 28, 1910.—Since delivering the lecture in November, 1909, I have spent the winter in Mesopotamia, and should like to add the following as a postscript:

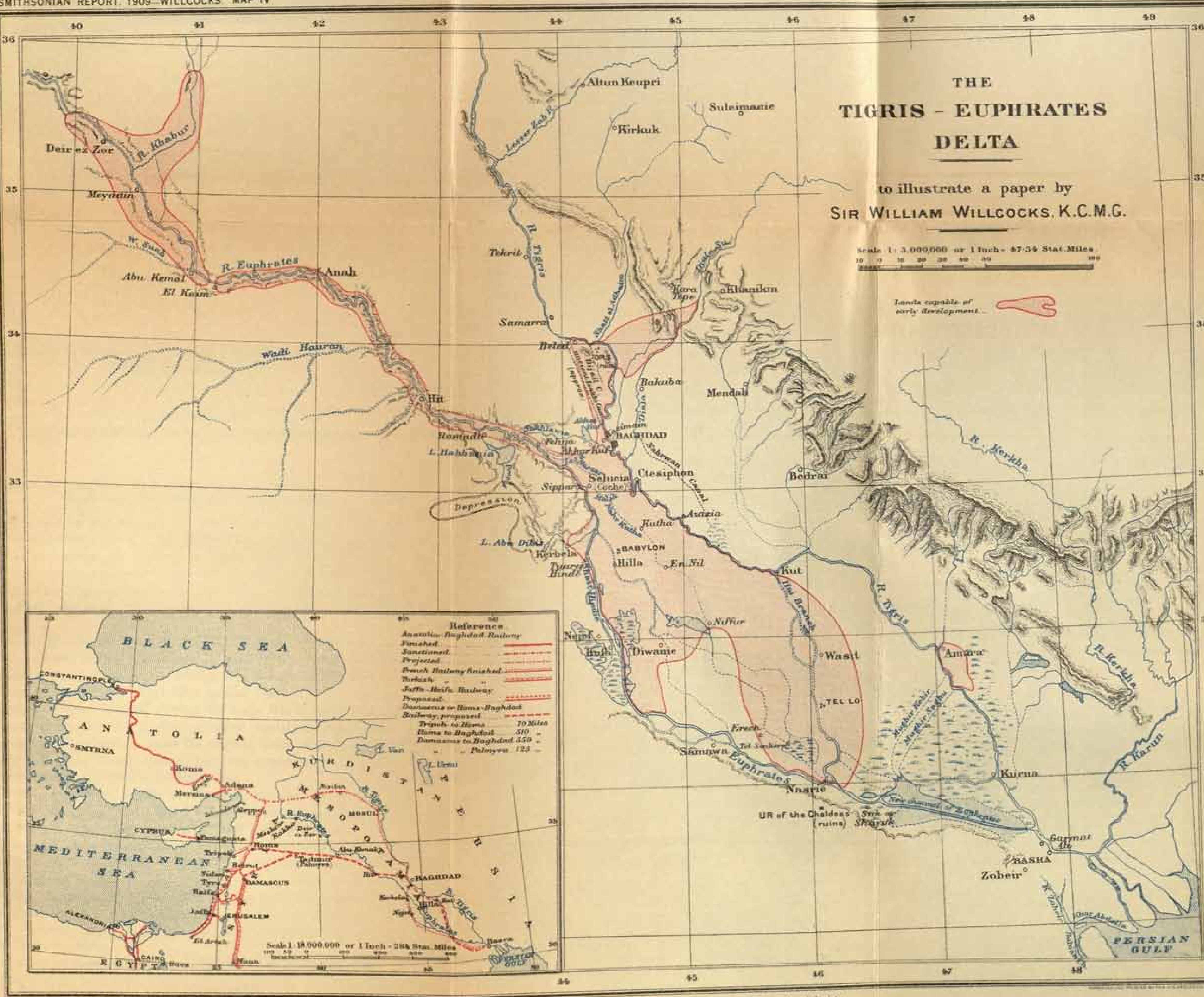
That the region to the south of Ur of the Chaldees is probably the spot where the ark rested is further confirmed by these two facts:

(1) A vessel drifting down the Euphrates with the current and wind from the north and northwest would at Ur of the Chaldees meet the strong current of the ancient Tigris coursing down from the north, and would be driven ashore somewhere near the junction of the two rivers.

(2) When at Ur of the Chaldees the other day we found that the Arabs called the mounds to the south of Ur "Nûawês." Now, "Nu" is Arabic for "Noah."

That those primitive and early peoples whose records we possess in Genesis were certainly under the impression that the whole world was drowned out with the Tigris-Euphrates Delta is proved by the only explanation they could find for the great influx of people into the valley from the surrounding countries once order began again to be established. They could attribute the multiplicity of languages which began to be spoken all at once to nothing but divine anger at their extraordinary high hopes and ambitions.

The tradition of the flaming sword of the Cherubim at the Eastern gate of Paradise near Hit may have been connected with the bitumen and naphtha springs which abound in that locality. The region today is called "El Nafitha" by the Arabs.—W. Willcocks.



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ALBERT GAUDRY AND THE EVOLUTION OF THE ANIMAL KINGDOM.

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French science has recently lost one of its most illustrious representatives, Albert Gaudry. My cherished and venerated master, who has departed at the age of 81 years, leaves behind him universal and profound regrets, not alone in the learned world, but among all those who had met him and known him, and even among those (and they are legion) who have read his works—works inspired by the loftiest ideals.

The scholar who devoted sixty years of his life to science, in an exclusive manner, leaves behind him a shining track which brightly illuminates the history of the faunas which have succeeded one another on our planet for about fifty million years.

Gaudry occupied himself during his whole life in seeking the laws which presided over the destiny of those vanished faunas, and endeavored, with success, to unite the various links of this captivating history. In doing this he became truly the creator of a new science—historical or philosophical paleontology.

I desire to set forth briefly in this place the characteristics of this fruitful work of Gaudry. But I ask permission to say a few words regarding the man before I occupy myself with the scholar.

He was the embodiment of kindliness and benevolence. These two qualities were native to him. All those who approached him, whether Frenchmen or foreigners, were won by his charming urbanity and courtesy. A rather thin voice gave a softness to his speech. If one adds great nobility of sentiment and integrity of character, which never wavered, one can comprehend the sympathy that his name everywhere evoked.

In order to comprehend the importance of Gaudry's work, it is necessary to go back more than a century, and to recall the different

paths along which have developed the ideas relative to the apparition of the faunas which have inhabited the earth during its various epochs.

I. CUVIER AND D'ORBIGNY.

At the beginning of the nineteenth century, the earlier works of Bernard Palissy, Faujas de St. Fonds, Guettard, Buffon, and especially William Smith, had made possible a comprehension of the importance of fossils, by means of which the age of the sedimentary deposits of our globe could be determined.

The researches of Cuvier on fossil faunas led this talented naturalist to announce that there existed in the terrestrial strata a series of superimposed and distinct faunas, which had disappeared successively and entirely under the influence of violent geological catastrophes, which he called the "revolutions of the globe." New and different faunas replaced the ancient faunas, not through new creations, as was commonly said, but by means of faunas derived from regions where similar revolutions had not taken place.

The revolutions of the globe, in the sense in which Cuvier understood them, were not universal. They resulted from considerable changes and extensive modifications in the distribution of seas and continents, brought about by the formation of new marine lands or the submersion of mountain chains, modifications caused by the cooling of the earth.

The two great treatises which summarize the work of Cuvier, one the "Recherches sur les Ossements Fossiles," and the other, "Discours sur les Révolutions du Globe," although more than a century old, remain as models of clearness of description and of scientific interpretation.

The first is the indispensable remembrancer of all naturalists who occupy themselves with the study of living and extinct vertebrate faunas; the second, of all geologists or geographers, who find in it at least the germs of the explanation of the causes of the physical changes wrought in our planet, and of the laws which govern them. Cuvier was, therefore, in reality the creator of paleontology. He first showed, contrary to the opinion of Buffon, that fossil animals are different from living ones, and, prompted by the researches of other naturalists, such as A. d'Orbigny, Al. Brongniart, von Buch, W. Smith, Werner, etc., who occupied themselves more especially with invertebrate animals, asserted that each stage presented peculiar and distinct fossils.

He thereby not only created paleontology, that is, the study of the fossils themselves, but also that of the order of their appearance on the globe. Thus, he not only enlarged the boundaries of this new science, which is indispensable to zoology, but he made it serve the

needs of geology, in the examination of sedimentary deposits. Thus has taken birth from Cuvier and d'Orbigny stratigraphic paleontology, the sister of zoology and the essential basis of all rational geology.

We recall in passing that d'Orbigny had divided the earth into twenty-seven epochs, among which he distributed the 18,000 known mollusks and echinoderms. The broad lines of the classification of this naturalist are still followed to-day. Cuvier and d'Orbigny believed that they had established by their works the fixity of species, and their sudden appearance and disappearance in time, due to successive cataclysms and creations.

II. GEOFFROY ST. HILAIRE AND LAMARCK.

Two of their contemporaries, Lamarck and Geoffroy St. Hilaire, arrayed against this "theory of the absolute" another theory, which was destined henceforth to agitate the minds of all learned and thinking men. From this time, and arrayed around these naturalists, were waged, under the banner of "transformism," innumerable scientific and philosophical battles. After a century of study and research the discussion still remains open on many points.

Lamarck and Geoffroy St. Hilaire, contrary to Cuvier, d'Orbigny, and Brongniart, planting themselves on the study of living and fossil forms, claimed that there was no sharp separation between these different organisms, but that a filiation existed between them. The first animals which appeared were "transformed" successively under different influences, leading, under the influence of needs or habits (Lamarck), or under those of the environment (G. St. Hilaire), to the development or atrophy of certain organs. It was no longer held that there were successive creations, but rather that nature had produced at first simple organisms, which little by little, under influences of which we shall speak presently, were modified, transformed into beings arranged in series more and more complicated, more and more nearly perfect, from the amorphous, gelatinous, but living, mass of the protozoan to man.

Lamarck, in his Zoological Philosophy, in which, unfortunately, paleontological data played but a small part, prepared a genealogical tree of all forms of animals, from the simplest to the highest mammals (man excepted). This essay in comprehensive synthesis is interesting only on account of its spirit and the ideas on which it is based. It is inexact in a very great number of essential points, but it is the original foundation on which later naturalists have erected more precise ideas, having for a basis a larger number of observations. It was, furthermore, difficult for Lamarck to produce other than a preliminary work. He lacked the knowledge of a large

number of fossils to support and establish it on a solid basis, and he should have taken into consideration this important law laid down by Geoffroy St. Hilaire: "The embryological development of a living being is an abbreviated résumé of the phases through which has passed the paleontological development with which any given species is related."

III. DARWIN.

Forty years later Darwin, taking up the ideas of Lamarck, gave to the transformation theory such éclat that many scholars henceforth called it the theory of Darwinism.

Darwin, who had traveled much, and, in consequence, had seen much; who had a prodigious gift of observation, and was possessed of vast erudition, added another important argument to the theory of transformism—that of vital competition.

According to this great English scholar, there was produced, in consequence of this competition among living forms, a "natural selection" analogous to the artificial selection employed by man in the production of varieties in the vegetal world and in the animal world. The best endowed species survived, but disappeared, in turn, before species better organized.

An exposition and discussion of Darwin's "Origin of Species" need not be made here. It is known to everyone. But it is necessary to note and set forth the great feebleness of the paleontological arguments of Darwin, arguments which, however, ought to constitute the basis of the whole theory of transformation, because there ought to be an inseparable bond between paleontology and zoology. It is Albert Gaudry, the rival and contemporary of Darwin, who offered him this indispensable support.

IV. THE WORK OF ALBERT GAUDRY.

Born in 1827 at St. Germain-en-Laye, Albert Gaudry was the son of the president of the order of barristers of Paris, an intelligent amateur of the natural sciences. At the age of 20 the young man, who, with his father, had traveled about the environs of Paris and had visited the principal deposits of fossils described by Cuvier, showed an irresistible liking for geology and paleontology. In 1850 he was attached to the geological laboratory of the Museum of Natural History, where he labored under the direction of d'Orbigny, his brother-in-law, and Cordier. In 1852 his first works "On a group of Echinoderms (Stelleridæ)" and "On the origin and formation of flints of the chalk and of the millstones of the Tertiary formations" gave him the title of doctor.

1. *Pikermi, the parent of ancient worlds and of the present world.*

Commissioned to visit the Orient, he traveled with his friend Damour in Greece, Syria, Cyprus, and Egypt. In passing through Athens he learned that Duvernoy and A. Wagner had found not far from that city, at the foot of Mount Pentelicus, in a place called Pikermi, traces of fossil vertebrate faunas. He made a brief visit to the deposit, and later obtained a commission from the Academy of Sciences to exhume the fauna which it contained.

It is in this country, over which hovers the genius of the ancient Greeks, that Gaudry began to resuscitate an entirely new world which existed many ages before the appearance of man. "On this classic ground his researches, his spirit, his thought, have created once more and in another connection a classic locality, for the name of Albert Gaudry will be forever united with the fauna of Pikermi." (Address of the president of the Royal Academy of Sciences of Berlin.)

The excavations at Pikermi, pursued for many years and with some danger (it was in the time of the Crimean war), in a country infested with brigands, yielded many thousands of specimens, representing 370 individuals. The skeletons of many fossil animals could be entirely reconstructed. Gaudry established the fact that this rich fauna comprised 35 genera, of which 20 were entirely extinct, and 5 species scarcely or not at all known previously.

In no country had ever been found a group of gigantic animals comparable to those of Pikermi. If the territory which these creatures inhabited had been regarded in olden times as the home of the gods, and had witnessed the splendor of the greatest geniuses of antiquity, the assemblage of creatures buried in the soil in a remote geological epoch also demanded vast areas.

"It is necessary to believe that the plains were not alone more extensive, but also richer than in our day. The marble slopes of Mount Pentelicus, Hymettus, and Laureium support for the most part only lowly herbs, which furnish food for bees, and it is probable that in ancient times there were, beyond these arid mountains, valleys with a luxurient vegetation, where prairie grasses alternated with magnificent forests, for the productiveness of the animal kingdom necessarily presupposes that of the vegetable kingdom." (Gaudry.) The abundance of herbivorous animals demonstrates the correctness of this view in an indisputable manner. The landscape was, indeed, enlivened by two-horned rhinoceroses and enormous wild boars, by monkeys (*Mesopithecus pentelici*), carnivores of the civet family, martens, cats, and hyænas, which dwelt in the caves of Pentelicus, while on the plains ranged flocks or herds—the hipparions and antelopes of slender and graceful form, with straight, spiral, or lyrate horns.

"Attica still possessed giraffes and other ruminants related to them, which Gaudry, haunted by the poetry of ancient Hellas, called *Helidotherium*—superb creatures, which were thought to have disappeared forever, but which came to light again, scarcely modified, some years ago in the pasture lands of the Congo." (F. Perrier.)

The large mammals comprise an edentate with hooked fingers (*Ancylotherium*), two mastodons, a carnivore with large canine teeth (*Machairodus*), and finally the enormous *Dinotherium*. With these forms we remark also the *Chalicotherium*, the wild boar of Erymanthus, the Amalthean goat (*Tragocerus amaltheus*), and, among the birds and reptiles, the cock of Esculapius, the crane of Mount Pentelicus, the tortoise of the marbles, etc.

All these animals were terrestrial and the deposit of Pikermi represents a torrential deposit. In the epoch in which lived the fauna of which we have spoken, Greece was united to Africa by a broad area and the climate was similar to that of the latter. It was not until much later that the separation of the two countries took place. The animals buried in the ravines of Pikermi were swept into this place by the water-courses of the age, bordered by a vegetation still African.

The other conclusions drawn by Gaudry from the study of this fauna were more remarkable, and it is of these especially that we wish to speak.

Gaudry was not, indeed, content with carefully describing all these interesting forms, as were his contemporaries. In pointing out the differences which separated them from known forms, he was led to consider the resemblances which they showed to other extinct forms or to living forms.

He sought the bonds, the relationships, which united the ancient organisms to one another and to living forms. It was these relationships, these bonds, established by his intellect, which determined his philosophy, which constituted the novelty, the originality, and the greatness of his work. These are the ideas which bring valuable support to the transformist doctrine.

After having demonstrated that the fauna of Pikermi belonged to the Upper Miocene age, M. Gaudry showed that there is something more fundamental than the apparent variety of faunas. It is the unity of plan which binds them together.

Among the examples cited by our author are the following: "The monkeys of Pikermi (*Semnopithecus pentelici*) are intermediate between the macaques and the Semnopitheci. They resemble the former in their limbs and the latter in their skull. The carnivore called *Simocyon* has the canine teeth of a cat, the premolars and carnassial teeth of a dog, while the form of its mandible and of its tubercular molars allies it to the bears. With *Amphicyon*, *Hemicyon*, and

Arctocyon, it binds this family to that of the dogs, which to-day are quite distinct. Associated with animals half civets and half hyænas one finds a true hyæna, intermediate between the common species now living in Africa, the spotted, and the striped hyænas." (Gaudry.)

In comparing the fossils of Pikermi with those which one finds in more ancient formations, as for example those of Sansan (Gers) or Auvergne, similar relationships were discerned by Gaudry, and indicated to him that Pikermi is not the only deposit which presents intermediate types.

"He concludes that organic types are not distinct entities, but that they ally themselves on the one hand to the older types, which can be considered the ancestors of the former, and, on the other hand, with more recent types, which may be regarded as their descendants. The modifications which he discovers, in passing from a given form to a neighboring form, are so inconsiderable, the transformations are so closely coordinated with the time, that he is led logically to conclude that the species of fossil animals are not immutable beings, but that they are transformed into others; that modification (*changement*) is the supreme law of the animal world as of the physical world." (Boule.)

Thus Gaudry gave to the theory of evolution a more solid basis, one which it lacked previously, the paleontological argument. And would it not be strange and unscientific not to take into account fossil animals, the species of which are so much more numerous than the living forms?

The appearance of the great and remarkable work on "The fossil animals and geology of Attica," in which Gaudry expounded his ideas on the fauna of this region, marked an important date in the history of paleontology and of the animal kingdom. The study of the fauna of Pikermi established the scientific reputation of the naturalist among scholars.

2. *Mount Léberon. Migrations.*

Some years later (in 1872) Gaudry undertook researches at Mount Léberon near Cucuron (Vaucluse) in a formation having very close analogies in age and faunas with Pikermi. He was led to study this formation "in order to discover whether not only the genera and families of mammals, but also the species, have been immutable entities, or whether they do not show sufficient plasticity to indicate that they are descended from one another."

The work on Léberon was done while that on Pikermi was in progress, and supplemented it in many points.

Gaudry, after having drawn a magnificent picture of Miocene nature, concluded that it was characterized by the great development of herbivorous animals, and demonstrated that the mammals, on account of their complexity, had undergone much greater variations than the invertebrates.

He developed also another very important idea, which had been entertained by Cuvier, and which to-day furnishes valuable results. I refer to migrations.

Notable differences are often found between two successive forms in superimposed strata, and these differences can only be explained by the modification in the habitat of the animals. But these modifications were caused by invasions or recessions of the ocean, by elevation or depression of certain continental areas. Briefly stated, the modifications of a biological nature in a region are dependent on modifications of a physical nature, the faunal changes bearing a close relation to the geographical changes. "When I say that the difference between the two substages of the Upper Miocene results from modifications in the habitat of the animals, I do not consider that I am pointing out an isolated fact in the history of the development of living beings. There is reason to suppose that the whole organic world has proceeded in a continuous manner, and that if geologists encounter sudden appearances of fossil species in passing from one stage to another, it is because they have, in general, placed the boundaries of the stages at points where displacements of faunas have taken place. The paleontologist who does not believe in migrations and in local extinctions can not admit the relatedness of ancient forms of life. He encounters appearances, disappearances, and revivals which he is unable to understand." (Gaudry.)

Thus are explained the close, inseparable bonds between geology and paleontology. A paleontologist, no matter how eminent he may be, should be a geologist in order to know the faunas which he studies, and a geologist who studies sedimentary formations is obliged to be a paleontologist.

3. *Primitive reptiles and the theory of the archetype.*

After having considered the evolution of mammals at the close of Miocene times, and having drawn the important conclusions already noticed, Gaudry undertook the study of amphibians and reptiles, specimens of which had been found in the Permian schists of Autun.

Before this epoch primary amphibians and reptiles were almost unknown in France. In describing the curious forms of Autun—*Protriton*, *Actinodon*, *Euchirosaurus*, *Stereorachis*, *etc.*—and pointing out their affinities, Gaudry filled a gap which existed in the history of the primitive vertebrates, and was led to discuss the question of

the manner in which the vertebrate type was formed, and also the archetype, which has caused so many controversies among zoologists and embryologists.

According to the learned paleontologist, "vertebrates are not derived from animals which conform to the idea of the vertebrate archetype. The prototypes of the vertebrates seem, on the contrary, to have been remote from the vertebrate archetype, since the archetype is supposed to be a compound of vertebræ, placed end to end and little modified, while the principal character of the most ancient vertebrates appears to have been that their vertebral column was incompletely formed. The oldest primary fishes were without vertebræ, or at least had vertebræ the centrum of which was not ossified. Equally, the first reptiles possessed remnants of the notochord, the elements of which were completely ossified. It can not be said that the head of the vertebrates is merely an expansion of the vertebræ, since the bones of the head and of the limbs were formed before the vertebræ."

These ideas are contrary to the theory of Oken, and many other theories, but the important conclusions of Gaudry are firmly based on facts.

4. *Fossil man.*

Before the appearance of his great work on Pikermi (1859) the scientific mind of Gaudry was arrested by another subject, which had equally raised very heated and, at times, violent discussions. It had to do with the discovery of fossil man, as asserted by Boucher de Perthes at the beginning of the quaternary epoch, a discovery denied or strongly disputed. In order to solve this problem, Gaudry undertook excavations at St. Acheul (Somme), a locality destined to become as celebrated as Pikermi, and he himself collected in the quaternary alluvium flints chipped by man, associated with bones of animals now extinct—large cattle, *Rhinoceros tichorhinus*, the mammoth (*Elephas primigenius*), and the hippopotamus. Thus was irrefutably demonstrated this contemporaneity which had been denied by some. This work formed the first rational scientific basis for a classification of the quaternary formations, which later was the object of an important treatise (Materials for the history of the Quaternary age), prepared in association with one of his young pupils, M. Marcellin Boule, who to-day is his successor.

The series of works of which we have spoken, works so original that each marks an epoch in paleontology, led to the appointment of Gaudry as professor of paleontology in the Museum of Natural History, in the place of Lartet (1872). He had there, as a laboratory, a small and dark apartment, with brick floors and worm-eaten windows that looked into the "Whale court." Paleontological col-

lections, properly speaking, did not exist as yet. They were divided among various zoologists. It was not until seven years later (in 1879) that Gaudry was able to gain possession of the fossils of Pikermi which he had collected and studied. The benevolent administration of the museum permitted him to erect a little glazed shed. This, fortunately, was only intended as a means of obtaining a building more worthy of the paleontological riches which he wished to display and make known to all. But what a mass of persuasion was necessary in order to obtain a palace similar to that of zoology! When the exhibit was assembled and arranged according to his ideas, it appeared, to quote the eloquent words of M. Liard, "like a history, like a philosophy. It is in effect the history of the animal creation, an interpretative history, rendered visible and tangible." In this splendid exhibit of the recovered evidences of past ages, arranged according to their appearance on the globe, one has in brief the history of the animal kingdom, from the radiolarians of the Cambrian formations up to the earliest of the human races, already the *Homo sapiens.*

Before arriving at this last stage, Gaudry had brought together his ideas as investigator and professor in the form of treatises which have had a considerable fame.

5. *The links of the animal kingdom. The unity of plan of the animal kingdom.*

After six years of teaching Gaudry brought out his first volume on "The links of the animal kingdom—Tertiary fossils" (*Les Enchainements du monde animal. Fossiles tertiaires*), a work whose suggestive title caused considerable enthusiasm among naturalists of all lands.

Some years afterwards appeared the "Primary fossils" and the "Secondary fossils." This scientific trilogy summarized a great part of the work and ideas of Gaudry. The word links (*enchainements*) reveals sufficiently the spirit which dominates it. There existed links, evident connections between the diverse beings which have appeared successively on the globe, and those which exist to-day. These last are merely the resultants, or the remainders, of an evolution of which the different steps are found in the geological series. The living world can be explained only through a knowledge of the worlds which have disappeared. There is not a fossil world and a living world, but a single world. If the evolution of different beings which from time to time have inhabited the earth has proceeded under the action of natural causes (modifications due to the environment, to wants, to migrations, to mutations, etc.), it appeared to Gaudry that "the causes themselves must operate for the realization of a plan,

and it is to discover this plan and to explain it that he wrote these remarkable works and consecrated his life." (Liard.)

In 1896 Gaudry published another treatise as a supplement to his "Enchaînements." This is the "Essay on philosophical paleontology," in which he revealed his thought on the problems raised by the study of paleontology.

In a series of chapters he showed that animated nature formed a great unity, the development of which it was possible to trace as one traces that of the individual. He passed in review the multiplication of organisms, their differentiation, the growth of their bodies, the progress of their activities, their sensibilities, and their intelligence.

A practical idea which proceeds from his studies is that which relates to the determination of the age of the terrestrial strata by means of the stage of evolution of the animals found therein. "No one denies to-day that by the aid of fossils it is possible to determine the age of formations. It is admitted that each of them contains a certain number of characteristic fossils. Why are they characteristic of one epoch rather than another? No one knew formerly, and that could not fail to be displeasing, because one does not enjoy what one does not comprehend and has great difficulty in remembering. But if paleontology gives us the assistance of a regular evolution of animated nature, it is evident that the stage of development of the fossils corresponds to their geological age. We then understand why certain fossils are found at a certain horizon. The stages of evolution of the fossils which are brought to us for identification mark not only the modifications of organization, but also of the principal divisions of geological time. Taking two different strata, if I find that in one the animals indicate a condition of evolution less advanced than the other, I conclude that the former are of the earlier age." (Gaudry.)

Thus, according to the state of development of the vertebral column, the tail, the teeth, or the scales on the body of fishes one can distinguish the Primary, the middle of the Secondary, and the Tertiary. Reptiles with the vertebral column imperfectly ossified indicate the Primary. The apogee of the reign of the reptiles announces the Secondary. Their resemblance to types now living indicates the Tertiary.

If one show to a paleontologist feet or teeth of various animals of different epochs, he will often say, "this is the foot of an Eocene, Oligocene, or Miocene animal," etc. Some modifications apart, the history of the discoveries of recent years, those relating to the Proboscidians, for example, offers a striking confirmation of these ideas, which are only a direct corollary of the continuous evolution of organisms.

A visit to the hall of paleontology in the Museum of Natural History will enable one to appreciate, by the aid of visible arguments, the ideas expounded by Gaudry. It is precisely on these arguments (as regards fossil species), taken from all lands, that he has established his doctrine in sober, pure and harmonious language.

In the last works which we have mentioned Gaudry showed very clearly, by the aid of numerous sketches, how the transformist doctrine was the only one which explained the history of fossil animals. He succeeded in doing more; he infused into this history a communicative enthusiasm, a poetic charm which makes the reading of his books as attractive as it is instructive.

But the scholar was now 75 years old. The official age for retirement had arrived for him, and it was necessary that he should leave his pupils, with whom he had lived in the closest intimacy, and the collections which he regarded with a genuine love. The sacrifice was so painful that his pupil, M. Boule, who had become in his turn an eminent master, when called upon to succeed Gaudry, sought to set it aside. Gaudry retained his office and all his habits of life, and he remained in this hospitable establishment, which he had had so great pains to found, until the last day of his life. Until the end he gave an astonishing example of continuous labor, lucidity, and productiveness.

6. *The faunas of Patagonia. A part of the Antarctic world.*

From 1904 to 1908 Gaudry directed his researches toward a world entirely new to him, to which the discoveries of Ameghino had attracted his attention. This world of strange fossil vertebrates of Patagonia, so disconcerting to a mind accustomed to European, Asiatic, and North American forms, attracted Gaudry. The remarkable collections made by the young Frenchman, Tournoüer, of the most curious forms of this fauna, supplied him with material for new studies, which aroused his enthusiasm, because here again he found problems awaiting solution.

In three successive memoirs he expounded the ideas which his studies suggested. A summary of them is as follows:

Except at the beginning of the Tertiary, the land mammals of Patagonia were widely separated from those of the Northern Hemisphere. All the genera were distinct and the majority of them to such a degree that it is not possible to place them in the orders established for the mammals of Europe.

Not alone are the genera different, but the progress of evolution is not the same. While the paleontology of our Northern Hemisphere offers us the spectacle of a continuous progress, South America shows an arrest of development. In the Miocene, no animal became a ruminant, a pachyderm with paired toes, a soliped like a horse, a proboscidian, a placental carnivore, or an anthropoid ape. This condition of affairs has continued until the present, since mastodons, horses, deer, bears, Machairodi, which have left their

remains in the Pampean strata side by side with the descendants of the Tertiary animals of Patagonia, are too distinct to be transformations. There is no doubt that they emigrated from North America. The faunas formed on the soil of Patagonia were not influenced by the new arrivals. Rather than become modified many of the species died out, showing to the end the separation of the southern world from the northern world.

Analogous conditions existed in Australia, where the mammals have scarcely passed the stages of our Eocene genera.

Thus, the surface of the earth is divided into two portions, the Northern Hemisphere where the progress has been continuous to our day, and where life is manifested in all its magnificence; and the Antarctic regions where the animal kingdom has suffered an arrest of development. Why? We do not know yet. This is a new problem which confronts students of the evolution of organisms, but it is not necessary that two centers of creation should be recognized, one in the Northern Hemisphere and the other in the Southern Hemisphere.

Gaudry died at the age of 81, after having passed the last years of his life in the study of Antarctic forms. He left a posthumous memoir, a very remarkable one, on Pyrotherium, one of the most curious creatures of the southern world, a work which will soon appear, and will be, as it were, a last homage rendered to his memory.

In the foregoing pages I have only skimmed over the work of Gaudry, but sufficiently to show its variety and greatness. It is due to him and his contemporaries and his followers, Cope, Marsh, Osborn, Leidy, Scott, and Ameghino in America; Fowler, Seely, Woodward, and Lydekker in England; Neumayr, Zittel, and Rütimeyer in Austria, Germany, and Switzerland; Douvillé, Boule, and Depéret in France, etc., that the evolution of the ancient world has been definitely and solidly established.

But it is necessary to remember that Gaudry was the precursor. By the depth of the problems which he studied, by the influences which he exerted, and by his theoretical conceptions, Albert Gaudry stands with Lamarck. But he is also, in virtue of his remarkable observations, the Darwin of the vanished faunas, and his name should shine side by side with the names of these illustrious scholars.

CHARLES DARWIN.*

By August Weismann.

Forty-one years ago, when I delivered my inaugural address as a professor of this university, I took as my subject "The Justification of the Darwinian Theory." It is a great pleasure to me to be able to lecture again on the same subject on the hundredth anniversary of the birth of Darwin.

This time, however, I need not speak of justifying the theory, for in the interval it has conquered the whole world. Yet there remains much that may be said—much, indeed, that ought to be said at the present time. In my former lecture I compared the theory of descent or evolution to the Copernican Cosmogony in its importance for the progress of human knowledge, and there were many who thought the comparison extravagant. But it needs no apology now that the idea of evolution has been thoroughly elaborated, and has become the basis of the science of life.

You know that Darwin was not the only one, and was not even the first, to whom the idea of evolution occurred; it had arisen in several great minds half a century earlier, and it may therefore be thought an injustice to give, as we now do, almost all the credit of this fruitful discovery to Darwin alone.

But history is a severe and inexorable judge. She awards the palm not to him in whose mind an idea first arises, but to him who so establishes it that it takes a permanent place in scientific thought, for it is only then that it becomes fruitful of, and an instrument for, human progress. The credit for thus establishing the theory of evolution is shared with Charles Darwin only by his contemporary, Alfred Russel Wallace, of whom we shall have to speak later.

Nevertheless, a reflection of the discoverer's glory falls upon those who, about the end of the eighteenth and the beginning of the nineteenth century, were able to attain to the conception of evolution, notwithstanding the incomparably smaller number of facts

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* An address delivered at the University of Freiburg on the occasion of the Centenary of Darwin. Reprinted by permission from The Contemporary Review July, 1909.

known to them. As one of these pioneers we must not omit to mention our own poet, Goethe, though he rather threw out premonitory hints of a theory of evolution than actually taught it. "Alle Gestalten sind ähnlich, doch keine gleichet der andere, und so deutet der Chor auf ein geheimes Gesetz."

The "secret law" was the law of descent, and the first to define this idea and to formulate it clearly as a theory was, as is well known, also a Darwin, Charles Darwin's grandfather, Erasmus, who set it forth in his book, "Zoonomia," in 1796. A few years later Treviranus, a botanist of Bremen, published a book of similar purport, and he was followed in 1809 by the Frenchman, Lamarck, and the German, Lorenz Oken.

All these disputed the venerable Mosaic mythos of creation, which had till then been accepted as a scientific document, and all of them sought to show that the constancy of species throughout the ages was only an appearance due, as Lamarck in particular pointed out, to the shortness of human life.

But Cuvier, the greatest zoologist of that time, a pupil of the Stuttgart Karlsschule, would have none of this idea, and held fast to the conception of species created once for all, seeing in it the only possible explanation of the enormous diversity of animal and plant forms.

And there was much to be said for this attitude at that time, when the knowledge of facts was not nearly comprehensive enough to afford a secure and scientific basis for the theory of descent. Lamarck alone had attempted to indicate the forces from which, in his opinion, the transmutation of species could have resulted.

It was not, however, solely because the basis of fact was insufficient that the theory of the evolution of organic nature did not gain ground at that time; it was even more because such foundation as there was for it was not adhered to. All sorts of vague speculations were indulged in, and these contributed less and less to the support of the theory the more far-reaching they became. Many champions of the "Naturphilosophie" of the time, especially Oken and Schelling, promulgated mere hypotheses as truths; forsaking the realm of fact almost entirely, they attempted to construct the whole world with a free hand, so to speak, and lost themselves more and more in worthless phantasy.

This naturally brought the theory of evolution, and with it "Naturphilosophie," into disrepute, especially with the true naturalists, those who patiently observe and collect new facts. The theory lost all credence, and sank so low in the general estimation that it came to be regarded as hardly fitting for a naturalist to occupy himself with philosophical conceptions.

This was the state of matters onward from 1830, the year in which the final battle between the theory of evolution and the old theory

of creation was fought out by Geoffroy St. Hilaire and Cuvier in the Paris Academy. Cuvier triumphed, and thus it came about that an idea so important as that of evolution sank into oblivion again after its emergence, and was expunged from the pages of science so completely that it seemed as if it were for ever buried beyond hope of resurrection.

Scientific men now turned with eagerness toward special problems in all the domains of life, and the following period may well be characterized as that of purely detailed investigation.

Great progress was made during this period; entirely new branches of science were founded, and a wealth of unexpected facts was discovered. The development of individual organisms, of which little had previously been known, began to be revealed in all its marvelous diversity; first, the development of the chick in the egg; then of the frog; then of insects and worms; then of spiders, crustaceans, starfishes, and all the classes and orders of mollusks, as well as of backboned animals from the lowest fish up to man himself. Within this period of purely detailed investigation there falls also the discovery, in animals and plants, of that smallest microscopically visible building stone of the living body, the cell, and this discovery paved the way for the full development of the newly founded science of tissues, histology.

In botany the chief progress in this period was in regard to the reproduction and development of the lower plants, or cryptogams, and the discovery of alternation of generations, a mode of reproduction that had previously been known in several groups of the animal kingdom, in polyps and medusæ, in various worms, and later in insects and crustaceans.

At the same time it was found that the proposition, which had hitherto been accepted as a matter of course, that an egg can only develop after it has been fertilized, is not universally valid, for there is a development without previous fertilization—parthenogenesis, or virgin birth.

Thus, in the period between the Napoleonic wars and 1859, an ever increasing mass of new facts was accumulated, and among these there were so many of an unexpected nature that further effort was constantly being put forth to elucidate detailed processes in every domain. This was desirable and important—was, indeed, indispensable to a deeper knowledge of organic nature. But in the endeavor to investigate details naturalists forgot to inquire into the deeper causes and correlations, which might have enabled them to build up out of the wealth of details a more general conception of life. So great was the reaction from the unfortunate speculations of the so-called "Naturphilosophie," that there was a tendency to shrink even from taking a comprehensive survey of isolated facts, which might lead to the induction of general principles.

How deep was the oblivion into which the philosophical conceptions of the beginning of the century had sunk by the middle of it may be gathered from the fact that in my own student days in the fifties I never heard a theory of descent referred to, and I found no mention of it in any book to which I had access. One of the most famous of my teachers, the gifted anatomist, J. Henle, had written as a motto under his picture, "There is a virtue of renunciation, not in the domain of morality alone, but in that of intellect as well." This sentence was entirely obscure to me as a student, because I knew nothing of the intellectual excesses of the "Naturphilosophie," and I only understood later, after the revival of interest in general problems, that this insistence upon the virtue of intellectual renunciation was intended as a counteractive to the over-speculations of that period.

This was one-sided, but it was a necessary reaction from the one-sidedness in the opposite direction which had preceded it.

The next swing of the pendulum was brought about by Charles Darwin in 1859 with his book on "The Origin of Species."

Let us now consider the development of this remarkable man, and note the steps by which he attained to his life work. Charles Darwin was born on the 12th of February, 1809, the same year in which Lamarck published his "Philosophie Zoologique." But he had not sucked in the doctrines of that evolutionist, or of his own grandfather, Erasmus Darwin, with his mother's milk. His youth fell within the period of the reaction from philosophical speculation, and he grew up wholly in the old ideas of the creation of species and their immutability. His birthplace was the little town of Shrewsbury, near the borders of Wales, where his father was a highly respected physician, well to do even according to English standards.

If we think of Charles Darwin's later achievements we are apt to suppose that the bent toward natural science must have been apparent in him at a very early age, but this was not the case, at least not to a degree sufficient to attract the attention of those about him. It is easy now, of course, to say that the pronounced liking for ranging about wood and field and collecting, quite unscientifically, plants, beetles, and minerals, foreshadowed the future naturalist. Even as a boy Darwin was an enthusiastic sportsman and an excellent shot, and the first snipe he brought down excited him so much that he was hardly able to reload.[a] But he must have been not merely a sports-

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[a] I can say the same of myself for, although in my boyhood I did not shoot birds, I had a passion for butterfly hunting. When I saw the rare *Limenitis populi* resting on the ground in front of me for the first time, I became so excited that I could not at first throw my net, and when I did throw it, though my aim was usually very accurate, I struck the butterfly obliquely over the wing with the iron ring of the net. The traces of this awkward aim are visible on the wing to this day.

man but an eager observer, especially of birds, for at that time he wondered "in his simplicity" that every gentleman was not an ornithologist, so much was he attracted by what he observed of the habits of birds.

The school which he began to attend at Shrewsbury in his ninth year was probably very similar to our earlier gymnasia. Darwin himself maintained that nothing could have been worse for his intellectual development than this purely classical school, in which nothing was taught, in addition to the ancient languages, except a little ancient history and geography.

Darwin had no talent for languages, and no pleasure in them. So he remained a very mediocre scholar, and his father therefore removed him from school in his sixteenth year, and sent him to the University of Edinburgh to study medicine.

The condition of the English universities at that time must have left much to be desired, for Darwin characterizes the majority of the lectures as terribly dull, and the time spent in attending them as lost. Moreover, anatomy disgusted him, and the tedium of the geological lectures repelled him so that he vowed never again to open a book on geology, a resolution which, happily, he did not adhere to.

In his student days, as in his school time, he roamed about in the open air, sometimes shooting, sometimes riding, sometimes making long expeditions afoot. But even then he was not a conscious observer of nature, not a naturalist, but rather a lover of the beauty of nature and a collector of all sorts of natural objects, though he collected still, as he had done at school, rather from the collecting impulse frequently characteristic of youth than from any real scientific interest. If he had had that interest his chief passion would not have been the shooting of birds. His friends even found him one day making a knot in a string attached to his buttonhole for every bird he succeeded in bringing down! Thus he must have been mainly a sportsman, a hunting fanatic whose chief desire was to bring down as many birds as possible in a day. However, this devotion to sport must have stood him in good stead later, especially on his great journey, for through it he not only acquired the technique of shooting, but he sharpened his naturally acute powers of observation.

He remained two years in Edinburgh, and then entered the University of Cambridge. His father, who had observed his disinclination for medicine, proposed that he should study theology, and Darwin knew himself so little that he was quite willing to agree to the proposal. He examined himself very conscientiously to see whether he was able to subscribe to the dogmas of the Anglican Church, and he came to the conclusion that he could accept as truth every word that the Bible contained. This was certainly remarkable,

and proves that the "Zoonomia" of his grandfather, Erasmus, and the doctrines of Lamarck, as far as he was acquainted with them, had not taken very deep root.

So he proceeded to study theology. But he did it much in the same way as he had studied medicine in Edinburgh; he listened only to what pleased him, and that can not have been very much, for here, too, he complained of the dullness of official lectures. Nevertheless, at the end of three years he passed his examination quite creditably and received the degree of B. A.

Of the greatest advantage to him in Cambridge was his intercourse with two distinguished teachers of the university, and this intercourse probably guided him imperceptibly toward the real work of his life. One of these teachers was Professor Henslow, a theologian who afterwards accepted a living, but who had a comprehensive knowledge not only of entomology, but of chemistry, botany, mineralogy, and geology. By Henslow, Darwin was introduced to the professor of geology, Sedgwick, and he, too, interested himself greatly in the young man, taking him with him on his longer geological excursions, and thus giving him a most valuable introduction to the science. This proved of the greatest use to Darwin on his travels, and probably enabled him to make his numerous geological observations.

Other older men also admitted Darwin to their friendship, so that it is obvious that there must have been something about him even then which distinguished him from others of his age. His interests now began to widen; he came under the educative influence of art, and studied the picture gallery in Cambridge, and later the National Gallery in London. He gained the entrance to a musical circle, and derived great pleasure from music, though, curiously enough, as he tells us, he was almost destitute of "ear," and could not even whistle "God Save the King" correctly. He was thus one of those rare persons who are exceedingly sensitive to the emotional effect of music and yet possess little or nothing of its physical basis, the sense of tone.

In addition to all this, Darwin retained his passion for beetles, and collected with such ardor that twenty years later he recognized at sight small rare species he had found under bark or moss at that time. His powers of observation had thus been awakened, although as yet they were employed mainly to minister to his zeal for collecting. But collecting is not a mere amusement for the young naturalist; it is a necessary discipline in surveying a definite range of forms, and it can not well be replaced by anything else. One who has never collected, and thus never made himself thoroughly acquainted with a limited circle of forms, will find it difficult to fill up the gap in his attainments in later life.

In vacation time toward the autumn of each year Darwin turned again with enthusiasm to sport, either at his home in Shrewsbury

or on his uncle Wedgewood's large estate of Maer. He did not lose a possible day from this amusement, for as he says in his autobiography, "I should have thought myself mad to give up the first days of partridge shooting for geology or any other science." Thus, notwithstanding his interest in geology and beetle collecting, in pictures and music, the old passion for the chase was still the dominant one; one pleasure crowded upon another, and the whole made his life a joyous symphony, so that he could say of that period, "The three years which I spent at Cambridge were the most joyful in my happy life." But in the midst of all the joyousness of life he was undergoing an inward preparation for the seriousness of it. We can gather from his own account of that time that the strongest impulse toward the study of natural science came from reading two works which aroused his interest, Humboldt's "Personal Narrative" and Herschel's "Introduction to the Study of Natural Philosophy." Darwin says of these: "No other book influenced me so much as these two." He used to copy long passages from Humboldt about Teneriffe and read them aloud to Henslow. He was very anxious to go to Teneriffe, and even made inquiries in London about a ship to take him there, when an event happened which overthrew that project, but at the same time opened up the way to a naturalist's career—the only one really suited to him—in a much more satisfactory manner. He received a proposal to make a voyage round the world.

It must appear to us singular that a young man who had just finished his university course, and had done no scientific work of any kind, should be invited to accompany, as a naturalist, a naval vessel which was being sent round the world by the Government for the purpose of making nautical observations. It proves that Darwin's older friends must have had very high expectations in regard to his future.

Captain Fitzroy, of the English navy, was looking for a young man who would go with him as naturalist, on a voluntary footing, on his voyage in the *Beagle*.

Darwin himself was at once eager to accept, but his father objected very decidedly, seeing no reasonable object in spending five years ranging over the globe. But he concluded his letter with the sentence, "If you can find any man of common sense who advises you to go, I will give my consent."

The necessary adviser was found in his uncle, Wedgewood, who, as soon as he heard of the matter, immediately drove the 40 miles from Maer to Shrewsbury and persuaded the elder Darwin that he must allow his son to go.

Thus it happened that Darwin made the journey which he speaks of later as "the most important event of my life," as it undoubtedly

was. It was only later that he learned that even then his going was not a certainty, for Captain Fitzroy, after seeing him, was in doubt as to whether he should accept him, for a reason not easy to guess—because of the shape of his nose! Fitzroy was an enthusiastic disciple of Lavater, whose doctrine of physiognomy was then widespread. He believed that the shape of Darwin's nose proclaimed a lack of energy, and he was doubtful about taking anyone deficient in that quality on such a journey. Happily, Darwin's friends were able to reassure Fitzroy on this point, and he must often enough afterwards have had opportunity to convince himself of Darwin's energy.

Thus it was apparently by mere chance that Darwin got the opportunity to develop actually into the great naturalist we now know that he must have been potentially. But I do not believe that this is a correct judgment. His inward impulse would certainly have forced a way after he had been led to perceive, through Humboldt and Herschel, what the way for him was to be. And even at that time no serious obstacle would be likely to stand in the path of a young Englishman of fortune who wished to explore foreign lands and seas. But undoubtedly this manner of traveling for five years through the seas and countries of different zones was particularly advantageous. And Darwin used his opportunities to the full. On board ship he studied the best books, especially Lyell's "Principles of Geology," but he also collected certain kinds of natural objects, and investigated all that came in his way, keeping a detailed journal of everything that struck him as worthy of note in what he observed. Thus he became a well-informed and many-sided naturalist. But he valued much more highly than any other result of the voyage the habits of energetic industry and concentrated attention to whatever he had in hand that he then acquired. And thus he became the great naturalist for which nature had designed him.

Darwin published his journal later; it fills a closely printed volume of 500 pages. Like all his books, it is characterized by a simplicity and straightforwardness of expression; there is absolutely no striving after sensational effect, but an innate enthusiasm and truth pervades it, and I have always found it most enjoyable reading. Other people must have found it so, too, for by 1884 16,000 copies of the English edition had been sold. I can not here give even a brief account of the voyage of the *Beagle;* I can only say that its work lay chiefly on the southern coast line of America, and the journey included the east coast of Bahia to Tierra del Fuego, and the inhospitable Falkland Islands, and the western coast to Ecuador and Peru.

This occupied several years, and thus the young explorer had a chance to make himself thoroughly acquainted with a great part of the South American continent, for while the ship lay at anchor taking soundings in some bay or other, Darwin ranged over the

country on horseback, in a boat, or on foot. In Brazil, on the plains of the La Plata River, and in Patagonia he made excursions into the interior which lasted for weeks, and he was thus able to see and investigate everything that interested him.

In all his descriptions of what he saw his keen appreciation of the beauty and grandeur of nature are manifest. Thus he writes from Bahia on the first day of his arrival in South America: "The day has passed delightfully. Delight itself, however, is a weak term to express the feelings of a naturalist who for the first time has wandered by himself in a Brazilian forest. The elegance of the grasses, the novelty of the parasitical plants, the beauty of the flowers, the glossy green of the foliage, but above all the general luxuriance of the vegetation, filled me with admiration. A most paradoxical mixture of sound and silence pervades the shady parts of the wood. The noise from the insects is so loud that it may be heard even in a vessel anchored several hundred yards from the shore; yet within the recesses of the forest a universal silence appears to reign. To a person fond of natural history such a day as this brings with it a deeper pleasure than he can ever hope to experience again" (p. 4, 1884 ed.).

Not less delightful are his descriptions of the monotonous and almost endless plains of Patagonia and the La Plata River, over which, accompanied by Gaucho Indians, he rode for many days; or his account of the wild mountain scenery of Tierra del Fuego, with its gloomy evergreen woods, broken into by deep inlets and bays in which whales disported themselves, and its mountains whose dark cloud-laden summits are swept by the most violent storms. A different picture is called up by Darwin's description of his ascent from the "Vale of Paradise" (Valparaiso) up the Cordilleras to a height of 13,000 feet, and the view from there down upon the coast region and the Pacific Ocean far beneath him. And how many other passages might be cited!

He cared, however, not only for what was beautiful, but for what was most interesting from a scientific point of view. Thus he discovered in a pass in the Cordilleras a stratum of fossil shells, a proof that this place was at one time a part of the sea floor, and that therefore it had been raised in the course of ages more than 13,000 feet.

His journal contains a wealth of observations about plants and animals as well as about man and many detailed accounts of the geological structure of the countries visited. We see how well his Cambridge studies and the excursions he made there had prepared him for this work.

I can not enter into any details of his observations, but I must at least mention those which deal with the facts that led him gradually

to change his previous views in regard to the nature and origin of species.

When he first began his explorations in South America he was, as he expressly says, still completely under the influence of the dogma of the creation of species once for all, and their immutability, and he regarded it as unassailable. But very soon he was struck by certain facts which seemed to him difficult to reconcile with this dogma, and these increased in number in the course of his journey, till finally they led him to the conviction that the old position was untenable, and that the organic world had not been created immutable, but had slowly evolved.

I select two of these phenomena, first, the occurrence of the fossil remains of gigantic mammals in the diluvial strata of the great plains of La Plata and Patagonia. Darwin found a gigantic armadillo (*Dasypus gigas*), and he was led to ask how it happened that small armadillos now live in South America, whereas they do not occur, either living or fossil, anywhere else in the world. The answer was easy, if it was possible to assume that the present-day species were descended from the diluvial forms, or from other smaller, still undiscovered forms from the same period. But he was especially impressed by the fauna and flora of the Galapagos Islands, which lie under the equator, 500 nautical miles to the west of the South American coast.

On these isolated and comparatively barren volcanic islands there live many animals which could not fail to arrest the attention of the naturalist—land birds which are like those of the neighboring continent, and are of purely American type, yet are not identical but closely related species. Most of them are so-called "endemic" species, that is, species which occur in no other part of the world. This was striking enough, but the matter proved even more remarkable on closer investigation, for several of the fifteen islands of which the archipelago consists possess species of the same genus peculiar to themselves—mocking thrushes, for instance, which are represented in the other islands by similar but not identical species.

What inference is possible from these facts except that, at some earlier period, bird migrants from the neighboring continent had landed on these volcanic islands, and in the course of thousands of years had varied, that is to say, had become distinct species on each island?

These and other phenomena aroused in Darwin's mind the idea of evolution, and he resolved to devote his attention to this problem after he returned home, for he was persuaded that he could attain to certainty in regard to it by patiently collecting facts. Thus he set himself the task of his life. It may be well to inquire here whether, or to what extent, Darwin had taken over the idea of evolution from

his predecessors at the beginning of the century, and especially from his grandfather, Erasmus. It is certain that at 16 he had read the "Zoonomia," and that he admired it. He relates in his autobiography that, during his student days in Edinburgh, Doctor Grant, afterwards a professor at University College, London, spoke to him, in the course of a walk, in the most enthusiastic manner of Lamarck and his views on evolution. Darwin listened to these views with interest, but was in no way impressed or convinced by them. The same is true of the "Zoonomia," and when he reread it fifteen years later he was disappointed in it, "the proportion of speculation being so large to the facts given" (p. 38).

Thus Darwin was quite familiar with the views of his grandfather and of Lamarck, but it was not these that incited him to follow in the same paths; it was rather his own observations of nature that led him to abandon his old opinions, and it was only after long years of investigation, study, and doubt that he gained sufficient certainty to venture on giving his ideas to the world.

I must refrain from saying more about this journey, which was so fruitful for Darwin himself and for science; the two groups of facts of which I have spoken were undoubtedly decisive in their effect on his conception of nature. In December, 1836, with a wealth of great impressions and rich experiences in all the domains of natural science, his mind concentrated on the new idea of evolution, Darwin returned to his fatherland after an absence of five years.

Two years after his return he married, bought the estate of Down, in the county of Kent, and retired there to spend the whole of the rest of his life in constant work, but also in constant fellowship and personal touch with the most prominent naturalists of the day, who were readily accessible in London. He gradually came to have correspondence also with many naturalists in other countries.

His "chief pleasure and constant occupation" was his work, which sometimes even enabled him to forget the daily discomfort due to his health, which had been bad ever since his voyage. From the very beginning of the voyage he had suffered from severe and persistent seasickness, and his constitution had apparently suffered lasting injury, for in his autobiography he often speaks of being unable to work because of illness, and sometimes of having lost days and weeks, and on one occasion two whole years, from this cause.

In dealing with his work it is impossible for me to speak of all the important volumes he published in the course of his life. The first were the results of his voyage, various geological observations, and a new theory of the origin of coral islands.

Up till that time it had been believed that the so-called atolls, or lagoon reefs, had been simply built up by the coral polyps from the ocean floor until they finally reached the surface, where they

formed flat islands. Darwin recognized that the process could not be quite so simple, because the polyps can not live at great depths. He therefore assumed that a secular subsidence of the ocean floor must have played a part, and this hypothesis not only explains in the most beautiful way the details of the structure of an atoll, but it has been brilliantly corroborated by later investigations, especially by borings on one of the islands, and the theory is now a permanent possession of science. After the completion of this volume he worked for eight years at the rich material he had brought from the coast of Chile, of that remarkable group of sedentary crustaceans, the Cirripedes, usually known as barnacles and acorn shells. Two thick volumes on this subject appeared in 1851, and later two other quarto volumes on fossil species of the same group. Even here, in this apparently dry and purely systematic province, the true spirit of the investigator revealed itself, for he did not neglect what was unintelligible to him, and therefore inconvenient for his theory, but devoted the most persistent attention to obscure points until he had found a solution of the difficulty. Thus he discovered that within the group there are species which, like all Cirripedes, are hermaphrodite, but which possess in addition small degenerate-looking males of different structure attached as parasites to the hermaphrodite animals. It is, however, only in our own day that it has become possible to understand the deeper significance of this important discovery.

In addition to these special pieces of work Darwin collected with untiring energy facts which had any bearing on the theory of transmutation, having begun in 1837, just after his return to England, a large collecting notebook, in which he entered all the facts referring to the variability of animals and plants, in particular of those which are under the care of man. By means of printed lists of questions, of conversations with expert breeders of animals and plants, and of wide reading in books and journals, he sought to lay the foundation of fact which he required in order to attain to clearness in regard to the supposed transformation of organisms.

He was very soon led to the conviction that the essential factor in the artificial modification of an animal or plant form was selection for breeding. But how could such selection take place in free nature? For a long time he was unable to find the answer to this question, until chance made him acquainted with the work of the economist Malthus on "Population," and the ideas developed in this book suggested to him the solution of the problem. Malthus showed that the human population multiplied much more rapidly than the means of subsistence could increase, and that therefore catastrophes must occur from time to time to diminish the excessive number of human beings. Darwin said to himself that in the rest of nature, among other forms of life also, an enormous number of individuals must perish, since

all that were born could not survive, and since the greater part of a species furnishes food for some other species. Thus the ceaseless "struggle for existence" became clear to him, and suggested the question whether it was merely a matter of chance which of the many born should survive and which should perish. He concluded that the answer to this question was, evidently, that favorable variations would have more prospect of survival than unfavorable, and thus he discovered the principle of natural selection—that principle at once so simple and so powerful, which alone enables us to understand the transmutation of organisms in adaptation to the conditions of their life. But it was a long time before Darwin ventured to publish this luminous idea. For his own satisfaction he wrote quite a short sketch of it in 1842, and in 1844 he expanded this to 230 pages; but it was not till the fifties that, urged by his friends Lyell and Hooker, he resolved to give his ideas to the world. Even then he might have delayed publication, but that in the meantime the same idea had occurred to Alfred Wallace, in Ternate, in the Malay Archipelago, and had been communicated by him, first to Darwin, and then through Darwin to Lyell and Hooker. Then followed the memorable meeting of the Linnean Society, London, in July, 1858, at which two papers were read, one written by Darwin, the other by Wallace, both setting forth the same far-reaching idea of evolution based upon the principle of selection—a beautiful example of the unenvying magnanimity of two great discoverers.

This private communication to a scientific society made no great stir. But the publication in the end of 1859 of Darwin's book, "The Origin of Species by Means of Natural Selection," attracted great attention. A new edition was called for on January 2, 1860, and during the twenty-two years between that time and 1882, the year of Darwin's death, one English edition followed another, and more than 24,000 copies were printed. During the same period one German edition succeeded another, and it is doubtful whether any other purely scientific book has ever attained to such a circulation.

Yet the book is simple and straightforward, never sensational in style, but advancing quietly and concretely from one position to another, each supported by a mass of carefully sifted facts. Every possible objection is duly considered, and the decision is never anticipated, but all the arguments on both sides are carefully and impartially discussed in a manner that is apt to seem to the impatient reader almost too conscientious and cautious.

To readers who were acquainted with the scientific results of the time, who were aware of the numerous important facts that had been discovered, but missed the unifying idea which should gather them all together into a harmonious picture of life, the book came as a revelation. I myself was at the time in the stage of metamor-

phosis from a physician to a zoologist, and as far as philosophical views of nature were concerned I was a blank sheet of paper, a tabula rasa. I read the book first in 1861, at a single sitting and with ever-growing enthusiasm. When I had finished it I stood firm on the basis of the evolution theory, and I have never seen reason to forsake it.

This must have been the case with many. You know that the generation at the beginning of the century, satiated with speculation, threw itself wholly into detailed research, and its whole endeavor was to acquire new facts. Darwin furnished the unifying idea for these: it was evolution. Almost the whole younger generation of naturalists ranged themselves at once on his side; the older generation gradually followed, first zoologists, then botanists; even my excellent friend, Anton de Bary, was only converted to the new views in 1880, and from that time onward there was little further opposition, even on the part of the botanists.

Although Darwin's book was straightforward and simple, its effect was nothing less than revolutionary; it upset the old deep-rooted doctrine of creation just as completely as Erasmus Darwin, Lamarck, and Oken had desired. The book raised a conflagration like lightning in a full barn. This was soon so widespread that people read only "against" or "for" Darwin, especially in Germany, but later also in England. At first the opponents had the upper hand; the church regarded the new doctrine as dangerous to religion, because the old Mosaic mythos of creation could no longer be regarded as the basis of belief, and many of the older naturalists did not care to give up their inherited opinions without a struggle, and therefore strove to depreciate the new theory, either by serious argument or by satire and ridicule. The first to publish a work "for" Darwin was the German naturalist, Fritz Müller (1864), in Brazil. His book contained the first important deduction from the Darwinian theory; it went further than Darwin himself, and contained the germ of what Ernst Haeckel called, in his suggestive "Generelle Morphologie" (1866), the "fundamental biogenetic law." I myself was probably the third champion of Darwin's views when, in 1867, I delivered my academic inaugural address on "The Justification of the Darwinian Theory."

At that period almost every special study in the domain of embryology and "comparative anatomy" revealed fresh facts which were only intelligible on the assumption that the theory of descent was valid; much was now observed that had formerly been overlooked, simply because it was not understood, and much of the work done in the period of detailed investigation had to be done over again, because the points that were now most important had pre-

viously been disregarded. In this no reproach is implied to the many excellent observers of that period. No one can possibly observe everything that takes place; for instance, in the development of an animal, each notes only what seems to him to have some significance, whether he is able to interpret it or not. We do not work with our eyes alone; we must think at the same time.

But I need not dwell longer on the manner in which the Darwinian theory gained over the scientific workers of all countries, and penetrated deeply even among the laity. We have all had some personal experience of it, for the triumph of the theory of evolution has not long been won. A few words may be necessary as to why it was won so easily and so completely.

This was due in part to the enormous and increasing mass of facts in support of it, but mainly to Darwin's discovery of a principle capable of explaining transformations, in so far at least as these are "adaptations"—the principle of selection. Lamarck, too, had thought out a principle of explanation—the use or disuse of parts—but it was obviously insufficient to explain evolution as a whole, since it could only apply to actively functional organs.

The discovery of the principle of selection is the greatest achievement of Charles Darwin and his contemporary, Alfred Wallace, and it alone, in my opinion at least, affords a secure basis for the theory of evolution. It reveals to us how the apparently impossible becomes possible, how what is adapted to its purpose can have arisen without the intervention of a directing power.

The principle of selection shows us how the thousands of adaptations in living beings which arouse our constant admiration may have arisen in a purely mechanical way. And they must necessarily have done so if the evolution of the living has resulted from the same forces and laws as the not living; in other words, if, in explaining natural phenomena, we can leave out of account altogether any forces outside of or beyond nature. The principle of selection enables us to do this, and therein lies its far-reaching significance. It is, I believe, the discovery of this principle that will make the name of Darwin immortal. Wallace, too, deserves a full share of the credit, although he did not base his theory on such a broad foundation of facts, and did not apply it in so many directions.

This principle is fully developed in "The Origin of Species by Means of Natural Selection," as, indeed, the title of the book shows. It might be thought that the publication of this book finished the labors of the hermit of Down, but this was not the case; it was followed by the richest creative period of his life. Between 1860 and his death in 1882 he issued a whole series of works, small and large, each of them based upon numerous observations and experiments, and most of them containing wholly fresh associations of

ideas, usually connected directly or indirectly with the theory of evolution, and sometimes extending and corroborating it more fully. I must at least give a few indications as to the nature of these different books.

In 1862 Darwin published his book, "The Various Contrivances by which Orchids are Fertilized by Insects." Orchids often exhibit the most special and diverse adaptations to the visits of insects, and they help to make clear to us how flowers may have been developed in all their manifoldness in relation to the needs of their insect visitors.

In the same year and those following there appeared several treatises on "Dimorphism in the Flowers of Primula." Darwin had discovered minute differences in the length of the stamens in the same species, and he demonstrated that these differences are not mere chance variations, but are adaptations which secure the crossing of individuals and prevent self-fertilization. He obtained the proof of this through many careful experiments.

This was followed, in 1864, by a treatise on "The Movements and Habits of Climbing Plants," showing the different ways in which they climb—another study in plant adaptations. In 1868 appeared the great work begun in 1860, "The Variation of Plants and Animals under Domestication," and this book greatly extended and strengthened the basis of his theory of selection. The phenomena and laws of variation and heredity are discussed and illustrated by a wealth of examples, and the work concludes with a theory of heredity which he called "Pangenesis."

"The Descent of Man" appeared in 1870. Up till that time Darwin had made no definite pronouncement upon this subject, though of course he must from the very first have deduced from the variability of species that man also was a product of evolution. He now discussed this view in detail in a two-volumed work, which also contained a fuller treatment of an aspect of the theory of selection only briefly sketched in "The Origin of Species." Here the phenomena of "sexual selection" are traced throughout all the animal groups in which preferential mating plays a part. The principle is illustrated by a positively overwhelming mass of detailed facts, and is shown to have been a factor even in the differentiation of the sexes in the human race.

Closely associated with this work is the one which followed it in 1872 on "The Expression of the Emotions in Man and in Animals." The birth of Darwin's first child in 1839 had induced him to record in a special notebook all his observations on the gradual awakening of the sensations, and their expression on the features of the child, for he was convinced that even the most complex and delicate emotional expressions of man had their natural roots in animals,

just in the same way as the parts of the body and the mental faculties. For thirty-two years he followed out this idea, experimenting, observing, collecting facts, until finally he was able to write his remarkable and fascinating book, the first English edition of which consisted of 5,000 copies.

Darwin's next book appeared in 1875, and this also had been a long time in course of preparation. In ranging about the country during a summer holiday in 1860 he had noticed a dainty little plant, the "sundew" (*Drosera rotundifolia*), to the viscous leaves of which several small insects were usually found adhering. Many other collectors had noticed this, because of the difficulty of procuring a clean specimen for the herbarium. Darwin took a few of the plants home with him, and soon discovered that certain parts of the leaves exhibit movement as soon as small insects are brought into contact with them. This led him to the discovery of "Insectivorous Plants," and his book bearing that title was published fifteen years later.

In 1876 Darwin published a work on "Different Forms of Flowers on Plants of the Same Species," and in 1880, jointly with his son Francis, "The Movements of Plants." Finally, in 1881, the year before his death, there appeared "The Formation of Vegetable Mould through the Action of Worms." This last book, like some of the earlier short treatises, had no direct connection with the theory of evolution, but it illustrates in a very characteristic manner Darwin's eminently scientific mood, which led him to note everything that seemed unusual or interesting in the most ordinary things, and to follow it out till it led him on to new discoveries. How many hundreds of people, and even of naturalists, had seen the little earth-castings that cover the damper parts of our garden paths on summer mornings! These are due to earthworms, and are the remains of the decaying leaves on which they feed. The earthworms cover the whole land with fertile mold, and through their agency in the course of time the surface of the ground is raised, and bad soil is transformed into good.

But no one had deemed the phenomenon worthy of attention.[a] It is a case parallel with that of the sundew, which hundreds of botanists had passed by without ever suspecting that the adherence of the insects was more than a matter of chance.

The fruitful discovery of the "struggle for existence," too, was due to this vision of the true naturalist, who sees in what lies before him much that others pass by unheeding. It was certainly no chance

[a] In regard to the earthworm, I must note that my countryman, Professor Hensen, the excellent zoologist of Kiel, displayed the same acuteness of observation and drew the same conclusions from the castings at the same time as Darwin did.

that the "struggle for existence" first revealed itself to men who had spent the greater part of their lives in the open air; no chance that it was two travelers like Darwin and Wallace who first perceived the dependence of one species upon another and the competition between them.

From the little that I have been able to tell you of Darwin's life in Down you can gather what a rich, full life it was. You will now wish to hear something of the man himself and his character. Unfortunately I never saw him. An affection of the eyes which has troubled me for forty-five years, and has restricted my activities in many directions, prevented my traveling to England while Darwin till lived and was relatively vigorous. Therefore I can not sketch the impression made by his personality from experience. But we have a short autobiography which reveals his nature clearly, and in addition a most detailed and sympathetic picture of him by his son Francis.

He was tall, nearly 6 feet in height, and his most striking features, the high forehead, the large, prominent and bushy eyebrows, the blunt nose, and energetic mouth are well known. No one interested in Darwin's personality should fail to read both Francis Darwin's account of him[a] and his autobiography. Taken together they give a picture of the man which could not be more truthful and could hardly be more complete.

Add to this picture what we can gather from his scientific works, and especially from the accounts of his journey, and we find that he had a great and comprehensive mind, concerned in the main with general conceptions, yet possessing in a high degree the faculty of becoming sympathetically absorbed in detail. He took pleasure in small things as in large, and was able alike to study with the most painstaking minuteness the structural details of a flower or a crustacean, or to draw far-reaching conclusions from an enormous number of isolated facts. He possessed the fundamental qualities of a naturalist; great powers of observation and absolute accuracy; the most extreme caution in judgment is revealed in all his writings, and his presentment of his ideas is always simple and entirely free from arrogance or vanity, for a great natural modesty was one of the main features of his character. But his theories clearly show that he was not lacking in imagination, for they could never have been thought out without it. He was not a keen critic, grasping a thing quickly and illuminating it at once; he was, on the contrary, rather inclined to take too favorable a view of the work of others, and had a tendency, by no means very common, to acknowledge the achievements of strangers, and to take a positive delight in them.

[a] "Life and Letters of Charles Darwin, including an Autobiographical Chapter." Edited by his son, Francis Darwin. London, 1887.

His mind was of the penetrating order which worked persistently at any problem until he began to see light on it.

He was not concerned with practical aims; he was an idealist who desired knowledge for its own sake, and not for any utilitarian end; a naturalist who worked for pleasure in the work itself, and rejoiced in the advancement of science his work brought about.

He was not lacking in ambition, but it was ambition on a large scale, not to gain fame and position, but to create works which should seem to him worthy. Fame came unsought, and, as he tells us, it was a satisfaction to him to feel that he was held in esteem by those whom he himself esteemed.

He has sometimes been called an amateur, and in a certain sense this is true, in as far as he worked in several different scientific provinces, each of which requires a man's whole strength. But he had full command over these different provinces, at least as far as was necessary for the end he had in view. He was certainly not a restricted specialist. The zoologists accepted him as a zoologist, the botanists as a botanist, perhaps also the geologists as a geologist. But he was not an expert in any, or rather, it would be more correct to say, he was so wherever he himself had done productive work. For he was essentially self-taught, and had passed through no normal school of zoology or botany, but with his great energy and unflagging industry he had acquired a profound knowledge from books and from personal intercourse with specialists, and every piece of work he did added to this store of knowledge. He was perhaps the last not merely to survey, but to do productive work in every domain of biological science. Yet I will not assert this, for we have all been convinced in recent times through the evolution theory that it is not enough to be at home in a single science; it is necessary also to have at least a general acquaintance with the essentials of allied branches.

Darwin has sometimes been accused of being one-sided, of caring for nothing but his science. But this was not the case; it is less true of him than of many specialists in natural science. He had a wide knowledge of English literature, Milton and Shakespeare having been his favorite reading in his youth. In later life he had novels, historical works, and books of travel read aloud to him every day. He was fond of music, too, though, as we have said, he had no musical ear.

Darwin was a man not only of lofty, noble spirit, but of the tenderest feeling. Let anyone who doubts this read the touching pages in memory of his little daughter Annie, who died young; they form one of the most beautiful memorials ever dedicated by a father to his child. His son's picture of him, too, reveals the beautiful and intimate relations that prevailed between them, and the whole

quiet and joyous life of the Darwin family testifies to the cheerful and affectionate disposition of its head.

It remains to estimate the influence of Darwin's theories on his time and on the future. But this is a task for which a whole book would not be too much, and a task, moreover, which could be better accomplished on the two hundredth than on the one hundredth anniversary of his birth.

We can at least say, however, that the influence was a great and many-sided one, and that it will endure throughout all time. All who know the position of science before 1859 will be ready to admit this; the younger generation have grown up so thoroughly under the influence of Darwin's ideas that it must be difficult for them to realize the state of matters before his day.

Let us speak of biology first. But was there a biology then? Strictly speaking, there was not; there was a zoology, botany, and even anthropology. Each of these sciences consisted of a very large and well-arranged mass of facts, but with no intrinsic coherence among them. This was supplied by the theory of evolution. The different departments of science were not even then regarded as complete; it was well known that there were many gaps in our knowledge, but we were only seeking for missing details, whereas in reality it was the main thing that was lacking—the unifying idea which Goethe had sought for, and tried to supply in his theories of the plant prototype, and of the skull.

The science of embryology, or, as we now call it, ontogenesis, at that time consisted of a great number of observations, interesting enough, but without any recognized unity; it was not a harmonious structure, but a collection of finely-cut building stones. But what a change when the luminous idea of evolution was added! Life seemed to be infused into the stones, and almost spontaneously they formed a magic edifice. The ovum, now at last recognized as a cell, was seen to be a reminiscence of the descent of all higher animals from unicellular organisms; rudimentary organs, such as the rudimentary eyes of blind cave animals, were found to be signposts indicating the racial history of these animals, and pointing back to their sight-endowed ancestors. This evolutionary view illuminated the whole science, and not embryology alone, but also "comparative anatomy," the understanding of the structure of animals. It became plain why the New Zealand kiwi should have little rudimentary wings under its skin, although it does not fly. It is not in order that it may conform to an ideal of a bird, as was previously thought, but because its ancestors had possessed wings which were used in flight.

Physiology also gained much, especially the theory of reproduction, of heredity, of organs, of the cell, and especially of the cell

nucleus. I do not mean to say that all these were the direct result of the idea of evolution, but they have an indirect connection with it.

Anthropology gained quite a new interest after it was recognized that man, too, was a product of evolution. A vast number of problems presented themselves; it was necessary to investigate the gradual becoming not only of the body but of the mind, the evolution of the Psyche and all that flows from it. Before that time there had been a history of language, of law, of religion, of art, and so on, but it now became necessary to carry these further back—beyond Adam and Eve to the animal ancestors. Undoubtedly a study of the psychology of animals is one of the essential tasks of the future! I can here only give a few hints without elaborating them, but I must emphasize the fact that the idea of evolution, in the form in which Darwin presented it to us, has given an impulse to new life and further development in every department of human knowledge and thought; everywhere it acts as the yeast in cider—it sets up fermentation. This has already borne rich fruit, and we may hope for much more in the future.

Our greatest gain from the theory of evolution has, however, been the evidence it affords of the unity of nature, the knowledge that the organic world must be referred back to the same great everlasting laws which govern the inorganic world and determine its course. Even if formal proof of this be still wanting, the probability is now so strong that we can no longer doubt it.

It is not only the theory of evolution as a whole, but the active principle in it, the principle of selection, that is transforming and illuminating all our old conceptions. It is teaching us to understand the struggle, silent or clamant, among human races, their rivalry for the possession of the earth, and to understand, too, the composition of human society, the unconsicious division of labor among the members, and the formation of associations. The development of "classes" and their union in a State appears in a new light when looked at from this point of view. In this department a good deal has been already accomplished.

The study of human health must be particularly influenced by the theory of evolution, and a beginning has already been made in this department also.

But there is another and very important point in regard to which the theory of selection must be our guide. If we take a survey of the evolution of the world of life as we know it, we see that, on the whole, it has been an ascending evolution, beginning with the lowest organisms and advancing through higher and higher to the highest of all, man himself. It must be admitted that at certain stages in this evolutionary series we find retrograde steps (as, for instance,

parasites and sedentary animals), but on the whole the direction of evolution has been an ascending one.

I see no ground for assuming that this will be otherwise in the future. According to the principle of selection the best will survive in the future as in the past, and mankind will ascend. I do not believe we are likely to undergo any essential changes in a crude physical sense; we are not likely to grow wings, and even our mental powers may not be capable of much further improvement, but ethical improvement seems to me not only possible but probable, on the principle of selection. Mankind will never consist of wholly selfless saints, but the number of those who act in accordance with the ideals of a purer, higher humanity, in whom the care for others and for the whole will limit care for self, will, it is my belief, increase with time, and lead to higher religions, higher ethical conceptions, as it has already done within the period of human existence known to us. But here again I can only indicate without following out my ideas. I wished to express them, because the principle of selection has so often been applied in an inverted sense, as if the brutal and animal must ultimately gain the ascendency in man. The contrary seems to me to be true, for it is the mind, not the body, that is decisive in the selection of the human race.

Thus we see the principle of evolution intervening, transforming, re-creating in every department of human life, and thought, and endeavor. We owe this principle, which has been so fruitful in results, mainly to Charles Darwin, though he was not the only one nor the first to think it out. But it was he, with Wallace, who secured it its place in science and made it a common possession of mankind by working it out in all directions, and supporting it with another principle, that of selection, which explains the riddle of the automatic origin of what is suited to its purpose in nature. Thus he cleared away the obstacle which would otherwise have stood in the way of the acceptance of the theory of evolution.

By all this he has earned enduring fame in the annals of science. His own country has not been ungrateful to him. A colossal statue of him in marble decorates the British Museum; from the background of the entrance hall he looks down on the passers-by with the calmness of the sage. His mortal remains lie in Westminster Abbey beside those of Newton.

Fate, too, was kind to him. He could truly say that his life was a happy one, for it was filled with a great idea, and he was supported by the consciousness that Goethe expresses through his Faust: "Es kann die Spur von meinen Erdentagen nicht in Aeonen untergehen." This is true of Darwin, and we may think of him as one of the great immortals among men.

PRESENT PROBLEMS IN PLANT ECOLOGY:[a] PROBLEMS OF LOCAL DISTRIBUTION IN ARID REGIONS.[b]

By Prof. VOLNEY M. SPALDING,
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The physical conditions prevailing in arid regions are such as render it unsafe to admit without further investigation generalizations regarding their plant life which have been drawn from studies conducted elsewhere. This is sufficient justification of an attempt to analyze certain problems which confront the student of desert ecology in his efforts to apply knowledge or principles drawn from previous experience. These problems have the advantage of a certain clearness of definition, which corresponds in a way with the sharp features of the desert and its characteristic vegetation. Their solution may involve great difficulties, and some of them, with our present methods, may be incapable of solution, but they are, at all events, capable of clear statement.

In the attempt to present such a statement, which may or may not prove successful, I shall for the present limit the discussion to the desert country of the southwestern United States, for the sufficient reason that my own studies have been conducted in that region; and I shall omit all consideration of the higher elevations of the mountains, which, though in the desert, are not of it; so that whatever is said at this time will be understood to apply to the floor of the desert, that is, the great plateaus and valleys which from Texas to California lie between the mountain peaks and ranges, together with the long slopes and low hills which border them on every hand and form the natural approach to the mountains.

Proceeding in a manner that will be indirectly a record of personal experience, one of the first questions presented to a student of desert botany is this: What are the conditions that determine the successful occupation of a desert habitat by certain plants, but prevent its occupation by others?

[a] A series of papers presented before the Botanical Society of America, at the Baltimore meeting, by invitation of the council.

[b] Reprinted by permission from The American Naturalist, vol. 43, No. 512, August, 1909.

It will be necessary at the outset to understand what is meant by a desert habitat, since on this point the popular conception—and possibly that of some botanists—is not clear. There is as much difference between habitats in the desert as in any other region, possibly more, and their definiteness of location and relative sharpness of demarcation form one of the most striking and characteristic features of arid regions. The rivers of the valley trough, such as the Santa Cruz, the Gila and Salt rivers in Arizona, though inconstant, are none the less the main drainage channels between the adjacent watersheds. Along their banks water-loving willows, cotton woods, and arrow weed find a congenial home. The adjacent flood plain, with its water table within reach of their roots, is the natural habitat of the mesquite and some other semimesophytic species. Within its limits the areas known as salt spots are inhabited by various halophytes, especially by species of *Atriplex* and *Suæda*. Just beyond the flood plain is the long slope, a most characteristic feature of desert topography, which rises slowly to the foot of the mountains, often miles away, its soil and drainage conditions presenting a sharp contrast to those of the flood plain, and its vegetation being correspondingly different. The low outlying hills, in their turn, present quite as marked peculiarities of soil, and furthermore introduce differences of aspect which are correlated with marked differences of vegetation. In short, the habitats of such a desert region as that of southern Arizona, as far as edaphic relations are concerned, present conditions which vary all the way from distinctly hydrophytic to extreme xerophytic, and all these may be in close proximity.

For all these habitats the fact is to be emphasized that the general climatic conditions are the same, and it is important to note that not a few of the plants which grow where a sufficient or even abundant water supply is assured are nevertheless marked, as a rule, as plants of an arid region by their coriaceous, hairy or otherwise xerophilous leaf structure. The point to be specially noted here is that while plants of the arid or semiarid southwest grow in a great variety of habitats, some of which are by no means dry, all are subject to the severe conditions of a desert climate, especially intense insolation, low percentage of atmospheric moisture, and drying winds. The problem, therefore, of the occupation of any one of these habitats is successfully met only by those plants that are already adapted, or are capable of individual adjustment to the dry air and hot sun in which they must live; all others inevitably fail.

This will be made clear by reference to the introduction, or attempted introduction, of various cultivated plants, a subject which presents a most instructive history. The yards of Arizona cities constitute an experiment station in which year by year, at private instead of public expense, the availability of one species after another

for desert planting is being determined. From the great number of plants successfully cultivated there seems, at first sight, to be sufficient justification for the reiterated assertion that anything will grow here if you only give it water enough, but closer attention to the actual facts of the case makes it evident that this statement is true only in part, and that there are many plants that will grow only indifferently or not at all under the atmospheric conditions which prevail here, especially in the summer time. To give a few examples, geraniums, the universal easily raised plants of moister regions, are very uncertain, some varieties accommodating themselves fairly well to the desert air, while others fail altogether. Cannas and gladioli, which grow side by side in the east, part company here, the former making a good growth in Arizona gardens, the latter failing altogether. Those who have handled roses for a period of years have learned what varieties may be expected to do well in the dry air of the desert, and what ones may be counted out, and so on through a long list of plants which, by knowledge gained in the costly school of experience, are coming to be depended on, or are being rejected one after another, as they are found to be unsuited to the environment into which they have been brought. Thus, in a purely empirical way, it has been found that many plants successfully cultivated in regions of greater atmospheric humidity make an entirely normal growth in the desert, if their roots are well supplied with water, but that others, however well cared for in this respect, either fail completely, or come short of making a healthy growth, and that this is especially true in the summer months when desert conditions are most pronounced.

With the accumulation of such facts the more evident does it become that a very complicated problem is here presented. Why is it that one plant, properly watered, does well in the desert, while another, though treated in the same way, makes a poor growth or fails altogether? At first thought it would seem as though there must be a difference in the capacity of the root systems of the two plants for absorption, and that this may be a sufficient explanation of their different behavior; but it is evident on consideration, that with precisely the same capacity for root absorption, a plant in which transpiration is successfully regulated may thrive in an atmosphere in which one subject to excessive transpiration will perish. The most elaborate experiments and the most exact determinations of rate of absorption—assuming that such determinations are possible—would be very likely to throw no light on the problem. Comparisons of the transpiration rate of the plants in question appear more promising, but the same difficulty arises in an attempt to pursue the investigation along this line, for there is no reason to suppose that two plants of widely different rates of transpiration

can not successfully occupy the same habitat if their capacity for root absorption differs in the same ratio. But supposing that with infinite patience and with a reasonable approach to accuracy both sets of physiological data have been determined, we are still, quite possibly, entirely in the dark as to the real cause of the different behavior of the plants under investigation. It may be in their case that the whole matter of absorption, conduction, and transpiration is beside the mark, and that certain plants can not succeed in the desert because the intense insolation exerts directly a prejudicial influence to which they have not become inured. The intricate nature of the subject is apparent, and it is also evident that there is little encouragement for any one to take it up who has not had extended training and thorough equipment for physiological research. Yet with all its difficulties the problem is an attractive one, and the abundance of material to be had in any desert city, together with the great mass of data that has accumulated in the hands of horticulturists and at the experiment stations, offers the best of opportunities for extended and fruitful work.

If, as we have seen, the different deportment in the desert of plants growing, or having the opportunity to grow, side by side in well-watered ground, is an exceedingly complicated matter, by how much are the difficulties increased when we pass from a habitat of uniform and highly favorable conditions to the various and often extremely trying conditions which prevail in different neighboring habitats, such as the dry slopes underlaid by caliche, the salt spots, and others. If the case of a plant growing in well-watered soil may become desperate because of the scorching winds or the intense insolation to which its top is exposed, what hope is there for one that essays to grow where both dry air and dry soil present the supreme test of endurance? As a matter of fact only relatively few species meet the test successfully, yet there are some that do, and they present some of the most instructive data yet derived from the study of desert plants.

But little reflection is needed to arrive at the conclusion that the classical question regarding the relative importance of physical constitution and chemical composition of the substratum to plant growth—though like the poor it promises to be always with us—does not and can not reach the heart of the problem. For every plant which successfully holds its place in a true desert habitat there is a delicate balancing of the regulation of transpiration, the power of absorption, the capacity of the conducting system, the presence or absence of storage tissues, and, we may well believe, the possession of protoplasmic properties which contribute to its powers of endurance. This being the case, it would seem that in future, investigations of the habitat relations, of desert species especially, must be directed mainly

to the plant itself. The advantage of a thorough knowledge of soils is too obvious to call for comment, but it must be remembered that we are as yet only at the threshold of a greater and more promising work; namely, the investigation of the physiological requirements and capabilities of plants that can grow in a true desert habitat as compared with those that can not. In such comparative study lies, as it seems, the hope of real progress. It is impracticable for any investigator at the present time to mark out a straight path for others to pursue, and it would very properly be regarded as an impertinence were he to attempt this; yet there are certain obvious suggestions that may be offered.

In the first place, important results have already followed the simplest experiments and observations when these have been conducted with exactness and with a definite end in view. To refer to a specific case, Professor Thornber, of the University of Arizona, undertook a few years ago to compare the habits of certain desert plants as regards germination. It was found that while the seeds of some species germinated at a given temperature, others could not be made to do so until they had been subjected to temperatures approaching the freezing point. These latter were seeds of winter annuals, and by this method a fundamental physiological difference between them and the summer annuals was established. Doubtless an indefinite amount of instructive and necessary work remains to be done in this direction, but the key to the situation was found in carrying out the simple experiments described. Again, partly as a relief from severer work, Doctor Cannon undertook, in the midst of his investigations at the Desert Laboratory, to map the distribution in the soil of the roots of some of the plants growing in the vicinity. Hardly was the work well in hand, and the root topography of less than half a dozen species mapped, when it was found that the clue to certain facts of distribution, blindly observed up to that time, had been discovered. I have spoken of this in more detail in another connection.

Obviously it is indispensable that determination of physiological data and of those belonging to the physical environment should proceed step by step together; and nowhere is this more strikingly true than in the investigation of soil relations. To refer to one more case of recent experience, within the past year Doctor Livingston has determined the percentage of soil moisture present in soils obtained from each of the topographic areas of the Desert Laboratory domain and the adjacent flood plain of the Santa Cruz River. His studies were conducted independently, though naturally not in ignorance of ecological studies which were being carried out at the same time on the same ground. It now appears that a well-nigh perfect correspondence exists between the two sets of facts obtained by independent workers, so perfect, in truth, that a causal relation offers

the only satisfactory explanation. The accumulation of physical data, however, has proceeded so far and so satisfactorily that the successful conduct of this line of investigation may be regarded as assured, but for the plant the relations are more complicated, and their investigation correspondingly more difficult. It seems likely that in the study of ecological relations from the side of the plant we shall employ more and more the methods and conceptions of physics and mathematics, but the fact is too patent to call for argument that neither now nor hereafter can these methods and conceptions be employed exclusively. In fact there has never been greater need than at the present time for exact observation coupled with correct judgment, and these can never be replaced or superseded so long as this department of botanical investigation continues to be cultivated. This will receive additional emphasis in the following division of the present paper.

The relations of desert plants to each other present a chapter the importance of which has been unduly minimized until the general impression, even among botanists, seems to be that desert plants are to be studied only in relation to their physical environment; they are thought to grow so far apart, in "open" associations, that they are quite uninfluenced by each other's presence. Like other erroneous or incomplete conceptions, this may be true in part, especially where the most extreme desert conditions prevail, as for example in parts of the Colorado or Mojave deserts, but in the great semiarid region of the Southwest, taken as a whole, it is most misleading. The Desert Laboratory of the Carnegie Institution was located where it stands on account of the great natural advantages which the region and locality offer for the study of desert plants in place, yet I venture the assertion that over at least nine-tenths of the area of the laboratory domain the establishment of a plant in the place which it occupies is conditioned quite as certainly by the influence of other plants as by that of the physical environment. It hardly needs more than simple observation to convince one that severe competition is the rule, though naturally its severity is heightened and the result hastened by the prevailing adverse physical conditions.

Beginning with some of the most obvious cases, the winter annuals of southern Arizona present an instance of as unmistakable competition of individuals with individuals and species with species as can be found in the eastern forest region of the United States. As the warmth of spring follows the winter rains the ground is thickly carpeted with *Amsinckia*, *Pectocarya*, *Bowlesia*, and various other herbaceous plants, which stand thick together and present to the eye the familiar crowding which is seen in a field of grain too thickly sown. Certain individuals dwindle and finally die, robbed of water, food, and light by their stronger competitors. It might be interesting to repeat

the experiment in the laboratory and to tabulate the results statistically, but it could hardly add to the conclusiveness of the demonstration. The same is true of the manifest competition of species with species, as seen for example in the occupation of relatively extended areas by some of the perennial grasses which, but for their presence, would certainly be covered, as the adjacent areas are, by a thick growth of other plants. Here the actual advance of the grasses from year to year may be observed, and such observations for the sake of more definite statement are now in progress on the Desert Laboratory domain. Convincing evidence of competition is thrust upon one's attention in passing from the desert to areas beyond its borders, and if the transition is abrupt, as for example on the western edge of the Salton Basin, where the desert abuts almost upon a mountain wall, the case is all the more striking. In this instance a straight course of less than 5 miles brings one from the actual desert, with its characteristic sparse growth of salt bushes, creosote bush, galleta grass, and the like, to the chaparral of the mountain side. Along the way the desert species fall out one by one, and are replaced by elements of the chaparral. As far as can be judged by their habits elsewhere and from their known range in altitude, there is absolutely no reason for this, except their inability to compete with plants of the chaparral, which, however incapable of normal development in the desert, hold their own ground where the conditions are less strenuous so tenaciously and completely that the desert species make no headway against them.

This, of course, is an interpretation merely, but with such an accumulation of evidence we are now in a position to proceed with the problem along definite lines with the expectation of definite results. Sowing together seeds of desert and other plants, the transference of individuals to denuded areas beyond their natural limits, and multiplied comparative observations of the deportment of different species on the "edge of the desert" are simple and obvious methods of procedure at the outset. Some of this work has already been done, enough to convince those engaged in it that in general the problem of the successful occupation of a desert habitat involves the recognition of actual competition on the part of its would-be occupants, a competition severe enough in some quarters to set up a barrier beyond which, in the midst of otherwise entirely favorable environmental conditions, they can not pass.

In their relations to each other, desert plants frequently exhibit not merely competition but accommodation. This has been clearly shown by recent studies of the root systems of certain cacti and other plants by Dr. W. A. Cannon. To take a striking example, superficial observation of the association of the sahuaro (*Cereus giganteus*) with one of the palo verdes (*Parkinsonia microphylla*) and some

other shrubby perennials gives no satisfactory clue to the reason of this relation, and the common explanation that they are plants of similar biological requirements, and therefore grow together, is altogether inadequate and in part misleading. The careful study, however, that has been given to the root systems of these plants brings out the important fact that they grow close together by virtue of simple accommodation, which enables them to utilize to the utmost the scanty rainfall. The roots of the sahuaro are spread just beneath the surface of the ground, where they take up and promptly pass on to the storage cells of the trunk the water brought to them by every light rain. The roots of the palo verde, on the other hand, extend much more deeply into the ground, and are in a position to utilize the water which soaks down to lower levels after heavier rains. Thus the sahuaro profits by all rains, light and heavy alike, while its constant companion, the palo verde, is free from all competition on its part for the water which penetrates to lower levels. Much the same thing is seen on the flood plain of the Santa Cruz and other rivers, where the mesquite, with its deep roots reaching to the water table, is associated with *Bigelowia* and other plants, the roots of which extend to relatively shallow depths. In short, it appears that just as in a tropical forest the vegetation occupies successive "stories," so here the root systems of various plants habitually reach to different depths, and thus enable at least some species that would otherwise compete with each other to live in close and advantageous association.

From what has been said it is evident that in the successful occupation of a desert habitat the mutual relations of the associated species play a highly important part. It is not quite easy at this stage of progress to point out the exact steps by which these complicated relations are to be determined and estimated; meantime the homely and effectual method of patiently gathering the data that are obtainable by careful observation is open, and as far as it has been pursued has yielded valuable results.

The broad general problem of the local distribution of desert plants is necessarily approached along the several lines that have been indicated. As we have seen, atmospheric conditions, whether of intense insolation or extreme dryness, that obtain in arid regions are limiting factors which many plants successfully meet, but to which many others succumb. There has been great need of more practical methods of determining and estimating the influence of atmospheric factors, and it is a matter of congratulation that the methods devised by one of the participants in this discussion, already widely in use in different parts of the United States, promise to meet this need to a degree that could not be hoped for at an earlier period. But it is never to be forgotten that under the same atmospheric conditions, and with equal chances in other respects, the deportment of two plants side

by side, their capacity for adjustment, let us say, is so different that the essential problem lies first of all in the physiological capabilities of the plant itself.

More strikingly true, if possible, is this seen to be the case when the relation of desert plants to the soil is considered. It is well that so much soil work has been done; that we have soil maps; that determinations of water capacity and other physical as well as chemical characteristics have been ascertained in so many habitats, and that we have a growing literature embodying observations of the relations of plants to underlying rocks; in short, that the substratum has been the object of so long and so thorough study. There is no danger that we shall have too much of this, but there may be danger that we may sometimes forget to place the emphasis where it belongs, namely, on the fact that every species and every variety of plant is a law to itself in its relations to rock or soil. It is true enough that the different percentages of alkali salts at different distances from the center of a salt spot stand apparently in causal relation to the growth of different plants in corresponding concentric zones, but it is equally true that this zonal arrangement is also the visible expression of the capacity of these different plants to cope with the conditions there existing, and of this capacity, if it is to be expressed, as some day it must, in physical measurements, how inadequate is our knowledge. How greatly we need to really know the physiological constants, not of one but of many desert plants.

It is in the same line of thought and with the same purpose that I have referred to the inadequate conception according to which the relations of desert plants to each other have been so persistently overlooked, or, at least, underestimated. It may now be set down as an established fact that over a large part of the arid or semiarid territory of the southwest, competition on the one hand and accommodation on the other have much to do with the association of plant species and the density of the plant cover. Far more, it would seem, than has usually been thought, the character of various associations in this region is determined not simply by the physical, but also by the living environment. More than ever, too, it is plain that the path of progress lies in the direction of applying to the plant itself, in its natural surroundings, the experimental methods of the physical laboratory. Notable and fruitful beginnings have been made in this direction, but one who has attempted quantitative work with the sahuaro or ocotillo in the open need not be told that it involves difficulties not presented by seedlings of *Vicia faba* grown in pots, and that progress will necessarily be slow.

Thus far adjustment and adaptation have not directly entered into the discussion, although a moment's thought shows that all the paths along which we have come converge right here. If one variety of

geranium flourishes in the desert air, while another by its side dwindles and dies, we can only say at present that the latter is not "adapted," or is apparently incapable of "adjustment" to the atmospheric conditions in which it has been placed. We find that plants growing in the wash near the Desert Laboratory do not, as a rule, succeed in gaining a foothold on the long slope leading to the hill near by; they are not adapted to the soil conditions there existing; but the creosote bush, which makes its home on these slopes, grows—thanks to its capacity of adjustment, even more luxuriantly in the wash than on its own domain. Similarly, certain plants of the salt spots grow better beyond than within their limits; they have become adapted to large percentages of alkali salts, but their capacity of adjustment is such that they grow just as well or better along an irrigating ditch carrying fresh water. Various other plants in the immediate neighborhood have not become adapted to the conditions prevailing in the salt spots, nor do they appear capable of adjustment to them, and accordingly are not found growing in such places.

We need not multiply citations of these familiar cases. Adaptation and adjustment have long been words to conjure with, out of the desert as well as in it, but we have made so little real scientific progress in the definition and determination of the things for which they stand that some of our foremost students of ecology seem ready to abandon the effort, while others apologize when they use the terms, as if they were myths and had better be left alone. But nothing is gained, and much may be lost, by this method of procedure. We are face to face with a great body of phenomena of the most striking character, in connection with which these words are fittingly employed. We can not ignore the existence of the facts, and as scientific men we can not let them alone, while they insistently rise at every turn in our pathway and demand investigation. True it is that they bring in their train whatever is fundamental in biological inquiry—heredity, the direct influence of the environment, and differences in the properties of protoplasm in different plants. It is not customary, however, in laboratories worthy of the name, to shun investigations that approach to the deep mysteries of life. There is every reason why students of ecological problems should seek, not shun, this difficult but hopeful line of study. I say hopeful advisedly, for within the past three years there have come under my observation various definite cases of adjustment in plants, some of which have been accurately measured, correlated with external factors, and expressed by curves. Though essentially more difficult, there is no reason, as far as now appears, why the different degrees of adaptation of two species or varieties to a given external factor may not be similarly determined and graphically represented, as the expression of a definite difference of physiological activity, as shaped by heredity, in

relation to that particular factor. Very little, as far as I am aware, has yet been accomplished in this direction, but it is a way that is wide open, and one that should attract those real investigators who, knowing difficulties, do not shrink from them.

We have considered in a way far from exhaustive some of the problems which specially interest the student of desert ecology, but which in their broader relations are not confined within geographical limits. In the efforts now being directed toward their solution the trend, as it appears to the writer, is not so much away from any previous form of thought or method as toward the wise and persistent use of every means that promises results. Progress is certainly being made in the direction of greater exactness; we are learning something of the possibilities of well-directed cooperation; and in these and other ways in which "science returns to the obvious," to use the apt words of Francis Darwin, is an encouraging promise for the future.

THE INSTINCT OF SELF-CONCEALMENT AND THE CHOICE OF COLORS IN THE CRUSTACEA.

By Romuald Minkiewicz.

(Translated by permission from Revue générale des Sciences pures et appliquées, Paris, 20th year, No. 3, February 15, 1909.)

In the following pages I shall give a brief though sufficiently detailed account of the results of my investigations carried on since 1903, which have already afforded material for a long series of publications.[a] This series, beginning with a short article that I published (in Polish) in 1905, in a weekly scientific review at Warsaw (Przyroda=Nature), is yet, however, far from being finished.

I. THE SELF-DISGUISING ANIMALS.

Although I am the first seriously to undertake this study, the strange phenomenon of self-concealment has in a general way long been known. I am not considering here animals recently discovered

[a] R. Minkiewicz: (1) Krab-ogrodnik. Rev. polonaise, *Przyroda*, vol. 2, No. 10, Varsovie (mars 1905).

(2) Sur le chromotropisme et son inversion artificielle. Comptes Rendus Ac. Sc., Paris, t. 143, No. 21 (nov. 1906).

(3) Le rôle des phénomènes chromotropiques dans l'étude des problèmes biologiques et psychophysiologiques. C. R., t. 143, No. 23 (déc. 1906).

(4) Chropotropism and phototropism. (Translation of the two preceding notes.) Journ. of Neurology and Comparative Physiology, vol. 17, No. 1 (1907).

(5) Analyse expérimentale de l'instinct de déguisement chez les Brachyures oxyrhynques. Arch. de Zool. expériment. et génér., 1907 (4), vol. 7, No. 2.

(6) Próba analizy instynktu metoda objektywna: porównawczal dóswiadczaina, Revue polonaise de Philosophie, vol. 10, fasc. 3–4, et vol. 11, fasc. 1–2, Varsovie (1907–8).

(7) L'étendue des changements possibles de coleur de l'*Hippolyte varians* Leach. C. R., t. 147, No. 20 (nov. 1908).

(8) Etude expérimentale du synchromatisme variable de l'*Hippolyte varians* Leach. Bull. internat. de l'Académie Polonaise de Cracovie (nov. 1908).

(9) Sur le chlorotropisme normal des Pagures. C. R., t. 147 (nov. 1908).

(10) L'apparition rythmique et les stades de passage de l'inversion expérimentale du chlorotropisme des Pagures. C. R., t. 147 (déc. 1908).

or unfamiliar; on the contrary, many people, including the bathers on the Breton coast, are acquainted with the creatures that I am going to discuss, which are commonly called by the name of sea-spiders.

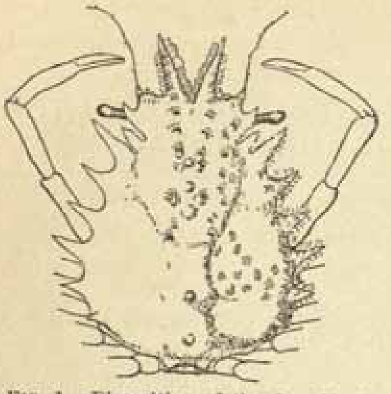

FIG. 1.—Disposition of the dorsal hooks in *Maja verrucosa* M. Edw. (Only the right side is completely drawn.)

These self-disguising Crustacea, although they belong exclusively to the rather restricted group of *Brachyura Oxyrhyncha*, are very common, not only along all the European coasts (of the Mediterranean, the English Channel and the

FIG. 2.—Second left foot, outer side. (*Hyas araneus* L.)

Atlantic as far as Spitzbergen and Greenland), but also along the coasts of the Far East and southern Asia (Japan, Celebes, Java, Bengal, India, etc.), in the Pacific along the coasts of Tasmania, Australia, and New Zealand, and along the coasts of of South America (Peru, Chile, Cuba, Brazil, etc.).

FIG. 3.—Group of hooks on a dorsal tubercle. (*Hyas araneus* L.)

Of this group there are more than 70 species belonging to 38 genera and 4 families.[a]

These Crustacea, whose strange habits impressed me forcibly during the very interesting dredging that we did in the vicinity of the Balearic Islands on board the *Roland*, of the Arago Laboratory, during the month of August, 1903, form a quite distinct group, possessing extraordinary morphological adaptations which are not found elsewhere. A Swedish naturalist, Carl Aurivillius, has made an elaborate study of these adaptations, and it is from his work[b] that I have taken the few drawings here reproduced (figs. 1–7).

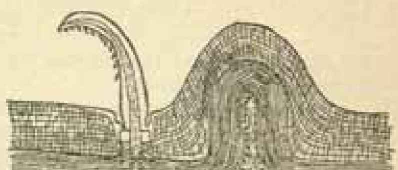

FIG. 4.—Vertical section made through a dorsal hook and the adjacent parts of the carapace. Beds of chitin, chitogenous epithelium and conjunction tissue. (*Hyas coarctatus* Leach.)

[a] The list published by C. Aurivillius gives only 66 species, but it is far from complete, not containing, for example, a form so common as *Maja squinado* Latreille.

[b] C. Aurivillius: Die Maskirung der Oxyrrhynchen Dekapoden durch besondere Anpassungen ihres Körperbaues vermittelt. Eine biologisch-morphologische Studie. Svenska Vet.-Akad. Handl., bd. 23, Stockholm (1889).

Of this entire group I personally know in life 14 species belonging to the genera *Stenorynchus*, *Inachus*, *Acanthonyx*, *Maja*, *Pisa*, and *Lambrus*. But although I have made observations on several different species, I shall speak in this article of only two, both belonging to the genus *Maja* Lamarck (*M. verrucosa* Milne-Edwards and *M. squinado* Latreille), species very closely allied and with identical habits.

II. THE SELF-CONCEALMENT OF THE CRABS.

With reference to *Hyas araneus* Linnæus, a species of the family Majidæ, the process of concealment has been very accurately described by Carl Aurivillius. It is almost identical with that of the species of *Maja*, which is described below:

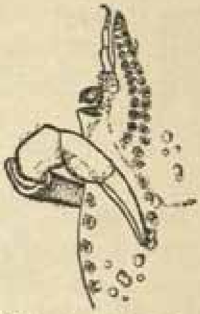

FIG. 5.—Left claw recurved on the back of the animal and scraping the hooks of the last group of the upper left line. (*Hyas araneus* L.)

Having found an alga (of any kind, red, brown, or green, depending upon circumstances), the crab seizes it with its long, slender claws, puts it first into its mouth, and, while holding it by one end with its maxillipeds, begins to tear it to pieces with its two claws, one drawing it toward its carapace, the other pushing it away.

When a piece, the size and form of which may vary indefinitely, has once been cut off, the crab pushes it with one of its claws between its maxillipeds and whirls it around several times, acting as if it were its prey—a mussel or a piece of fish.

After having rumpled it, it takes it again with one of its claws (indifferently with the left or the right), then extends the claw forward as far as possible, and, after making a rotary motion, bends it around over its back[a] and proceeds to affix the alba upon a group of dorsal hooks, rostral, branchial, etc., moving the claw slightly back and forth until the alga hooks on. Sometimes it attaches it on the outer surface of the ambulatory feet, which are similarly provided with hooks, by flexing the foot and bending it under the ventral face of the carapace.

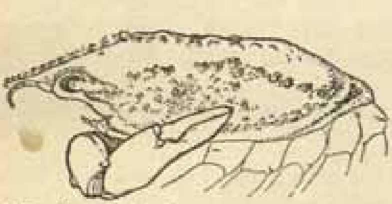

FIG. 6.—Right claw curved under the ventral surface of the animal toward the branchial hooks of the left side. (*H. araneus* L.)

I have more than once shown this operation to my fellow-laborers in the laboratories of Villefranche-sur-Mer and of Roscoff.

[a] This movement is seen only in the crabs under consideration.

The proceedings are the same if the crabs are furnished with sponges, hydroids, or compound ascidians instead of algæ. If they do not find living material they content themselves with débris, with pieces of the carapace of dead Crustacea, with shells—in fact, with anything that they may find, paper, rags, threads, etc.

The species which we dredged on board the *Roland* having come from different bottoms and different depths, varied correspondingly in their method of disguise, especially in regard to color; and it is this very fact which suggested to me the idea of undertaking some investigations in regard to the question of the relation between the color of the covering and that of the environment.

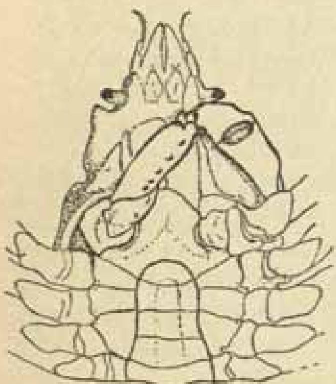

Fig. 7.—The same movement seen from the ventral side. (*H. coarctatus* Leach.)

The material suitable for these experiments I found indicated in this passage by M. Hermann Fol:[a]

> I tried once to take away from it (*Maja*) all the weeds it might have taken for cuttings, and to give it instead bits of hay and of white paper. It conscientiously stuck on its back these objects, which could only serve to make it still more conspicuous than if it had put nothing there at all.

I decided, therefore, to use colored paper, and employed a fine paper called papier de soie.

The crabs behaved in regard to this material just as if it had been an *Ulva* (*U. lactura* Linnæus).

III. EXPERIMENTS MADE IN AN ENVIRONMENT OF VARIABLE COLOR.

§ 1. The Covering following the Environment.

The best preparation for experiments, of which I have made hundreds, is the following:

In an aquarium constructed entirely of glass, the bottom and the sides to a certain height are covered with colored paper pasted to cardboard, so that too much light may not pass through, as the crabs have a strongly marked negative phototropism; they are photophobes, in the psychological language of Vitus Graber and others; that is to say, they avoid the direct light, as well as fire screens and light places. There are then placed in the aquarium a few thoroughly cleaned crabs, not more than two or three, and some pieces of two kinds of papier de soie—one the same color as the environment and the other any different color, no matter what. The shape,

[a] H. Fol: L'instinct et l'intelligence. Rev. Scient., 3e série, No. 7 (1886).

the size of the pieces of paper, and their quantity must be absolutely identical for the two colors, so that all the conditions will be exactly the same and no secondary influence may vitiate the result.

For the same reason, the pieces should not be so large or so numerous as to conceal the bottom of the aquarium.

These preparations made, the crabs are left in perfect quiet, an absolutely necessary precaution.

After a little while (the lapse of time, however, being very variable), sometimes at the end of a quarter of an hour, the crabs will be found covered with little bits of paper; if everything has been normal, the physiological state of the crabs, the temperature of the water, etc., they will have chosen the pieces presenting the same color as the surroundings. If the walls are white, they will be covered with white only; they will take neither green, nor yellow, nor black; if the walls are green, they will be clothed only in green.

As a control experiment, the crabs are put into two aquaria, differently colored and placed side by side, or else the color of the aquarium is changed, leaving in it the same crabs and placing in it the same bits of paper. The results are then very striking, the color of the costume always corresponding exactly with that of the environment. There is perfect instinct in all its admirable teleology!

Thus it is shown that these are Arthropods which distinguish colors and, still more important, distinguish all colors.[a]

It can not be questioned, since I have established the objective proof, furnished by the covering, that corpus delicti found each time on their backs.

Thus the very long discussions in regard to the choice of colors among the Arthropods may be closed.

I am certain that similar proofs could be established regarding other animals. I can already point out two of them: The movable dwelling of the Pagurids and the burden of the Dromiids.

My experiments on these animals having scarcely begun, I can at present only assert the possibility of solving the question, the Pagurids living very well in tubes of colored glass, and the Dromiids taking voluntarily on their backs pieces of colored material.

It may be possible to increase the number of these cases. The question is worthy of the attention of biologists.

Returning to our *Maja*, it is to be remarked that the process is not so simple as one might think at first sight. Positive results are not easy to obtain. But this I dare affirm after all that I have seen in

[a] It has been impossible for me to determine absolutely whether they can distinguish yellow from green, in spite of the often repeated experiments but that is the case with the Pagurids, the *Lineus*, and other animals, which distinguish them most clearly, better than we do.

the course of two years of research, that if the results are negative or undecided, it is because the animals are disturbed by secondary causes, which it is necessary to find and to eliminate if possible.

There is one inconvenience about the material employed, certain papers, like red and blue, being quickly and almost completely changed in color by sea water. In these cases I have used successfully some coarse paper placed in the water several days in advance in order to soften it and to make it sink.

§ 2. The Habitat according to the Covering.

The crabs are put into two preparatory aquaria of different colors, each aquarium containing material for concealment of the same color. Another aquarium is divided in halves, each half corresponding in color to one of the preparatory aquaria, and the crabs are transferred to it after they have clothed themselves in the preparatory aquaria.

The crabs are then invariably seen to make their way toward the half of the aquarium corresponding in color to their covering, remaining there a long time. Thus, for example, in the aquarium red-green, the red crabs go toward the red end, the green crabs toward the green one.

The most surprising experiment was one that I made in an aquarium divided into three equal parts, the middle white, the other two black. The white crabs reached the central part (white) and stayed there during the time of the experiment (several hours). The control experiment in the aquarium white-black-white gave me the same result for the black crabs.

These last results are all the more striking, as it is a well-known fact that crabs rest normally in crevices, having, as is said nowadays, a thigmotropism (Jennings=stereotropism of Loeb), that is to say, taking a regular position (+) in contact with solid bodies.

The experiments I have just described in paragraph 2 are perhaps more difficult to perform than those described in the preceding paragraph, because the crabs, upon being transferred from one aquarium to the other, are usually much excited and consequently in an abnormal physiological state. This must be taken into consideration if one has not attained definite results.

What marvelous instinct, is it not, of active variable mimicry, if we would employ the Darwinian expressions in use, although to my mind too anthropomorphic! Or, indeed, if we go a little further in the psychological and determinate path, it would be rather conscious choice, perhaps even deliberate, carried out with premeditation, etc. For myself, I prefer the new expression, instinctive synchromatism, containing nothing but the statement of the facts, with no explanation, mechanical, selective, or psychological. I prefer this definition

because all the striking finality of the instinct in question is only apparent, as we shall see immediately.

§ 3. Observations Apparently Contradictory.

There are plenty of these facts, and they are not the negative or indistinct results mentioned above; on the contrary, they are most clear and absolutely positive. I will select from them these three:

The first, which I have already quoted from the observations of H. Fol, is that the crabs place on their backs objects which make them still more visible than they were before.

Secondly, in spite of H. Fol's observation that "when the vegetable covering has increased to the point of becoming cumbersome it tears it bit by bit with one of its pairs of feet (always with its claws! R. M.), cleans itself thoroughly, and then proceeds to stick on its carapace"—in spite of that—I say—the crabs, covered with one color, when transferred to an aquarium of another color, even the most discordant, from what I have been able to observe, never remove their old costume. They hang new papers beside the old ones in sufficient quantity to fill the unoccupied space.

Lastly and most important: In the black aquarium the crabs never take black paper if they find any other color. They cover themselves with green, red, or white, making a bright patch on the black floor of the aquarium, instead of concealing themselves.

How can these strange errors of so perfect an instinct of so-called mimetism be accounted for? Can facts recurring constantly under definite conditions be considered, as is usually done, as errors of instinct?

It will be said, perhaps, that we have here a case of terrification, of warning colors, to use Wallace's term, or aposemathic colors according to Poulton. But is it possible that under the conditions of experiment the self-disguising animals transform themselves in a moment into terrifying animals?

Is it not more logical to seek some other explanation? Is it not possible to penetrate by careful analysis the ultimate significance of these actions, and to find a scientific explanation by which these will be shown neither as exceptional or contradictory occurrences, nor as normal teleology of instinct, but as a resultant of the physiological determinism of instinctive actions? This is what I shall try to bring out in what follows.

IV. BLINDED CRABS.

I found it impossible successfully to blind the crabs by covering their corneæ with asphaltum or any other black substance, as the claws of *Maja* are too mobile and quick; I therefore cut the ocular peduncles.

The animals thus operated upon become greatly excited, running incessantly here and there, and fighting with all the other crabs they meet. But they disguise themselves at once, and in quite a normal manner without, however, any reference to the color of the surroundings.

The fact of the persistence of normal concealment in blinded animals is of very great importance, because it proves that the primordial cause of that instinct is not in the photoperceptions. It is rather the tangoperceptions, or the tactile receptions of the claws, and of the flexible dorsal hooks, which give rise to the whole series of instinctive actions previously described. If that is true, then in order to accomplish these operations the animals have no need of the action of their cerebral ganglia, all the movements of the buccal and thoracic extremities having their centers in the central gangiionic mass.

V. THE INSTINCT OF MAJA AFTER THE COMPLETE SEVERANCE OF THE BRAIN.

It is impossible for me to give here either a description of the method of operating or detailed observations on the animals operated upon. I shall simply point out that I made use exclusively of the sharp hook employed for the first time by Ward, and that I always performed the operations on the ventral side by Bethe's method slightly modified.

If the operation is well done [a] the animals, after the severing above the œsophagus of the two longitudinal connectives, the only communication between the cerebral ganglia and the subœsophageal ganglionic mass, live long enough (I have kept them as long as five weeks) for one to study them sufficiently.

When the shock of the operation has disappeared, all the most complete reflexes remain intact, as has been known for the last ten years from the excellent work of Bethe: The animal can walk, chooses its nourishment, eats well, defends itself, etc.

But what interests us especially is, that it begins before long to clean itself, scratching the hooks with its claws, especially those of the ambulatory feet and the posterior extremity of the thorax, but also, though very rarely because of the weakness of the muscles, those of the superior surface of the thorax. If the crab happens to touch with its claws a piece of paper or alga, it is often seen to disguise itself, executing the whole series of movements without omitting any, and in the same order as when in the normal condition.

[a] This is verified in studying the simple reflexes, especially those of the antennæ and the eyes. After the observations are finished an autopsy is performed.

I have been able to show this more than once at the laboratory of Roscoff. On the other hand, the crab often takes bits of paper with its claws and throws them far away, as it rejects the nourishment that it can also hook anywhere on its carapace.

There is nothing strange in this variability of the reactions, when analogous facts, sometimes much more striking among animals not operated upon, are borne in mind. The explanation is found in the internal perturbations of the physiological state, which are completely unknown, but of which the modified reactions of the animals give incontestable proof.

The essential thing in these experiments is that the instinctive actions of concealment take place after the removal of the brain.

What conclusions can be drawn in regard to the psychology of instinct? I know of only two: Either it must be frankly admitted that we can know nothing definite, and, consequently, must renounce in scientific studies of instinct all psychological tendency, or else it must be declared as frankly that the animal psychism, at least the inferior, instinctive, and unconscious psychism, as it is customary to call it, is not necessarily connected with the brain; that it is, instead, diffused in the entire ganglionic nervous system without the necessity of its anatomical functional integrity.

I might be criticized[a] on the ground that, in cutting the connectives, I did not eliminate other possible means of communication, as by the peripheral nervous network (cf. of the tegumentary nerve). But the experiments made afterwards at Villefranche-sur-Mer (1907) on completely decapitated *Phronimas* as well as the numerous analogous observations on completely decapitated insects and myriapods, especially those of Wagner,[b] on *Blatta*, *Nepa cinerea*, *Geophilus longicornis*, etc., show in an indisputable manner the slight foundation for this supposition.

Thus, the experimental method by operation enables us to establish the physiological determinism of the instinct of self-concealment, which is nothing else than a series of reflex actions of the anterior thoracic extremities, induced by the tangoperceptions of the claws, directed by the tango- and chemoperceptions of the buccal pieces and helped on by the tangoperceptions of the flexible dorsal hooks.

It is not difficult to demonstrate directly the sensibility, or perhaps the tactile receptibility, of the hooks. It would be most interesting to study their innervation in more detail.

The determination here indicated is not yet complete, as it concerns only instinct artificially simplified in animals modified by the

[a] As, by M. Yves Delage in the discussion which took place after my first lecture at Roscoff (September 11, 1906).

[b] W. Wagner: Les problèmes de la Zoopsychologie (St. Petersburg, in Russian, 1896).

removal of the eyes (or of the ocular nerve cords), and thus deprived of all the perfection and the charm given by the photoreactions. It would perhaps be sufficient to conceal the crabs under the normal conditions of their life at the bottom of the sea, among algæ, sponges, etc.

It is, however, much more complicated, and the most difficult part remains for us to analyze.

The problem of the choice of colors, of the existence of which we have given incontestable proof, cannot be solved at once. It was impossible to enter upon it before the discovery of chromotropism as a phenomenon *sui generis*, independent of common phototropism—a discovery made by myself at Roscoff in 1906.

VI. ANIMAL CHROMOTROPISM.

I have given this name to the kinetic reaction of animals in relation to the action of colored rays (or screens), this reaction being either positive or negative, as in all other tropisms.

It must be pointed out that I do not propose any theory of chromotropism, nor of tropisms in general, the physiological nature of the phenomena being at present too obscure. I understand the fact, to which I apply the word tropism, as including only the objective statement, with no explanation, which would be premature in the present state of knowledge.

The freshly hatched larvæ of *Maja squinado* (Zoææ) present, as is well known, a very marked positive phototropism and heliotropism. I have been able to prove that they are at the same time very sensitive to the chromatic rays, that they are constantly directed toward the rays with the shortest wave, that is to say, toward the violet, and in its absence, toward the blue, etc.

They distinguish also all the visible rays. The reaction is almost instantaneous: All the Zoææ swarm toward the most refrangible rays as soon as they come under their influence.

The phenomenon takes place not only in the horizontal glass tubes, but also in vertical tubes, whatever may be the distance from the most intense region to the surface of the water.

The Nemertean, *Lineus ruber*, behaves in a very different manner.

First and foremost, it is strongly negative with respect to diffused light. If the individuals are put in small square crystallizing pans, and colored light is made to fall upon them from only one side, it is found that the animals turn immediately and invariably toward certain rays (red, yellow: positive chromotropism), while they are repelled by others (blue, green: negative chromotropism), all the other conditions being identical in the crystallizing pans, which are placed side by side.

Now, the animal is decidedly positively erythrotropic (+) and at the same time negatively janthinotropic (—). The result is, it seems to me, sufficiently conclusive.

But I have ascertained facts much more suggestive, drawn from numerous experiments that I made during these last years, very varied experiments, bearing upon the most dissimilar animals (*Antedons*, *Nemerteans*, *Daphniids*, *Phronimas Dromiids*, *Pagurids*, larvæ of *Saccocirrus* and of Crustacea, etc.), and concerning both the action of incidental light coming from the prismatic spectrum or from colored glass, and the action of light reflected by screens and by colored backgrounds.

It would be superfluous and inconsistent with the aim of this article to dwell too long on the question of chromotropism and to give a detailed description of all my results.

I shall select only what is necessary to find the data in the successive development of my analysis. Among all these results there are two which are of chief importance to the problem which occupies us.

The first is, that it is not only direct colored light which produces its specific tropic action, but also daylight reflected by colored surfaces on which the animal is placed.

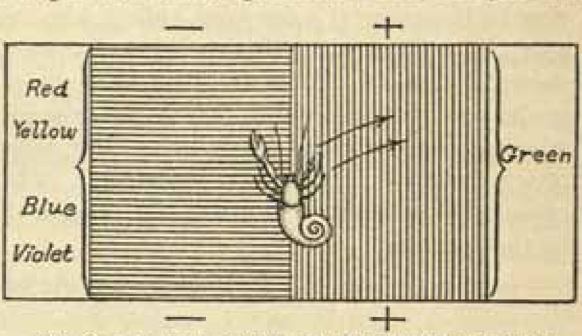

FIG. 8.—Diagram showing the chromotropism of the Pagurids.

Thus, for example, *Lineus ruber*, an erythrotropic animal, becomes motionless in diffused daylight on the red floor of a small aquarium the bottom of which is divided into two parts differently colored, or, in the absence of red, on the yellow, green, etc., always on the background which has the color nearest to red and avoids the one the color of which is nearest violet, the conditions of lighting being identical.

The second result is the autonomy of the phenomena of chromotropism and their functional independence of ordinary phototropism (with relation to daylight).

One of the best proofs in this matter is furnished us by the case of the Pagurids. It is to be remarked that each animal requires particular conditions in order to manifest its chromotropic pecularities. Those conditions must be ascertained or no results will be forthcoming in regard to the present question. Thus the Pagurids (*Bernhardus prideauxii*, *B. cuanensis*, *B. striatus*, etc.) manifest their chromotropism only when placed on the bottom of an aquarium of

two colors with diffused and equal light in the two halves, as shown by figure 8.

All the other processes successfully employed in my studies on other animals give no definite results in the case under consideration.

But in the conditions indicated, the Pagurids are very favorable subjects for experimentation, as their shell permits them to turn aside from all external excitation and they may be placed in a desired position on the line between the two colored surfaces without over exciting them. Placed on this line and left in complete quiet, they gradually emerge from their shelter, and at the moment of their emergence from their shells they feel the difference in the reaction of two colored environments on their eyes and their neuro-muscular tonicity.

This difference manifests itself as soon as the Pagurids begin to move, and then they are seen to turn immediately toward the tropic color (more strongly positive than the other).

The color green, is, in the case considered, the most positive; whatever be the spectral color (red, yellow, blue, violet) coupled with the green, the Pagurids will turn always toward the green, as is well shown in figure 8. They are, then, chlorotropic. If kept a long time in the aquarium described, they occupy the green side, never crossing (during the day) the fatal limit. But they are at the same time phototropic (+), or rather, leucotropic. On the white-black background the white will be constantly chosen. This can be represented by the formula:

(1) (—) black → white (+).

The white background is even more positive than the green, as is expressed by the formula:

(2) (—) green → white (+).

The tropic value of any other color (green excepted) corresponds to its position in the solar spectrum and increases in the spectral order toward the violet, according to the formula:

(3) (—) red → yellow → blue → violet (+).

Thus, for example, on the red-yellow surface the Pagurids proceed toward the yellow; on the yellow-violet surface, toward the violet.

Black is the most negative, thus:

(4) (—) black → red (+).

If green did not exist, the scale of tropic values would be:

(5) (—) black → red → blue → violet → white (+),

normal, according to Loeb's theory.

But the green possesses the same influence over the Pagurids as over the human eye; consequently the tropic scale appears quite different:

(6) (—) black → red → yellow → blue → violet → green → white (+).

It is certain that it is not the intensity of color that plays a preponderant rôle here; careful comparison of the tropic reactions of the Pagurids (positive animals) with those of *Lineus* (negative) and especially with those of Zoææ (positive), in relation to the same chromatic rays, gives sufficient proof. In the case of the Pagurids, the yellow is much less tropic, not only with regard to green, but also in relation to colors as slightly intense as blue and violet.

VII. THE EXPERIMENTAL INVERSION OF CHROMOTROPISM.

Thus, each chromatic ray has a specific action, autonomous and independent of the action of the other chromatic rays and of that of white light.

But this statement, although very important, would not give us the means of examining carefully the instinct of self-concealment, had I not obtained at the same time the inversion of chromotropism.

After long and fruitless research with isotonic solutions of various chlorides, with concentrated sea water, etc., I accomplished my ends in quite an unexpected fashion, by an extremely simple process, namely, the addition of distilled water (from 25 to 80 cubic centimeters to 100 cubic centimeters of sea water). Placed in that solution *Lineus ruber* becomes the next day wholly janthinotropic. While remaining negative in relation to white light, it turns toward the most refrangible rays of the spectrum as decidedly as it had previously avoided it. It is by this process that I have been able to separate chromotropism from phototropism, and thus prove in an indisputable manner its functional autonomy, which I have mentioned above.

If, before this, the normal *Lineus*, put into a horizontal tube parallel to the luminous source and placed behind a series of differently colored plates, all assembled under the red plate or, in its absence, under the one which allows the least refrangible rays to pass, they will now all assemble under the plates which allow the passage of the most refrangible rays.

Thus, the change in the physiological state of the organism under the influence of the dilution of the surrounding medium brings about a change in all the reactions due to chromotropism.

But hydratation is not necessarily united with janthinotropism of *Lineus*, nor dishydratation with erythrotropism, as might be inferred from the statements of G. Bohn.[a]

The following facts show this well:

1°. The inversion of the chromotropism of the Nemerteans, appearing the second day, continues generally two days and disappears the fourth. The animal becomes normal—erythrotropic.

2°. After having lived during two or three weeks in my solutions (sea water with distilled water), and presenting consequently their normal chromotropism (erythrotropism), the *Lineus* changes again when it is transferred to pure sea water and become janthinotropic.

It would seem to be therefore rather the disturbance of the physiological equilibrium which provokes the inversion of the tropism, a fact which agrees well with my recent experiments on the Pagurids.

Let us leave a normal and chlorotropic Pagurid in a square, bicolored basin, of one to two liters, without changing the water.

Let us try from time to time its chromotropism by putting it on the line dividing the two colors.

A few days afterwards we shall see the animal gradually intoxicated by the products of its excretions, change the type of its chromotropism and become clearly erythrotropic (and negative with regard to the white screens). The scale of tropic values of the different colors remains the same, but it diminishes toward the green and white, the negative action of which is strongest, according to the formula:

(+) black ← red ← yellow ← blue ← violet ← green ← white (−).

Thus, on the green-violet background, the Pagurids proceed toward the violet, though they are negatively phototropic and erythrotropic, which again confirms the relative autonomy of the tropic actions of the different light radiations.

The results essential for us are: 1°, that the change of chromotropism is no longer a possibility a priori, but a concrete fact, experimentally established; 2°, that the disturbance of the physiological equilibrium, which determines the changes, can be provoked by the most diverse agents.

VIII. THE VARIABLE CHROMOTROPISM OF HIPPOLYTE AS A NORMAL PHENOMENON, ACCOMPANYING SYNCHROMATISM.

Is it not possible that among the agents which provoke the alteration of the chromotropism may be also found the luminous agents and especially the chromatic properties of the surrounding medium?

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[a] G. Bohn: Attractions et oscillations des animaux marins littoraux sous l'influence de la lumière. Mém. Inst. gén. psychologique, t. I.

It has long been known that there exists a close relation between the phototropism of an animal and the intensity of the light to which it is subjected.

Groom and Loeb[a] first on the larvæ of *Balanus* and later G. H. Parker on the copepod *Labidocera;* S. J. Holmes on the amphipod *Orchestia* and on the flagellate *Volvox;* G. P. Adams on the annelid *Allolobophora*, etc., have shown that the changes from positive to negative phototropism, or the reverse, are produced under the influence of the intensity of the light alone; that is, of the amplitude of the waves of the luminous radiations.

It is not impossible, then, at least a priori, to find analogous cases in which the inversion of the chromotropism might be produced under the sole influence of the wave length of the luminous radiations, otherwise called their chromatic quality.

Of course, this phenomenon can be established only with regard to animals which are extremely sensitive to luminous agents.

They must be endowed with such plasticity of their sensorimotor organization that its state is capable of being changed under the direct action of the chromatic environment and that this change may be manifested by their tropic movements.

The number of such creatures is evidently very small.

At present I know, belonging to this category, only the little shrimps of the genus *Hippolyte* (*H. varians*) and the self-disguising crabs.

It is as a result of the work of two English biologists, Messrs. Keeble and Gamble,[b] that I have recognized this phenomenon among the *Hippolyte.* I give here some passages from their first work:

> That the prawns exert powers of selection with respect to their weed will be readily realized from plates 32 and 33, figures 1 to 9, representing prawns placed in a dish with sea water, to which subsequently pieces of different coloured weeds were added. The prawns were left free to select their weeds, and . . . they succeeded in making wonderfully accurate colour matches. . . . The brown variety of *Hippolyte varians* (mature specimens) abounds amongst the masses of brown *Halidrys siliquosa* which flourishes in the "Laminarian zone." . . . Young specimens of a uniform brown tint occur chiefly among the fronds of *Dictyota dichotoma.* Mature green prawns are somewhat rare at Piel, though young ones are plentiful in the clear and shallow water of the *Zostera* pools. Red, again, is not a tint commonly found in full-grown *Hippolyte varians* at Piel, though a few large and many small pink specimens were from time to time discovered. Very probably the somewhat muddy water, stunted weeds, and the comparative scarcity of clean red weed are the causes of the rarity of this form.

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[a] Groom u. Loeb: Der Heliotropismus der Nauplien von *Balanus perforatus* und die periodischen Tiefenwanderungen pelagischer Tiere. Biol. Centralbl., bd. 10.

[b] Keeble and Gamble: Hippolyte varians, a Study in Colour-change. Quart. Jour. Micr. Sc., t. 43, pp. 601–603.

This phenomenon, which the English authors term choice (power of selection), is only chromotropism, but very complicated, very much differentiated, and as it were, individual.

For this phenomenon I have proposed the objective name of synchromatic chromotropism, a name well describing its specific character.

What, then, are these chromatic varieties of *Hippolyte*, having each its synchromatic chromotropism?

In the third memoir by Keeble and Gamble,[a] in the chapter entitled "Sympathetic colouration," we read that the young individuals, still colorless, or nearly colorless, rapidly assume the coloration of the algæ upon which they are placed.

What is still more interesting is, that not only young colored individuals, but also adults which have been transferred to backgrounds of another color, readily change their initial coloration and assume a new one, which is exactly that of their environment.

The following are the principal results of the experiments that I performed on this animal at Roscoff in 1906–7:

1°. I obtained numerous *Hippolyte* of the following colors:

A. Simple colors; that is to say, in which the corresponding pigments are only dilated: (*a*) Red, dark and light; (*b*) yellow, dark, light, and whitish; (*c*) blue and bluish (transparent).

B. Composite colors: (*d*) Orange (yellow pigment+red pigment); (*e*) green, lemon and olive (yellow pigment+blue pigment in different mixtures); (*f*) violet, dark and lilac (red pigment+blue pigment).

Without counting the usual colors—green, brown, and brownish (the last two composed of red pigments+yellow+blue).

Thus I obtained all the fundamental colors of the solar spectrum with numerous shades, corresponding always to the color of the paper used.

It is surprising to find in the above results the bright colors, yellow, blue, and violet, which are not met in the natural environment of *Hippolyte* as it lives among plants and algæ.

It must be deduced from this fact that the extent of the chromatic plasticity of *Hippolyte* is not due to natural selection, that it is of primary origin, and depends directly upon the chromatic agents of the environment.

2°. Every chromatic variety, whether natural or obtained experimentally, can be changed into any other.

3°. The intensity of the colored light plays a much less important part than its chromatic equation; this may be concluded, at least, from

[a] Keeble and Gamble: the colour physiology of higher Crustacea. 3. Phil. Trans., series B, vol. 198.

the experiments made in 1906, in which I obtained the same colors in *Hippolyte* with varied intensities of lighting, in small crystallizing pans wrapped in fine colored papers. This method is a little too primitive, but it was the only one that I was able to employ.

4°. There exist *Hippolytes* very ill adapted to change (within a week or more). But if they do alter their color, it is only after the molt[a] that the change appears, either in part or totally. This proves that the molting is not merely an external process, but a process which affects all the tissues while increasing their plasticity.

5°. Once changed, the color of the *Hippolyte*, even in the most obstinate, becomes plastic and can be changed with astonishing rapidity, sometimes in ten minutes.

The fact is most interesting to me, because it demonstrates the part that habit (in the purely physiological meaning of the word) may have; that is to say, the use or the want of use of an organ (as Lamarck has said) in the formation of the permanent varieties of an animal primitively polychromatic.

Thus the ideas of Lamarck, often derided, again take the place that is their due.

Now the chromatic varieties of *Hippolyte* are developed only individually, without being hereditary.

And since each of these diversely colored individuals has, according to the observations of Keeble and Gamble, its corresponding specific chromotropism, it is evident that in acquiring its coloration it acquires simultaneously its synchromatic chromotropism.

Color and chromotropism are here intimately connected; they are always synchromatic with the color of the environment, under the direct action of which they develop each time by a sort of resonance of the entire organism, as well as of its chromatophores and its "retina" as of its neuro-muscular apparatus. It is impossible for me to concern myself here with the question of this chromo-kinetic resonance, to which I shall devote a special chapter in my next work. I have wished only to insist upon this constant parallelism of variable color with variable chromotropism.

It would be most important and interesting to study by the experimental method the progressive steps in the changes in these two phenomena; to try to establish whether these changes are absolutely simultaneous or whether they follow each other in time, the parallelism being then only the definite stage of the physiological process.

This is a problem to tempt a biologist, and one which, I believe, it is not impossible to solve.

It is certain, from my researches, that the power to effect changes of color diminishes with the prolonged failure to exercise the chro-

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[a] The molting of *Hippolyte*, as of many other Crustacea, occurs habitually during the night.

matic plasticity of the animal. It is probable that in the fixed conditions of a colored environment the plasticity of the chromatophores, diminishing by degrees, would become nonexistent (after a long time). The color would then be constant.

Would the chromotropism lose its synchromatic resonance also? I know nothing about this. But it is probable on a priori grounds that there are creatures which, having completely lost their power of changing color, because of the anatomical structure of their integuments, have preserved or evolved their chromotropic plasticity and their chromo-kinetic resonance of their instinctive movements. Such is the case of our *Maja*.

And so we are brought back after all to the immediate subject of the present analysis.

IX. THE "CHOICE" OF COLORS, AS INSTINCTIVE, VARIABLE SYNCHROMATISM, DUE TO THE CHROMO-KINETIC RESONANCE OF THE ANIMAL.

We are so fortunate as to be aided in this difficult question by the objective proofs which *Maja* presents by its covering and as *Hippolyte* presented by its organic color.

The covering indicates each time the chromatic past of the crabs, the environment in which the crabs have lived. The "choice" of colors presents itself then in the following aspect:

§ 1. THE "CHOICE" OF COVERING.

The animal, put into a colored environment—green for instance—in acquiring under its direct influence, by chromo-kinetic resonance, the corresponding chromotropism (synchromatic), becomes chlorotropic, and consequently negative in relation to other colors. If it finds colored papers, it can take (that is to say, approach) neither the red nor the white, etc., these colors making, in the green aquarium, negative spots (repellant) for the chlorotropically adapted animals.

It will disguise itself, then, in such green as it encounters while wandering over the green surfaces. It will do the same in an environment of any color, except black.

It will now be understood, what would otherwise be inexplicable, why the old coverings in the experiments of chapter III, paragraph 1, had no influence upon the color of the new covering.

It will also be understood why one should not use too large or too numerous bits of paper, the characteristic color of the aquarium diminishing relatively its decisive influence. The bits of paper should not be, however, too small, the negative tropic surfaces effecting, then, either no action at all or an action too weak to prevent the animal from approaching it.

Again, it can be seen why the crabs, in numerous experiments, selected all the synchromatic papers, without having touched the discordant papers, although these were present in considerable quantity.

§ 2. The Choice of Environment.

The animals disguise themselves in preparatory aquaria of a certain color, containing only papers of the same color. Under the direct action of this environment they acquire the corresponding chromotropism. Once put into the conditions where chromotropism can be attained, as in our experiments of chapter III, paragraph 2, in the aquarium divided in differently colored halves, the crabs proceed toward the corresponding environment. The covering itself plays no part in this phenomenon. It is of use only to the experimenter, constituting a true recognition mark, thanks to which one cannot be deceived as to the chromatic past of the animal.

In order to confirm this manner of regarding the facts, I went again to Villefranche, especially to perform some new experiments and to procure some irrefutable data.

1°. I raised several *Maja* during a certain time in colored aquaria, without giving them material with which to cover themselves. I then studied their reactions with relation to the colored surfaces of another aquarium divided in two. The corresponding chromotropism was established without covering.

2°. In an aquarium of any color whatsoever, for example red, I have noticed the "favorite" corner where my thigmotropic crabs habitually crowded together. Afterwards I have changed that corner to a different color, for instance green.

Then the crabs harmonizing with red no longer came into this green corner which now presents a surface negatively tropic. Many times I found them near the limit of that color, where they stopped and after a short time drew back.

Then I changed the discordant corner. The crabs frequented it again, but now they could not go beyond the boundary of the new negative corner. These two recent series of experiments are, it seems to me, sufficiently conclusive.

§ 3. Errors of Instinct.

"Errors of instinct" no longer exist in our explanation of the facts of self-concealment.

In the black aquarium, the chromotropic action of the environment being nil, each colored surface (papers) which might be found would exercise a positive action; the animal would go toward it and would clothe itself eventually with colored paper and not with black paper, which exerts no action. It may take some occasionally, if it meets it by chance, on its way toward the tropic paper; but that only very rarely occurs.

If we compare once more the facts of histological synchromatism of *Hippolyte* with the facts of accidental or instinctive synchromatism of *Maja*, we shall see that the essentials of the two phenomena are identical, and that they consist in a chromo-kinetic resonance in response to the luminous agents of the environment.

This resonance, by the medium of the retino-neural channel, is manifested in *Hippolyte* by the kinetic phenomena of the chromatophores, while, in the *Maja*, it is interpreted by the chromo-kinetic phenomena of the entire animal, that is to say, by the chromotropic movements which necessarily determine the corresponding concealment.

This is all that I have to say in regard to the experimental analysis of the instinct which leads the Brachyura Oxyrhyncha to disguise themselves. There remains only to recapitulate the results.

X. GENERAL CONCLUSION: THE PHYSIOLOGICAL DETERMINISM OF THE INSTINCT OF SELF-CONCEALMENT IN ITS ENSEMBLE.

I feel obliged to speak only of physiological determinism, exclusive of any psychological tendency. The reason is, that it is absolutely impossible for us to know anything whatever respecting the psychic state of the lower animals, to which one can not even apply reasoning by analogy with our introspective states. Thus, the question of "choice," either conscious and voluntary, or determined by "sensations" of color, sensations "agreeable" in certain conditions and "disagreeable" in others, this question may be very interesting, but it does not exist for us as a scientific question; all the more as everything takes place with our animals as if psychic states did not exist, these states having no influence over the course of the instinctive reactions that we have just described and analyzed.

Now, neither from the gnoseological point of view, nor from the methodological [a] point of view, have we committed an error in limiting ourselves in this study to the objective method: Physiological (experimental) and biological (comparative).

Here is the general result:

The instinct of the *Maja* in all its curious complexity is composed of two parts, the second of which, the one which constitutes the fundamental part of instinct, can be separated and studied by itself.

This simplification of instinct is shown in the case of the resection of the cerebral mass containing the photo-receptive ganglia or of the removal of the peripheral organs of photo-reception.

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[a] The fundamental statement of my gnoseological and methodological conceptions in zoopsychology will be found in the first part of my complete work in the Revue Polonaise de Philosophie (Przeglad filozoficzny), vol. 10, fasc. 3, Warsaw, 1907.

In instinct not maimed, the first phase is that of the chromoreactions of the animal in regard to the color of the environment and the colored surfaces of the objects of concealment. The material for disguising is determined by the variable synchromatic chromotropism, which drives the animal inevitably toward certain colored surfaces, according to the sum of the given conditions. Once the animal touches the material, whatever it may be, if nothing prevents it, there begins immediately the long series of very complicated reflex movements provoked by the tangoperceptions[a] of the claws, directed by the tango- and chemoperceptions of the buccal pieces, and helped on toward the end by the tangoperceptions of the dorsal hooks.

[a] Tactile perceptions.

THE ORIGIN AND DEVELOPMENT OF PARASITICAL HABITS IN THE CUCULIDÆ.[a]

[With 2 plates.]

By C. L. Barrett, Melbourne.

For nearly two thousand years certain remarkable habits of the family Cuculidæ have exercised the minds of naturalists and philosophers. The origin of these habits has remained hidden behind an impenetrable veil of mystery, which is only now being slowly and patiently lifted by means of the observations and researches of a number of ornithologists in different parts of the world. The first actual record which has come to us out of the past of the unusual ways of these strange birds is contained in a scientific treatise written by one Aèlian, a Latin author, who flourished during the second century. In this ancient monograph it is stated that the cuckoo always lays her eggs in the nests of other birds, being too indolent to undertake the care of her own offspring.

We do not find many other important references to the cuckoo until the time of Gilbert White, the famous old naturalist-parson of Selborne, whose charming series of letters on the wild life in his Hampshire home, known to us as "The Natural History of Selborne," are full of interest still. White mentions that the European cuckoo (*C. canorus*) is a summer migrant, appearing in his garden early in the month of April each year, and the whole of one letter, dated from Selborne, February 19, 1770, is devoted to a consideration of the habits of the mysterious stranger.

Daines Barrington, a wealthy and aristocratic young naturalist, had written to the Reverend Mr. White, asserting that the cuckoo did not deposit her egg indiscriminately in the first nest she came across, but, on the contrary, searched out the home of a bird whose natural food was to some extent similar to her own and therefore a desirable foster parent for the prospective baby cuckoo. White, in reply, said that the idea was quite new to him, and that, after giving much thought to the subject, he had come to the conclusion that the

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[a] Reprinted by permission of The Emu, Melbourne, vol. 6, 1906–7, pp. 55–60.

hypothesis was reasonable enough, as, personally, he could not remember ever having witnessed a young cuckoo being tended by any but soft-billed insectivorous birds. He adds, very quaintly, that the depositing of its eggs by the cuckoo in another bird's nest is such a monstrous outrage on maternal affection that, had it been related of a bird in the Brazils or Peru, it would not have merited belief. On October 8, 1770, the observant old naturalist again writes, this time from Ringmer, in Sussex, to the effect that he has just seen a young cuckoo in a lark's nest, and that it was very pugnacious, pursuing his finger and buffeting and sparring with its wings like a game cock. I have often noticed this bad-tempered disposition myself amongst our Victorian species, and it seems to be quite in accordance with the general nature of the birds as a class.

Coming to more recent time, we find Charles Darwin, in his chapter on instinct in the "Origin of Species," throwing the searchlight of his genius into the dark corners of the cuckoo problem. Variation and natural selection, the great naturalist considers, have undoubtedly been the main factors in building up the parasitical instinct which we see working in all its horrible perfection to-day. Let it be supposed, for instance, that an early progenitor of our lovely little shining bronze cuckoo (*Chalcococcyx plagosus*) occasionally departed from the natural order of things, and deposited one of her tiny eggs in the nest of some other species of bird, either accidentally or by reason of being compelled to lay before her own nest was completed, just as to-day we frequently find the pale blue eggs of starlings and mynahs scattered about the open fields or on our suburban lawns. If we conceive further that the egg thus consigned to its fate in an alien nest has duly brought forth a baby cuckoo, which, being reared by the foster-parents, has unconsciously acquired, during the nestling period, a predilection for the company of its foster-parents and their kind, is it not probable that this particular cuckoo would, if a female, sometimes deposit an egg in the nest of a bird belonging to the species amongst whom her infancy was passed? The cuckoo would also naturally transmit this predilection to her own offspring, and they in turn would rear young, or leave them to be reared by foster-parents, endowed with the same inclination toward parasitism. As time went on, and successive generations of cuckoos from the same parent stock had been born and died, the parasitical instinct would gradually become more pronounced in the family, and, being an aid to its preservation and perpetuation, would finally become a fixed, immutable instinct.

As a proof of this theory I may cite the peculiar habits of certain species of the American Icteridæ or cowbirds (*Molothrus*), which, according to Mr. W. H. Hudson, author of "The Naturalist in La

BRONZE CUCKOO (CHALCOCOCCYX PLAGOSUS), ABOUT 3 WEEKS OLD.

Plata" (with whom I am in correspondence), are only partially parasitical, being apparently still at the halfway house between virtue and vice. The cowbirds live together promiscuously, in flocks composed of many individuals of both sexes, and either build a nest for themselves or forcibly seize upon a suitable one belonging to some unfortunate member of another family of birds. In the event of there being either eggs or young in the appropriated nest the feathered robbers proceed to cast them out—a first trace of the ejecting instinct—before laying their own eggs therein. Strangely enough, cowbirds will sometimes construct a loose, untidy nest for themselves on top of a stolen one, without making use of the latter for purposes of nidification. One species of *Molothrus* has the parasitical habit much more strongly developed than other members of the genus, as it almost invariably lays its eggs in the nests of other birds; but sometimes several individuals will club together and attempt the construction of a large, shapeless nest, which, however, is never completed or made use of. These strange birds frequently lay as many as twenty eggs in a single nest, and they also possess the remarkable habit of piercing holes with their bills either in their own eggs or in those of other birds. Another curious fact relating to cowbirds is that one species (*M. rufaxillaris*) is actually parasitic upon another member of the same genus (*M. badius*), which builds its own nest.

Additional proof of the gradual development of parasitism among the Cuculidæ is found in the fact that an American cuckoo (*Coccyzus americanus*), which, as a general rule, builds a nest and rears its own offspring, has yet been known to depart from its normal habit in this respect and leave its pale green egg in an alien nest. The hawk cuckoos (*Hierococcyx*) of southern India, which exactly resemble both in color and flight the sparrow hawks of that region, furnish still another instance. Of the six known species of *Hierococcyx* one only is said to build a nest, the remaining five being parasitic on the babbling thrushes. In the great spotted cuckoo (*Coccystis glandarius*), ranging through southwestern Europe, Asia Minor, and Africa, we can see the instinct to shirk parental cares yet more highly developed. These birds are truly parasitical, inasmuch as they foist their eggs on certain species of crows and magpies whose eggs bear a marked resemblance in color to their own. In this case, however, several cuckoo's eggs are found in the same nest, and when these are hatched out it is stated that the intruders live in perfect harmony with such of their foster-brethren as have survived, and make no attempt to eject them. Occasionally the female spotted cuckoo, before laying in the chosen nest, breaks the eggs of the rightful owner in order to make more room for her own. Thus we find the parsitical habit and instinct to eject fellow-nestlings being mani-

fested in various stages of development by certain existing representatives of the Cuculidæ.

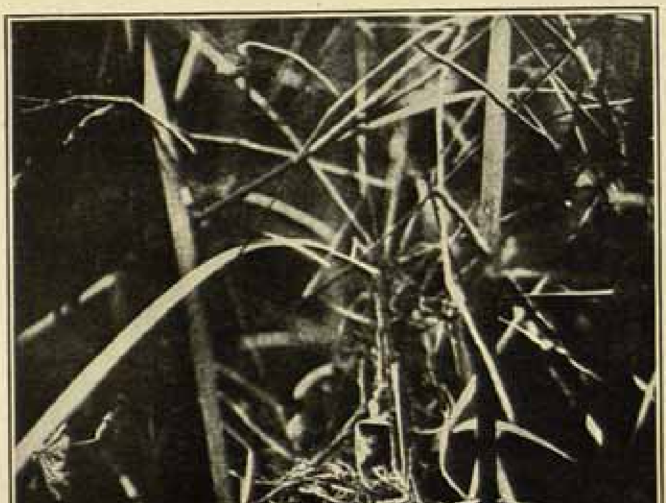
Concerning the origin of these instincts and habits, the theory that natural selection, acting during a long period of time upon a chance beneficial variation in habits displayed by an early progenitor of the race, is responsible for the habit, receives much support from a further fact. Certain birds have been known to lay eggs in the nests of others belonging to widely different genera, moor hens' eggs have been found in a coot's nest, and an egg of the former species was taken in the half-finished home of a blackbird. Starlings eject woodpeckers from their nesting-holes in trees, and eggs of gulls and eider ducks have been noticed in each other's nests. Romanes in his "Animal Intelligence" says that we are justified in setting down the cuckoo instinct to the creating influence of natural selection, and a consideration of the facts just mentioned will show how easily the parasitic instinct may have originated. The practice is by no means confined to birds, and an interesting comparison may be made between birds and insects by referring to the habits of a certain kind of bee, which always consigns its eggs to the care of another species. These parasitical insects are structurally modified in obedience to the law of coordination of structure with function and habit, for they are devoid of the pollen-gathering apparatus, which would have been absolutely essential had they been obliged to rear their own offspring.

There are two other phases of the cuckoo problem that I should like to touch upon briefly, viz:

(1) The resemblance that certain cuckoos' eggs bear to those of the chosen foster parent.

(2) The nature of the impulse acting on a newly-born cuckoo and causing it to eject its fellow-nestlings from their home.

As regards the first much debated point, it is interesting to note that the great spotted cuckoo (*C. glandarius*) of South Africa lays eggs closely resembling those of certain crows and magpies which constitute its victims. Other members of the Cuculidæ, especially some of the Australian species, do the same thing. The salmon-tinted egg of the pallid cuckoo (*C. pallidus*) is frequently found among a clutch of flesh-colored honey eaters' eggs; the narrow-billed bronze cuckoo (*C. basalis*) favors the blue wren (*M. cyaneus*), with her tiny pink-spotted egg; and most wonderful of all is the fan-tailed cuckoo (*C. flabelliformis*). I have found a great number of the eggs of the last-named species in nests of the white-browed scrub wren (*Sericornis frontalis*), and in several instances the resemblance between the eggs of foster parents and cuckoo has been most pronounced.



YOUNG NARROW-BILLED BRONZE CUCKOO (CHALCOCOCCYX BASALIS) BEING FED BY FOSTER PARENT—BLUE WHEN (MALURUS CYANEUS).

It is thought by some naturalists to be highly probable that the food eaten by birds during the nesting period has much to do with the future coloration of their eggs, and, if such be the case, it goes far to explain the similarity between the eggs of many species of cuckoos and those of their foster parents, for it follows that the latter would rear the alien chicks upon the same food on which they would have fed their own offspring. The stomach of a female bronze cuckoo (*C. plagosus*) shot at Olinda Creek last September was found, on dissection, to contain the remains of a number of the large green caterpillars of the cup moth (*Pelora*) and the emperor gun moth (*Antherea eucalypti*). In the oviduct was a soft-shelled egg, on which the beautiful bronze-green tint characterizing the eggs of this species was just becoming visible. I have watched closely several young bronze cuckoos being fed by blue wrens and various species of *Acanthizæ*, and in many instances have noticed that the devoted little nurses were attempting to satisfy the voracious appetites of their charges with lepidopterous larvæ of a greenish hue.

With reference to a recently made suggestion that the action of the infant cuckoo in ejecting its nest fellows is purely automatic,[a] rhythmic, and governed by external stimuli or reflex action, I still cling to the belief that the process is referable to hereditary instinct or subconscious memory, aided by dawning reason. I am strengthened further in my conclusions by comparing notes with other ornithologists in various parts of the world. Mr. Edward Step, F. L. S., in his essay on "The Cuckoo," distinctly stated that "shortly after birth the young cuckoo shows that it has inherited the knowledge that its foster parents will have all they can manage to satisfy its own wants, and that the presence of nest fellows means overcrowding and inevitable death for the majority, should they be allowed to remain." My friend, Mr. W. Percival Westell, M. B. O. U., a well-known British ornithologist who has devoted years of study to elucidating the habits and life history of the European cuckoo (*C. canorus*), writes that his observations lead him to credit the blind nestling with hereditary reasoning powers, and that he agrees almost entirely with my theories on the subject as set forth in a previous paper published in The Emu, Vol. 5, Part 1, July, 1905. Mr. Westell has been kind enough to forward me copies of his series of remarkable cuckoo photographs, which were exhibited recently before the Royal Society of Great Britain.

I was fortunate enough to witness a miniature combat between a narrow-billed bronze cuckoo nestling and a baby blue wren, which took place in a nest of the last-named species at Olinda Creek in November, 1904. A snapshot of the struggle by Mr. C. P. Kinane

[a] The Emu, Vol. 5, p. 145.

has already appeared in The Emu.[a] The actions of the blind, featherless, infant cuckoo on this occasion certainly showed no sign of being due to reflex action, but on the contrary appeared to me a marvelous and almost uncanny exhibition of instinct and subconscious reasoning. If it be objected that the term instinct is meaningless, I can only reply that there are many things in nature to which we attach convenient labels, although they still remain beyond our understanding.

[a] Vol. 5, Part 1, July, 1905.

SOME REMARKS ON THE PROTECTIVE RESEMBLANCE OF SOUTH AFRICAN BIRDS.[a]

[With 2 plates.]

By Alwin Haagner, F. Z. S., M. B. O. U.

In this article it is my intention to give a short general sketch of this subject, dealing chiefly with those families with which I have had some field experience, supplemented by a few of the more striking instances in detail.

It is greatly to be regretted that hitherto local ornithologists have paid so little attention to this interesting branch of research, and it is sincerely hoped that the contents of this paper may stimulate their activity toward further observations.

Order Passeres.

Family Ploceidæ.

At first sight one would be inclined to think that there was very little protective resemblance in this family, containing, as it does, some of the most gorgeously plumaged of South African birds; but this is, perhaps, the most interesting part of it. It is a very noteworthy fact that with the majority of the smaller and defenseless species the female is almost always a most inconspicuous object, with a somber-colored feathering, and generally manages to pass unobserved among its surroundings. On the other hand, the males are often very gaudily attired, which is true of a large number of the Ploceidæ. This is the case with the bishop birds (*Pyromelana*), the males of which may be numbered among South Africa's most beautiful birds, while the females are little brown-colored objects, whose coloration, blending, as it does, with the grass and reeds of their favorite haunts, renders them almost invisible to the casual eye. The same remarks apply to the widow birds (Viduinæ). Can anyone imagine anything more conspicuous than the long-tailed widow bird (*Coliopasser procne*), or even the smaller red-collared species (*C. ardens*)?

[a] Reprinted by permission from The Journal of the South African Ornithologists' Union, Pretoria, Transvaal, vol. 4, No. 1. April, 1908.

Yet their spouses are the very opposite, resembling the females of the *Pyromelana* in their somber dress, which is of very material assistance to them among the long grass of the veld, and especially so in the nesting season. During the winter months, when the cock birds have doffed their showy attire, they have the same advantage as the females of an inconspicuous plumage. This is also the case with regard to the pin-tailed widow (*Vidua principalis*) and the remainder of the species of *Vidua;* also the red-billed weaver (*Quelea quelea*).

One of the reasons for the gaudy attire of the males, or rather lack of protective coloring, may be the more or less polygamous habits these birds are accredited with. An interesting case is that of the little scaly-feathered weaver (*Sporopipes squamifrons*), which is a denizen of bushy country, where its light-brown plumage lends itself admirably toward the concealment of the bird; even during the winter months, when the camel thorns and mimosas (*Acacia giraffæ* and *A. horrida*) are devoid of leaves, their inconspicuous dress is of enormous value in aiding them to find a hiding place. The second subfamily, the Estrildinæ, is a large one, containing those well-known little birds called rooibekkies (from the color of their bills) and tinktinkies (from their call). Two of the commoner species of *Estrelda*, the red-breasted and black-faced waxbills (*E. astrilda* and *E. erythronota*), may be said to possess protective resemblance in a fairly well-developed degree. Although they have conspicuous colors relieving the brown tint of their plumage, they are nevertheless very inconspicuous when feeding on the ground among the short grass on the partly bare patches of old lands and alongside roads (their favorite haunts), as the brighter portions of their plumage are then hidden. Their upper surface, which is of a very assimilative color, blends with the bird's surroundings to such an extent that to walk among a flock of them, and suddenly flush them from almost under one's feet, is a common occurrence.

To a certain extent these remarks also apply to the orange-breasted species (*E. clarkei*), affecting the banks of spruits, etc., and grassy slopes of damp localities; they are most inconspicuous little birds, notwithstanding the bright colors which relieve the olive brown of their upper parts. Perhaps the best-endowed member of the subfamily, so far as assimilative coloration is concerned, is the little bar-breasted weaver finch (*Ortygospiza polyzona*), which has only a white chin and a black throat to relieve the buff and brown tints of its feathering.

Family Fringillidæ.

Before I pass on to the next family I would like to briefly refer to the cape and rock buntings. The former (*Fringillaria capensis*), a tame and pleasing little bird, was fairly common around Aliwal

North, C. C., in 1894. Its brown coloration struck me as being of immense protective value, as the bird is not easily discernible when sitting against a rock or when creeping among the crannies between the stones. I also noticed this fact with respect to the rock bunting (*Fringillaria tahapisi*). Once, at Irene, on the 18th of April, I shot one and it fell among some loose stones; it took me fully a minute to find the bird, such was its protective coloring, although the body was not actually hidden.

Family Alaudidæ.

I have unfortunately given but little attention to this interesting group of birds, so can not do better than quote the remarks of Mr. Guy A. K. Marshall, F. Z. S., of Salisbury, Mashonaland, with reference to a member of the lark family. In an article in the Zoologist (vol. 1900, p. 543), entitled "Conscious Protective Resemblance," he says: "There are few birds in this country which show a stronger apparent reliance on their protective coloring than the little rufous-capped lark (*Tephrocorys cinerea*) or the cape long-claw (*Macronyx capensis*). They will readily permit one to approach within a few yards of them, and they will merely run on ahead in their curious crouching rat-like manner. This action is certainly of considerable protective value in their ordinary surroundings." I concur fully with these remarks, as this bird is very common at Modderfontein, and I have often noticed that its plumage is decidedly assimilative in its coloring. To this bird I can add, from personal experience, the following species: Rufous-naped lark (*Mirafra africana*), gray-collared lark (*Alæmon semitorquata*), and the rufous long-billed lark (*Certhilauda rufula*), as Mr. Marshall's observations in a measure also apply to these birds.

Family Motacillidæ.

Perhaps one of the most conspicuous cases of protective resemblance in this family is that of the cape long-claw, already referred to. This bird has a bright orange-red throat, but when it is in the crouching attitude so aptly described by Mr. Marshall this brightly tinted portion is invisible.

The remarks on the *Alaudidæ* may serve for most of the pipits, if not all, so I need not go into a reiteration. I will only draw attention to the commonest local member of this family, the tawny pipit (*Anthus rufulus*). This bird's coloration is strongly assimilative with regard to the surrounding sea of grass of its natural home. Its movements also closely resemble those of *T. cinerea*, already referred to, so that when it is crouching down, even among the more stubbly portions of the veld, it becomes all but invisible. This applies to *A. pyrrhonotus* and several other species as well.

Family NECTARINIIDÆ.

The sunbirds, or zuiker-bekkies (*lit.* sugar-bills) as they are called by the Boers, may be ranked among the most brilliantly plumaged members of the local avifauna, yet their gay colors are often of a decidedly protective nature. They spend such a large portion of their existence feeding on various flowers that their coloration lends itself to assimilation. Mrs. M. E. Barber, a most observant naturalist, drew attention to this fact as far back as 1878, when she published a paper in part 2, volume 1, of the Transactions of the South African Philosophical Society, entitled "Peculiar Colors of Animals in Relation to Habits of Life." She noted how the colors of certain South African sunbirds accorded with those of the flowers of the aloes and Erythrina trees on which they feed. She says: "The most unguarded moments of the lives of these birds are those that are spent among the flowers; it is then they are less wary than at any other time. * * * Even the keen eye of the hawk will fail to detect them, so closely do they resemble the flowers they frequent." She particularly draws attention to *Cinnyris afer* in connection with the latter paragraph. With regard to the scarlet-chested sunbird (*Cinnyris gutturalis*), according to the late Doctor Stark these birds feed largely on the scarlet blossoms of the kaffir-boom (*Erythrina caffra*), hence it naturally follows that their scarlet feathering is conducive toward protective resemblance. The malachite sunbird (*Nectarinia famosa*) is of a bright green color, with yellow pectoral tufts. Yet, when sitting among the almost equally bright foliage of the mimosa, with its fluffy yellow blossoms (a favorite haunt of theirs), it is not easy to locate, always provided, of course, that the bird does not move. This species, moreover, loses its bright plumage about the same time as the mimosas shed their leaves, both assuming a general brown tint, the bird thus still retaining its assimilative coloration. The females are of a brown color at all seasons, which naturally renders them, winter and summer, inconspicuous among the branches of trees.

I can also speak from experience regarding the black sunbird (*C. amethystinus*), having had the good fortune to watch many, both in the gardens of Johannesburg, and among its natural scrub on Modderfontein. I can do no better than quote Doctor Stark's words: "* * * so closely does the nearly black plumage of *C. amethystinus* assimilate in color with the dark naked branches of the tree, that as long as the bird is still it is not easily distinguished on its perch." This I can fully substantiate. One instance, that of a young male in the "brown," is perhaps worth quoting. In my journal, under date September 3, 1899, I find: "While strolling through an orchard I heard the plaintive 'peep' of a sunbird, so I halted and

crept under the tree from whence the sound emanated. I searched the branches carefully, and finally traced the call to a certain twig. I then climbed the tree cautiously, but look as I would I could not locate the bird among the twigs and blossoms, although as soon as I remained quiet it continued uttering its cry. I was beginning to lose patience when the bird moved, changing its position, and only then I saw it, wondering at the same time why I had not done so sooner." Mrs. Barber also relates the following of this species: "The black sunbird is never absent from that magnificent forest tree the 'kaffir-boom' (*Erythrina caffra*); all day long the cheerful notes of these birds may be heard among its spreading branches, yet the general aspect of the tree, which consists of a large mass of scarlet and purplish-black blossoms without a single green leaf, blends and harmonizes with the colors of the black sunbird to such an extent that half a dozen of them may be feeding among its blossoms without being conspicuous or even visible."

Family Zosteropidæ.

I will only make a passing reference to this family, as all the members are doubtless of protective coloration. I have often noticed how the green plumage of *Zosterops virens* and *Z. capensis* assimilate to the foliage of the trees which they frequent.

Family Laniidæ.

One would hardly think that the members of this pugnacious family required protective resemblance, but I noticed a case with regard to the ordinary fiskal shrike, which leads one to an interesting phase of the subject. The male is a fairly conspicuous bird in its dress of black and white, the female, with her duller feathering, not nearly so much, and the fully fledged young still less so; as a matter of fact, the last named possess a plumage of a most protective nature, as the following will show: On December 29, 1904, while collecting on the Jokeskei River, District of Pretoria, I first noticed this fact. I found three fully fledged young shrikes hopping about a tree. As I neared them they suddenly stiffened themselves and sat motionless. When I kept still they soon recommenced their excursions among the branches, but I had only to shout or shake a branch of the tree when they would suddenly assume the stiffened posture alluded to. They seemed (unconsciously, I presume) to rely on the perfect harmony existing between the tints of their ashy-brown plumage and that of the tree bark and twigs of their arboreal abode. They could not fly more than a couple of yards, so that the assimilative nature of their feathering must have been of immense assistance to them. This

instance was so striking that I could not help noticing it, and since then, having been on the alert for similar cases, I have verified my experience.

Family Sylviidæ.

The warblers need only a passing reference, as, owing to their dull coloration and small size, they can all be said to more or less possess protective resemblance, and it would therefore be idle to attempt to give a list of those species endowed with it. I am well acquainted with the habits of many of the species, and have often noticed how inconspicuous they are when sitting among the grass or bushes of their usual haunts. They are, moreover, for the most part of retiring habits.

Order Picariæ.

Family Caprimulgidæ.

The members of this family are on the whole very well endowed with assimilative coloration. I have noticed this fact in regard to the European nightjar (*Caprimulgus europæus*). Crouching on the ground it is a most inconspicuous object, even on brightly moonlight nights. I first became acquainted with the case of the rufous-checked nightjar (*C. rufigena*) on September 27, 1898. During a collecting excursion to a farm about 5 miles southwest of Kaalfontein station I happened to be resting under a tree. Staring aimlessly up into the foilage overhead, my gaze was arrested by an irregular bump or protuberance on a bough about 12 feet above my head. I could not make out what it was, so, thinking it might be a nest of some sort, I ascended the tree and was considerably astonished to find a nightjar fly up from almost under my nose. The bird had been sitting lengthways on the bough, flattened up against it, and the assimilative nature of its plumage was most marked, the mottled gray-brown and rufous feathering harmonizing beautifully with the bark of the tree on which the nightjar sat. I followed the bird with my eyes as it flew up, and descending to the ground I proceeded to the tree it had taken refuge in, but was forced to study every branch before I located it again. Being mostly nocturnal in habits, a protectively colored plumage would naturally be of very material assistance to them when in hiding during daylight in some recess or on a bough. Since this occasion I have repeatedly verified this experience, as this bird is fairly common in the Modderfontein district. In the neighborhood of Grahamstown I also noticed this fact with reference to *C. pectoralis*, which seems to be the commonest species of the bush region. My friend, Mr. Robert Ivy, has also repeatedly noted the remarkable assimilative coloration of this bird, and photographed a

female on its eggs on the ground, a reproduction of which is given herewith. The bird is nearly in the center of the picture (pl. 2). I also show a photograph of a young nightjar on the ground among the forest débris; the resemblance even here is extraordinary (pl. 1, fig. 1).

Families Picidæ and Capitonidæ.

Among the woodpeckers and barbets—birds all more or less of a coloration which, although often conspicuous enough in the open, lends itself decidedly to the reverse among the twigs and branches of its home—I have found the cardinal woodpecker (*Dendropicus cardinalis*) when clinging to a tree trunk to be almost invisible. This is still more marked in regard to the South African wryneck (*Iynx ruficollis*), whose mottled brown and gray plumage so closely assimilates to the colors of the tree trunks on which the birds feed. This is also true of the pied barbet (*Tricholæma leucomelas*), but to a less extent, as this bird has more white in its plumage.

Family Musophagidæ.

These birds, all more or less of a green tint and denizens of thick forests, are bound to be protectively colored. Writing of the knysna lourie (*Turacus corythaix*), Mrs. Barber, that excellent lady naturalist, says: "The favorite food of that superbly arrayed bird, the lory, are the berries of the wild vine. Like the plumage of the lory, the foliage of this climber varies considerably in its shades of green, and the berries alter in color as they ripen, from light red to crimson, and ultimately to almost a black color, while the twining stems of the plant are of a pale gray or white. These colors being the same as the lory, blend and harmonize with them admirably, rendering the bird protection from her foes. This climber, with its long twining branches, covers large patches of the forest; it is seldom without fruit, and forms the favorite haunt of the lory; it is there they may be found if you seek diligently, but they are by no means conspicuous, hidden among its sheltering leaves." This I can fully substantiate by my own experience of these birds during the month of January, 1907.

Order Striges.

Families Strigidæ and Bubonidæ.

The reasons for an owl requiring protective coloration are obvious to anyone conversant with the habits of the members of this order, and need not be detailed here. Probably every species of the Striges is more or less endowed with this provision of nature, at least everything seems to point that way. The birds are lighter or darker in coloration as their place of abode may require, even to the extent, as

we well know, that those species inhabiting the regions of snow and ice are white or very nearly so. Of South African owls, all those with which I can claim personal acquaintance are certainly protectively colored: *Strix capensis*, *Strix flammea*, *Scops capensis*, *Asio capensis*, and *Bubo maculosus*. With reference to the last named, which is a fairly common bird in the district in which I reside, I have had some correspondence with Mr. W. L. Distant, the editor of the Zoologist magazine. He is of the opinion that this species does not possess protective resemblance in the same sense as this term is generally understood, and ascribes to the bird what he calls "active mimicry;" as he says the bird consciously conceals itself. Perhaps it does this—the instinct implanted in every dumb creature would lead it to do this; but with all due respect to Mr. Distant's superior knowledge in matters zoological, I must contend that if its coloration was not of the protective order, of what use would the conscious concealment of the bird be, unless it crept into a hole or otherwise completely hid itself? Therefore why should the mere fact of its conscious concealment be against the theory of "protective resemblance?" I will just relate two instances in brief detail to illustrate my meaning and prove my theory. On July 30, 1898, while out shooting I put up from almost under my feet an eagle owl. It settled a short distance ahead; so I followed it. When I reached the spot I commenced searching for the bird and after some minutes succeeded in flushing it again, but very nearly treading on it in so doing. This invisibility of the owl somewhat puzzled me, so I determined I would see it on the ground before firing at it. I followed this bird from place to place for over half an hour before I could see it clearly enough to be sure of its identity, and then even it was more its "ears," momentarily erected, that betrayed it, as, although it was only sitting among the grass tufts, I could not make out anything like the outline of an owl, so beautifully did the tints of its mottled gray and brown plumage harmonize with the surrounding grass and stones. It was a clear case of "protective resemblance," as had the bird been of any other color—red, green, or black, for instance—I must surely have seen it repeatedly from a much greater distance than I was from it when it was flushed. I have noticed this fact repeatedly since, but will only relate one other instance in further defense of my assumption. On the 18th of October, 1903, I found a nest (if such the depression in the soil can be termed) of this species on a ledge or platform in a rocky hollow. This ledge was covered with ground on which several of the ordinary veldt plants grew. I flushed this bird from her two eggs quite suddenly, and was certainly not more than 10 feet distant when it flew up. I returned to the spot later with my camera, but in trying to get it properly focused on the bird had perforce to drive it up to find its exact locality. I was above the owl's position at the time

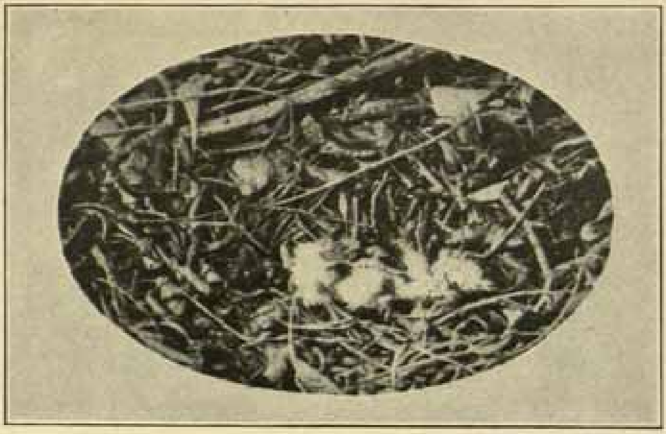


FIG. 1.—YOUNG SOUTH AFRICAN NIGHTJAR.

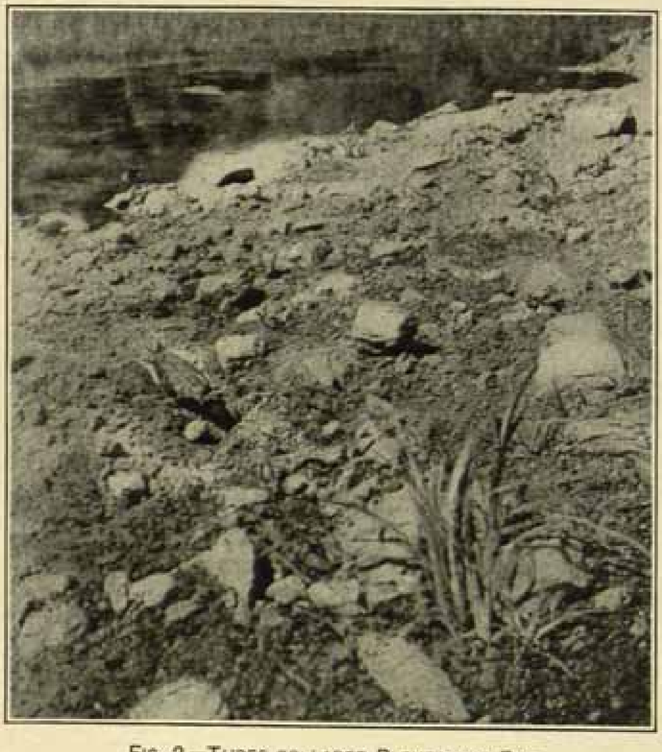


FIG. 2.—THREE-COLLARED PLOVER AND EGG.

SOUTH AFRICAN NIGHTJAR ON ITS EGGS.

and would have seen it easily enough but for its assimilative coloration. When the bird settled again I immediately lost sight of it, and although it was only partially screened by the herbage I had to use my glasses to be sure of its identity. I took particular notice of this case, remembering Mr. Distant's friendly criticism. That owls are subject to dimorphism is a well-known fact. Professor Newton mentions it in his admirable Dictionary of Birds. This dimorphism, not necessarily sexual, obtains in *Bubo maculosus* without a doubt. I have noticed a very fair degree of difference in the tints of the various birds that have come under my observation, and there are, or were, several specimens of this owl in the Pretoria Zoological Gardens which amply illustrate this fact. This, then, is a further proof of my contention that this species does possess protective resemblance.

Order Columbæ.

The doves and pigeons afford another group of birds seemingly well endowed with assimilative coloring.

With reference to the green wood pigeon (*Vinago delalandi*), Captain Shelley has noticed the advantage this bird derives from its protectively tinted plumage. Writing of this species in the eastern Cape Colony, Mrs. Barber says: "The colors of the green wood pigeon of the Transkeian country so closely resemble those of the fruit and foliage of the wild fig (*Ficus* sp.), their favorite fruit tree, that a flight of them may be concealed among its branches without being seen; on anyone approaching the tree, the birds being fully aware of the protection which their colors afford them, remain perfectly motionless. A shot, however, fired into the tree will send them flying in all directions. The plumage of this pigeon consists of beautiful shades of green with red beak and legs; these colors blend admirably with those of the wild fig. The tree is an evergreen, and bears fruit all the year round, this continually affording the green wood pigeon not only food, but also protection, because it is the home of these birds."

I have repeatedly noticed how beautifully the slate and drab tints of the majority of our doves lend themselves to the concealment of the birds. This is so with regard to *Turtur capicola* and *T. senegalensis*, and the fact is more worthy of notice in winter, when the mimosas have shed their leaves; the birds are even then most inconspicuous objects as they sit motionless among the naked branches and twigs. Writing of *Haplopelia larvata* (cinnamon dove), W. R. Ogilvie-Grant (in the Royal Natural History) says it is common in thick bush along the coast of Natal, where its brown coloring renders it difficult to detect as it sits motionless among the dense creepers. This is also applicable to the so-called bush dove or rock pigeon (*Co-*

lumba phæonota). Its coloration is particularly helpful toward the effective concealment of the bird when among the rocks, etc., of its nesting haunts.

Order Pterocletes.

This is another group where every member may be assumed to possess nature's gift of protective resemblance. I have seen the namaqua sand grouse (*Pteriocles namaqua*) among the scrub and sand of its Karoo home and in the stunted grass of the Transvaal "winter" veld, and in both cases the assimilative coloration of the bird was admirable.

It seems to me as if the majority of the game birds of South Africa are possessed of this type of coloration, and I need, therefore, not go into detail with regard to the francolins, which are all more or less of the "veld" tint, and consequently the reverse of conspicuous.

Orders Otididæ and Gallinæ.

I have just referred to the general veld tint possessed by most of the members of these orders. I have hunted the various bustards in the O. R. C. and Transvaal and, even guided by their harsh croak, it is often no easy matter to locate them without a dog. Their coloration is very similar to the surrounding grass of the veld, and unless the males protrude their dark-colored heads above the grass you will find your horse almost on them before they take wing. The male of *Otis afra* is much more conspicuous than the female, with its dark head and white wing patches, so that the protective coloring is much more developed in the female, being particularly helpful to the latter during the nesting season.

Other observers have also noticed the assimilative nature of the South African bustards. Writing of *Otis cærulescens* in the Journal of the South African Ornithologists' Union, Mr. Guy C. Shortridge says: "When on the ground these birds, in spite of their size, are very difficult to see, even when the very spot they have alighted on has been marked." The cape quail (*Coturnix capensis*) is also of this veld color. I have often been startled by one suddenly whirring up from under my feet, so closely do they sit and so well does their coloration fit in with that of the surrounding herbage.

Order Limicolæ.

The Dikkop (*Œdicnemus capensis*) has the advantage of a wonderfully assimilative coloring. Anyone who has observed this bird in its native haunts must have been struck with the wonderful re-

semblance existing between the coloration of the thickknee's plumage and that of the grass, stones, and tree trunks of its most cherished haunts among the mimosa scrub. I have hunted this bird often in the O. R. C. and Transvaal and always noticed this fact; it is no easy matter to sight it while it is on the ground. It does not readily rise, nor does it seem to be a very strong flyer, requiring a run before it rises on the wing. It seldom, if ever, goes higher than the tops of the mimosas. Hence the probable reason for the very protective nature of its plumage.

Coming to the *Charadriidæ*, burchell's courser (*Cursorius rufus*) is perhaps one of the best examples of protective coloration in this family. I have often observed this in the Maroka district of the O. R. C. between Thaba N'chu and Ladybrand, where they are very common, feeding in flocks on the dried and burnt stretches of veld. When in pairs or small parties they are seldom flushed at once; they run with great rapidity and then suddenly drop down and crouch close to the earth, possibly relying on their assimilative coloration, which is very great, for further concealment. These birds make delicious eating, and consequently were often hunted by me. When one is wounded and settles a little way off it requires no small amount of patience and perseverance to locate it, as it crouches close to the ground among the grass. The foregoing observations hold good for *C. bicinctus*, which bird can be met with in the O. R. C. consorting with *C. rufus*. It is, however, a much scarcer species. The three-collared plover (*Charadrius tricollaris*) is also protectively colored. They are well endowed with this, as Charles Dixon has also noticed (Curiosities of Bird Life); but when it is most useful is during the period of nesting, at which time the bird requires this gift of nature, hatching as it does in the open or among sparsely growing weeds (see pl. 2). This applies equally to the crowned lapwing (*Stephanibyx coronata*), as indeed, we may safely assume, to most if not all of the species of the family under discussion. One notable exception, of course, is the cape painted snipe (*Rhynchæa capensis*), the female of which (contrary to the usual course) is a brightly plumaged bird. The reason of this strange case has as yet not been ascertained.

I will now close my remarks on protective resemblance with a very brief reference to the nest and eggs of some South African birds.

The eggs of the majority of birds which lay in the open are protectively colored, viz, those of the sand grouse, which are deposited in a slight hollow in the bare sand; the plovers, etc., which are laid among the mud clots and dried weeds of the water's edge or among the half-dried grass of the veld; the game birds (francolin, bustard, etc.), which are deposited among the grass. All are tinted with

shades which certainly harmonize with the eggs' surroundings, a provision of nature most valuable for the continued existence of the birds as species.

Lastly, many nests are also constructed in such a manner that they fit in with their surroundings, as, for instance, many of the fly-catchers, which build their nests in trees and cover the sides with lichen to conceal their real identity; or the warblers, which build in grass tufts, and construct their nests of various grasses deftly woven and placed to appear as inconspicuous as possible.

AN INQUIRY INTO THE HISTORY OF THE CURRENT ENGLISH NAMES OF NORTH AMERICAN LAND BIRDS.[a]

By SPENCER TROTTER.

Technical nomenclature is the embodiment of that orderly and definite arrangement of knowledge which constitutes a science. It serves to symbolize a conception of the relationships that exist between living beings, one with another, and is at once the expression of a logical system of classification; a working basis for the ideal scheme which the mind constructs from observed facts. It is eminently a rational process. In direct contrast to this is the vernacular—the loose, quite indefinite, and often haphazard way of naming things, that has its root in the soil of common life. The stratum out of which it springs is emotional rather than rational. In ornithology these two contrasted forms of the embodied ideal—the technical or scientific and the vernacular names—have been of more equal value than in many other branches of natural history, from the fact that birds have always presented themselves to men's minds in a peculiarly attractive way. Most of us think of the various kinds of birds, certainly of the more familiar ones, in terms of the vernacular rather than in the garb of science. A song sparrow is a song sparrow more often than a *Melospiza melodia* as well to the ornithologist as to the untechnical wayfarer.

A respectable antiquity attaches itself to the vernacular. Long before the scientific mind had invaded the field of natural history the folk had given voice to its ideas about various animate and inanimate things. A vast vocabulary of popular names was an early heritage of the common people. With this stock of names and notions about Old World birds the colonists in Virginia and New England were fairly well equipped, and the more familiar birds of the new country soon received names indicative of some trait or likeness to certain of the Old World varieties. Mark Catesby in his History of Carolina was the first one to give any substantial

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[a] Reprinted by permission from The Auk, Cambridge, Mass., new series, vol. 26, No. 4, October, 1909.

account of American birds, and his work contains an array of names, some of them more or less familiar in the speech of to-day. To William Bartram we owe a large number of our common bird names, names that reached the intellectual world of eighteenth century England through the works of Edwards, Pennant, and Latham. Alexander Wilson was likewise a large debtor to Bartram for the names of numerous species, but he blazed his own trail by applying names to species discovered by himself as well as in the recasting of many Bartramian names.

In the present inquiry I have arranged the matter of the history of our American bird names under the following six heads:

I. Names of old English origin applied to American birds.
II. Names derived from a Latin equivalent.
III. Names suggested by voice.
IV. Names suggested by some peculiar habit or habitat.
V. Names suggested by color or other external feature.
VI. Names suggested by geographical locality (place names) or in honor of some person.

I. NAMES OF OLD ENGLISH ORIGIN.

Many of the Catesbian names of birds undoubtedly originated in the vernacular of the colonists and some are clearly of old English ancestry. In the main they are of generic rather than of specific application, as is the case with most of the folk terms for natural objects. The specific distinction is often one of locality merely, as, for example, "the cuckow of Carolina." Relationship is often broadly recognized by the people and embodied in a general name with appropriate qualifications to indicate minor differences or differences in distribution. The "species" of the *profanum vulgus*, however, more nearly corresponds to the generic conception of the naturalist, even in some cases to the idea embodied in the term "family."

A number of these Old World bird names, given to American birds, appear very early in the history of English speech. In a vocabulary compiled by Archbishop Ælfric toward the close of the tenth century (955–1020 A. D.) there is a *Nomina Avium* in which a number of bird names appear, though somewhat different from their modern form. In this list the robin redbreast is called "rudduc" or "ruddock," which long continued to be its general English name and is probably still alive in local dialects. The word appears as a variant of the modern "ruddy," referring no doubt to the russet of the bird's breast. The earliest recorded instance of the use of the popular epithet, "robin," which as a word of endearment has been transferred to many different birds throughout the English-speaking

world, occurs in the *Nomina Avium* of an English vocabulary of the fifteenth century, where the name appears as "robynet redbreast," literally "little robin redbreast." Our American robin was known to the early southern colonists as the "fieldfare," and is so termed by Catesby ("The Fieldfare of Carolina," vol. 1, 29). The bird has many of the qualities of the fieldfare, and, like its British congener, came from the north in autumn, scattering over the cleared lands in loose flocks. William Bartram (Travels, 290) speaks of it as the "fieldfare or robin redbreast," and Kalm mentions it under the latter name (English Trans., II, 90). Our familiar name "robin" is thus a contraction of the "robin redbreast" of old English speech.

In the *Nomina Avium* of Ælfric the cuckoo occurs as "geac." In some provincial dialects it is still called a "gowk," a survival of the little-altered Anglo-Saxon name. "Cuckoo" or "cuckow" (the latter an earlier form of the name and given as such by Catesby) is undoubtedly derived through later Norman speech (French *coucoü;* Italian *cucco* or *cuculo;* old English *cuccu*). The German name *kuckuk* or *koekoek*, the Danish *kukker* or *gjög*, and the Swedish *gök* are clearly allied to the Anglo-Saxon *geac* or *gowk*, all being undoubted variants expressive of the bird's voice, and the same is true of "cuckoo" and its variants.[a] The colonists were not deceived in giving to the American species its rightful name, though Catesby may have been the first to bestow it.

"Crow" appears in Ælfric's vocabulary as *crawe;* "kite" as *glida* and *glede*, the last name continuing down to the fifteenth century. The Anglo-Saxon *staern* or *staer* (later *stare*) has become the modern "starling."

A manuscript in the Royal Library at Brussels, of eleventh century date, contains a number of bird names, among which are the *goshafoc* (literally "goose hawk") modernized to "goshawk," and *spear-hafoc* ("sparrow hawk"). It seems curious that our little American sparrow hawk has not borne the name of its near relative, the kestral, rather than that of the quite different sparrow hawk of the Old World. "Turtle" was an old name for the dove and appears as such in Catesby ("The Turtle of Carolina," I, 24). It originated, as Skeat observes, from an effort to express the cooing note and is altogether different from the word used to designate the reptile of the same name. This last was rendered by English sailors into "turtle" from the Spanish *tortuga*.

Wren, sparrow, and swallow appear in these old vocabularies as *wraenna*, *spearwa*, and *swealewe*. The first of these names Skeat asserts is derived from a base *wrin*, to squeal, chirp, or whine, in allusion to the bird's voice. A curious old belief existed among the

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[a] To call a man a "gawk" (simpleton) appears equivalent to calling him a "cuckoo," a term of no uncertain meaning in the old days.

folk of several European countries that the wren was the "king of birds." Hence, probably the generic term *Regulus* formerly applied to various species of wren, and, likewise, its English equivalent "kinglet." "Sparrow" is literally a "flutterer" (*spar*, to quiver), and "swallow" means a "tosser, or mover to and fro; from its flight" (Skeat). "Lark" has been softened down from the old English "laverok" or "laverock" (Anglo-Saxon *laverce*), literally "a worker of guile," from some old superstition regarding the bird as of ill omen. The bestowal of this name upon an American bird allied to the starlings was no doubt due to an effort on the part of the early settlers to name birds after the more familiar ones of the homeland. The ground-nesting habits, the long hind claw, the loud twittering flight notes and clear song of the American bird may have given some slight reason for this incongruous title.

"Thrush" with its variants "throstle" and "throstle-kok," as applied to the song thrush (*Turdus musicus*) of Europe, is an old word and appears in its older forms in a treatise by Walter de Biblesworth at the end of the thirteenth century. In the Brussels Manuscript "throstle" seems to refer to the missel thrush (*Turdus viscivorus*). The song thrush is also referred to by its other old English name of "maviz" (later "mavis"). In this same treatise of de Biblesworth's the European blackbird (*Turdus merula*) is spoken of as "osel" or "hosel-brit," and likewise by its old English name of "merle." Later it became "ousel-cock" as in the quaint ditty in "Midsummer-Night's Dream"—

The ousel-cock, so black of hue,
  With orange-tawny bill,
The throstle with his note so true,
  The wren with little quill.
The finch, the sparrow, and the lark,
  The plain-song cuckoo gray,
Whose note full many a man doth mark,
  And dares not answer, nay; * * *.

"Mawys" or "mavis" as a dialectic name has lasted down to the present day in the counties of east England. It seems curious that it was not transferred to any American thrush, notably the wood thrush. "Osel" is clearly the parent word of the modern "ousel" and in this latter form is still applied to an allied species of the European blackbird—the ring-ousel (*T. torquatus*), as well as to a distinct, though related, family—the dippers or water ousels (Cinclidæ).

Without doubt the word "thrasher," applied to the birds of the American genus *Toxostoma*, is a varient of "thrush" and "throstle," for we find "thrushel" and "thrusher" as variants in the provincial English dialects. The term "thrasher" occurs in Barton's Fragments (1799), and Wilson also uses the name as a vernacular in his

account of the brown thrush or "ferruginous thrush" (*Toxostoma rufum*) as he calls it, both of which facts are clear evidence as to the early current use of this common name for the species in question. Catesby figures the bird under the title "fox-colored thrush" (I, 28). In the South it is known here and there as the "sandy mocker" and formerly as the "French mockingbird," this last from the fact that its song was considered inferior to that of the true mockingbird (*Mimus polyglottos*)—all things French being regarded with a certain contempt by the English colonists. There is a curious suggestion of the throstle's song in the song of our brown thrasher, a fact also noted by Wilson, and this may have given rise to the current vernacular name.

In a metrical vocabulary, supposedly of the fourteenth century, "sparrow" appears in its modern form; likewise "larke," "pye" (the magpie, "mag" being a contraction of "magot" or "madge," a feminine name formerly bestowed upon this bird), "revyn" (raven), "parthryd," and "quale." "Jay" also appears in its present day spelling and with its Latin equivalent *Graculusque*, which may be the origin of our modern word "grackle." "Jay" is from old French "gai" equivalent to "gay" (plumage).

In a *Nominale*, or list of words, of fifteenth century date we find "wagsterd" (wagtail), "nuthage" (nuthatch), and "buntyle" (bunting). In a curious pictorial vocabulary, also of the fifteenth century, "kingfisher" appears as "kynges-fychere" and "woodpecker" as "wodake" or "woodhock." Our "redstart" evidently received its name by suggestion from a very different bird of the Old World (*Ruticilla phœnicurus*). It is so called by Catesby (I, 67). "Start" is from Anglo-Saxon "steort," a tail. "Titmouse" has been transferred to various American species of the family (Catesby figures the "crested titmouse," I, 57), the prefix "tit" meaning small. "Mouse" is from Anglo-Saxon *máse*, a name, according to Skeat, for several kinds of small birds, and not to be confounded with the mammal of the same name. Hence, the plural "titmouses," not "titmice," is the proper form, though usage has established it otherwise. "Shrike" is another name transferred from European to allied American species. The name probably had its origin in the voice of this bird or of some thrush, and later bestowed upon the members of the Laniidæ (see Newton, Dict. of Birds, 843). "Martin" (and its older form "Martlet") was evidently a nickname applied to a European swallow (*Chelidon urbica*) and given by the colonists to our species of the genus *Progne*. Bartram calls the bird "The great purple martin."

"Blackbird," applied to certain American species of Icteridæ, is a name suggested purely by color. Catesby early gave to our *Agelaius phœniceus* its more nearly correct title of "Red-wing'd

starling" (I, 13). Kalm (Forster) uses the older form "stare" (Eng. Trans., II, 73–79) and likewise refers to the species of *Quiscalus* as "blackbirds," remarking that "The English call them *blackbirds*" (Eng. Trans., I, 291). Our goldfinch appears first in Catesby as "The American goldfinch" (I, 43), the name clearly borrowed from the Old World *Carduelis elegans.* "Siskin" in like manner comes from the Old World, the word being originally of Scandinavian origin and meaning "chirper" or "piper." "Snow bunting" is the old name of *Plectrophenax nivalis* and should rightly replace the fanciful "snowflake," Our "tree sparrow" is the result of a confusion of the American species (*Spizella monticola*) with the mountain or tree sparrow of Europe (*Passer montanus*). This was corrected by Pennant, but the name "tree" was retained.

A rather curious case of name transfer is that of our yellow-breasted chat (*Icteria virens*). The bird first appears under this title in Catesby's Work (I, 50), and was evidently so called by him in a mistaken idea that it was related to the birds of the same name belonging to the European genus *Saxicola.* This fact is made evident by the Latin word *œnanthe* used in the descriptive designation.

The name "buzzard" as applied to the turkey vulture appears early in the literature of American birds. Catesby calls it "turkey buzzard" (I, 6). As an old English name of Norman French derivation (*Busard*, Latin *Buteo*) it had, as Newton points out (Dict. of Birds, 767), a definite meaning in relation to the old sport of "hawking." Birds of the genera *Buteo* and *Circus* (Harrier) were styled "buzzards" (more especially the species of the former genus), of slow and heavy flight, and "were regarded with infinite scorn, and hence in common English to call a man a buzzard is to denounce him as stupid." With the exception of eagles and owls and a few kites all birds of prey in this country are termed "hawks," and "buzzard" has been relegated to this slow-moving, carrion-feeding species.

II. NAMES DERIVED FROM A LATIN EQUIVALENT.

Several of our English bird names have come into every day speech by the anglicizing of their generic titles. The Linnæan genus *Oriolus* (from "Oriole," Latin *aurum*, *gold*) included certain species of Icteridæ, which though very different from the European *Oriolus galbula*, still bear its name. "Junco" and "Vireo" are anglicized generic names. The word "grackle" applied to certain species of our Icteridæ appears to be an anglicized word derived from the Linnæan genus *Gracula.* The word originally referred to the daw or jackdaw of Europe and the relationship between the American birds and the European species, though somewhat distant, was recognized by early writers. *Quiscalus quiscula* appears in

Catesby as "The purple jackdaw" (I, 12). Bartram calls it the "Lesser purple jackdaw or crow blackbird" (the first notice I have found of this last common name). Wilson calls it the "purple grackle," from which source it has without doubt spread into the current vernacular of ornithology, though not into the speech of the people at large.*

The name "parula" recently in vogue for the warblers of the genus *Compsothlypis* is clearly borrowed from the old Bonaparte genus *Parula* (diminutive of titmouse). The bird (*C. americana*) has appeared under various titles—"the finch creeper" of Catesby (I, 64), "the various-colored little finch creeper" of Bartram (Travels, 292), and the "blue yellow-backed warbler" of Wilson, Audubon, and later authors.

In "Kinglet" we have a word rendered into English from the generic name *Regulus* (Cuvier), though its use is somewhat recent, "wren" being the vernacular designation of the species of *Regulus* until a comparatively late period. Edwards (Gleanings, V, 95) refers to the species as "Le Roitelet" (also Buffon).

"Tanager" is another derived word from the Linnæan genus *Tanagra*, probably of Brazilian origin (Marcgrave, Hist. Rer. Nat. Bras., 214).

III. NAMES SUGGESTED BY VOICE.

In this group, and in the ones that follow, the vernacular names are more specific in their nature, indicative of some peculiar feature or habit of a species. Bird voices have been embodied from the earliest times in various expressive syllables which have given rise to a variety of names. "Cuckoo" was one of these, and in like manner "wren," "crow," and other bird names of the Old World. The babble of our voluble chat, as we have seen, undoubtedly led Catesby to ally the bird with a group of very different species. In America the colonists soon found names by which to designate a number of birds from peculiarities in their vocal performances. Latham speaks of the "Phœbe-bird" (*Sayornis fuscus*), unquestionably given him by some trans-Atlantic correspondent. Our name "pewee" is given "pewit" by Bartram. Wilson named the "wood pewee" (*Contopus virens*) from its voice and its habitat.

The older writers give "rice bird" as the chief caption of *Dolichonyx oxyzivorus* (Catesby, I, 14) and Bartram calls the male "the pied rice bird." Wilson calls it "rice bird," but mentions its other names, "boblink" and "reed bird." Nuttall, as a good New Englander, gives "bob-o-link" as its principal name, and Barton, in his Fragments, has "bob-lincoln." I find this last title also in a sketch of the English writer William Hazlitt (1785). These

are the earliest references I can find to this song name of the bird which appears to have been early in use throughout New York and New England.

Among the current specific appelations of certain sparrows some recent changes are noteworthy.

The "yellow winged sparrow" of Wilson is now the "grasshopper sparrow," the first allusion to its grasshopper-like notes being, as far as I can find, in Coues's Birds of the Northwest (p. 133). We owe the attractive name of "vesper sparrow" to John Burroughs (Wake Robin), which has superseded the older "grass finch" of Pennant and Gmelin and the "bay-winged finch" of Wilson. The "chipping sparrow" is through Wilson from the earlier "little house sparrow or chipping bird" of Bartram. "Song sparrow" unquestionably originated through Wilson, as also the specific title *melodia*. Catesby (I, 34) figures and describes "the towhe-bird" (*Pipilo erythrophthalmus*). Wilson speaks of its name in Pennsylvania as "chewink." "Towhee" is a later form of the word by adding an additional "e." "Swamp robin" and (in Virginia) "bulfinch" are other names mentioned by Wilson.

"Pipit" is an old English name applied to the titlarks (*Anthus*) and is derived through "peep" from "pipe," imitative of the bird's note.

Catesby calls the mockingbird (*Mimus polyglottos*) "The mock bird," though Bartram gives it its modern form. "Catbird" appears as such in Catesby (I, 66) and Bartram adds "chicken bird" as a synonym (Travels, 290). "Chickadee" as a general imitative vernacular name for the species of *Parus* I find first in Audubon. The name "veery," given to the tawny thrush (*Turdus fuscescens*) in imitation of its note, is first used as a synonym by Nuttall.

"Warbler," as a general term for small song birds of the Old World family Sylviidæ, has come down from a word in several of the old European tongues (Old French, Old High German, Middle English—*Werbler*, *Werbelen*), meaning to whirl, run around, warble, as a bird (Skeat). In its special application to the species of *Sylvia*, which we owe to Pennant (1773), it included the American warblers (Mniotiltidæ) which were later separated as a distinct family (Sylvicolidæ) under the title of "wood warblers." "Wood warbler," however, has not prevailed, and "warbler" continues to be the current vernacular for the various species of this characteristic American family, though, as we are well aware, the name belies the insect-like notes, drawling monotones, lispings, and wheezing performances of the majority of the species. A few do really warble in the accepted sense of the term (*Geothlypis*), but most speak in a tongue peculiarly their own.

Kalm (Travels, Eng. Trans., II, 151) speaks of "whip-poor-will" as the English name of *Antrostomus vociferus*. A confusion appears in Bartram (Travels, 292), who has it "night hawk or whip-poor-will." *Antrostomus carolinensis* is called by Bartram (292) "the great bat, or chuck wills widow." "Night hawk" is given by Wilson, though this species (*Chordeiles virginianus*) appears to have been described by Catesby under the name of "the goatsucker of Carolina" (I, 8).

Colinus virginianus has long proclaimed his proper title of "bob white," which has now become the accepted name of the species, superseding the older and less distinctive terms of "quail" and "partridge."

IV. NAMES SUGGESTED BY SOME PECULIAR HABIT OR HABITAT.

"Flycatcher" is a name of obvious application given to an Old World group of birds. From the peculiar habits of certain American species the term "tyrant flycatchers" has become current. The "kingbird" is first so called by Bartram. Catesby figures the species as "the tyrant," whence the name of general application. Wilson speaks of its name in Maryland as the "field martin," and "bee martin" is another name in certain localities.

"Gnatcatcher" is a name that first appears in Audubon, from the Swainsonian genus *Culicivora*. The species (*Polioptila cœrulea*) was originally "the little bluish gray wren" of Bartram (Travels, 291), and later the "small blue gray flycatcher" of Wilson (A. O., II, 164)."

Several species of warblers early received names indicative of peculiar habits. The worm-eating warbler (*Helmitheros vermivorus*) of Wilson and later authors was originally "the worm-eater" (Edwards, Gleanings), from Bartram; also Latham and Pennant from the same source. The pine-creeping warbler (*Dendroica vigorsi*) of Wilson was the "pine creeper" of Catesby (I, 61). Edwards (Gleanings, 92), quoting a letter from Bartram, says of *Seiurus aurocapillus* that it "builds its nest upon the ground, and always chooses the south side of a hill; that it makes a hole in the leaves, like a little oven, and lines it with dry grass," etc. This is the first reference I have found of the familiar vernacular "ovenbird," although Edwards calls the species "golden-crowned thrush." "Water thrush" and "wagtail" were names early given to the other species of the genus, and Pennant speaks of one as the "New York warbler" (Arct. Zoöl., II, 308), whence its old specific name of *noveboracensis*. The vernacular "myrtle bird" first appears in Nuttall, hence probably "myrtle warbler" of authors, though early accounts speak of the bird's fondness for the berries of the wax myrtle (*Myrica*). Catesby calls it "the yellowrump" (I, 58) and

Edwards (Glean., VI, pl. 298) "the golden-crowned flycatcher." The magnolia warbler was found by Wilson "among the magnolias, not far from Fort Adams, on the Mississippi." He called it the "black and yellow warbler, *Sylvia Magnolia*" (A. O., III, 63), hence "magnolia warbler" of later authors. *Dendroica palmarum*, the "palm warbler" of Latham (Synop., II, 491), is the "yellow red pole" of Edwards (*Parus aureus vertice rubio* of Bartram and the "yellow red-poll warbler" of Wilson. Wilson called *Dendroica discolor* the "prairie warbler" from the open tracts of Kentucky where he first found it.

Of the sparrows, several species have received names indicative of habitat. The "little field sparrow" of Bartram became the "field sparrow" of Wilson and later authors ("bush sparrow" of Burroughs). Wilson first bestowed the vernacular title of "swamp sparrow" upon *Melospiza georgiana*, though it was known to Bartram as "the reed sparrow." In like manner the name "seaside finch" was given by Wilson to *Ammodramus maritimus* from habitat (A. O., IV, 68). *Junco hyemalis* was called "snowbird" by the early settlers, from the fact of its appearance in the late autumn and at the onset of winter in the coastal plain region (Catesby, Kalm, Wilson, and later authors). "Junco" is a comparatively late adoption in order to avoid confusion with the snow bunting, *Plectrophenax nivalis*.

The "house wren" is so called by Bartram (Travels, 291) and the "marsh wren" likewise (the latter most likely referring to the long-billed species). Wilson, correcting earlier errors, gave the title "winter wren" to *T. hiemalis*.

"Chimney swallow" is an old name for the "chimney swift" (*Chætura pelagica*) and is given as such by Kalm, Bartram, and early writers.

"*T. melodes*, the wood thrush," is so called by Bartram (Travels, 290). Wilson named the "hermit thrush" (*T. solitaria*, A. O., V., 95) from its habitat and its retiring habits.

The Cowbird was "the cow-pen bird" of Catesby (I, 34) and likewise of Audubon, and the "cow bunting" of Wilson. "Meadow lark" first appears in Wilson. Bartram calls it "the great meadow lark," and Catesby "the large lark" (I, 33). Pennant, nearer the truth, calls it the "crescent stare" (Arct. Zoöl., 192). Wilson also speaks of "old field lark" as its common name in Virginia. The "shore lark" is so called by Pennant. Catesby calls it "the lark" (I, 32), Bartram the "skylark," and Wilson the "horned lark."

Several of our American swallows received names indicative of habit or habitat. "Barn swallow" originated as a specific title with Barton (*horreorum*, Fragments, 1799). It was the "house swallow" of Bartram. The bank swallow is the "bank martin" of Bartram.

"Cliff" and "eave" swallow are names of *Petrochelidon lunifrons* according to the particular nesting site adopted by this species. I have failed to find any early reference to the name "tree swallow" for *T. bicolor*, the "white-bellied swallow" of earlier authors. It appears to have come into use at a comparatively late period.

Bartram speaks of *Ampelis cedrorum* as "crown bird" or cedar bird" (Travels, 290), the latter its current name.

V. NAMES SUGGESTED BY COLOR OR OTHER EXTERNAL FEATURE.

A large number of our American bird names owe their origin to color or to some conspicuous external feature. The "great crested flycatcher" of Wilson is the "great crested yellow-bellied flycatcher" of Bartram and "the crested flycatcher" of Catesby (I, 52). The word "great" evidently originated with Bartram. "Baltimore," as applied in the vernacular to *Icterus galbula*, was first used in ornithological literature by Catesby—"The Baltimore bird" (I, 48)—the name being derived from its color pattern, that of the livery of the Calverts (Lord Baltimore). Bartram calls it "Baltimore bird or hang nest." The specific appellation "orchard" appears first to have been bestowed by Wilson upon *Icterus spurius*, which was the "bastard Baltimore" of Catesby (I, 49). Wilson goes to some length to set things right concerning this species. "Scarlet," as applied to the tanager (*Piranga erythromelas*) appears first in Edwards (Gleanings, 343) as the "scarlet sparrow." Pennant calls this species "Canada tanager." The "summer redbird" is so called and figured by Catesby (I, 56). Bartram speaks of it as the "sandhill redbird of Carolina." Among the sparrows and grosbeaks there are a number of species, the names of which have a color origin. "Red poll," given to a species of *Acanthis*, appears as the "lesser red-headed linnet" and "lesser redpole," of Ray and Pennant. "Linnet" is an ancient name common in several European languages and is in reference to the fondness of these birds for the seeds of the flax (*Linum*). Bartram undoubtedly refers to this species (*Acanthis linaria*) under the name of "hemp bird." "Purple," as applied to *Carpodacus purpureus* first appears in Catesby's work (I, 41) as "purple finch" and is a monumental witness of an inability to properly discriminate either between two very different shades of color or in the use of the right word. "White-throated sparrow" is so called by Edwards from a drawing of the species sent him by Bartram, who speaks of it in his Travels as "The large brown white-throat sparrow." *Zonotrichia leucophrys* is the "white-crowned bunting" of Pennant. The vernacular of *Passerella iliaca* has been contracted from the earlier "fox-colored" (or "colored") to simple "fox sparrow." Bartram calls it "the red or fox-colored

ground or hedge sparrow." Barton, in his Fragments, speaks of this species' name in New York as "the shepherd" (Fragments, 15). Our modern "cardinal" is undoubtedly of French origin. Catesby gives it its English title of "red bird" and also "Le Cardinal" (I, 38). It is "the red bird or Virginia nightingale" of Bartram and other early writers. Catesby figures *Guiraca cærulea* as "the blew grosbeak" (I, 39). "Rose-breasted" (Wilson) may be traced to *Le Rose Gorge* of Buffon and "red-breasted grosbeak" of Pennant. *Passerina cyanea* is "the blew linnet" of Catesby (I, 45), who further alludes to it as the "indigo bird of Americans." The "painted finch" (*P. ciris*) is so called by Catesby, and Bartram likewise adds its other title of "nonpariel." "Lazuli" was bestowed upon *P. amœna* by Say (Long's Exp., II, 47, 1823).

Pennant first uses the name "black-throated bunting" for *Spiza americana*, but Bartram mentions this species under the title "*Calandra pratensis*, the May bird" (Travels, 291). "Dickcissel," its modern name, appears to have originated through Mr. Robert Ridgway from Middle West localities (Coues, Birds of the North West, 166). Wilson borrowed the term "sharp-tailed" for *Ammodramus caudacutus* from Turton (Syst., 562). "Lark," as applied to two species of Fringillidæ—*Chondestes grammacus* and *Calamospiza melanocorys*—was bestowed upon these different birds, in the one case by Say and in the other by Townsend, in view of their lark-like appearance and habits.

Among the warblers we have a host of color names. "Mourning warbler" we owe to its discoverer, Wilson. The summer warbler or "yellow warbler" (*Dendroica aestiva*) was "the yellow titmouse" of Catesby (I, 63), "the summer yellow bird" of Bartram, the "yellow poll" of Latham and Pennant and the "blue-eyed yellow warbler" of Wilson. Say first described the orange-crowned warbler (*Helminthophila celata*) (Long's Exp., 1823). *Mniotilta varia* was the "black and white creeper" of Edwards (Glean., VI, received from Bartram who gave it its name). In his Travels Bartram calls it the "blue and white striped or pied creeper" (p. 289). Of the prothonotary warbler Pennant (Arct. Zoöl., II, 30) says: "Inhabits *Louisiana*. Called there *le Protonotaria;* but the reason has not reached us." Probably in allusion to the vestures of that office. Many species of warblers were earlier known by the various names of "flycatcher," "titmouse," and "creeper," according to their peculiar habits, the specific vernacular being mainly in relation to color. *Dendroica cœrulescens* was the "blue flycatcher" of Edwards (Glean., pl. 252, received from Bartram); the "black-throat" of Pennant (Arct. Zool., II, 285); the "black-throated warbler" of Latham, and the "black-throated blue warbler" as first applied by Wilson. Wilson first named the "caerulean warbler." The "black poll warbler"

appears as such in Latham and Pennant, "poll" or "pole" being an early name for "head" as in our "poll tax." The "yellow-throated warbler" (*D. dominica*) was "the yellow-throated creeper" of Catesby (I, 61). The "blue-winged yellow warbler" (*Helminthophila pinus*) was formerly confused with the "pine creeper" of Catesby (*D. vigorsii*), hence *pinus* as applied to this species of *Helminthophila*. Its vernacular is a clear translation by Wilson of Bartram's "*Parus aureus alis ceruleis*, blue-winged yellow bird." In like manner *H. chrysoptera* was the "*Parus alis aureus*" of Bartram, the "golden-winged flycatcher" of Edwards (from Bartram), and the "golden-winged warbler" of Wilson and later authors. Wilson first bestowed the names "bay-breasted" and "chestnut-sided" upon *D. castanea* and *D. pensylvanica*. The former was Bartram's "little chocolate breast titmouse" (Travels, 292) and the latter his "golden crown flycatcher." This last species, also, was the "red-throated flycatcher" of Edwards and the "bloody-side warbler" of Turton as a result of Edwards's badly colored plate. *D. virens* was the "green black-throated flycatcher" of Bartram and the "black-throated green flycatcher" of Edwards (Glean., VI, pl. 300, from Bartram). The "hooded warbler" (*Sylvania mitrata*) is figured by Catesby under the name of "the hooded titmouse" (I, 60).

"Black-cap titmouse" is Bartram's name for the species (*Parus atricapillus*) and probably also its near relative *P. carolinensis*. The "olive-backed thrush" was first so-called by Giraud (Birds of Long Island, 1844, 92). *T. fuscescens* was called "tawny thrush" by Wilson. "Bluebird" is an early name. The species is figured by Catesby (I, 47) as "the blew-bird." Pennant called it the "blue-backed red-breast" (Arct. Zool., II, 91). *Lanius ludovicianus* was called the "logger head shrike" or "loggerhead" by Wilson, as its common name in the South.

Most of our species of woodpeckers early received their names from color markings or other external feature, as "red-headed," "yellow-bellied," "golden-winged," "pileated," "downy," "hairy," "ivory-billed," etc. The word "flicker," as a vernacular of *Colaptes auratus*, probably originated from the bird's call notes. It is referred to by Wilson.

VI. NAMES SUGGESTED BY LOCALITY (PLACE-NAMES) OR IN HONOR OF SOME PERSON.

A curious misapprehension as to the significance of the current English name of *Ammodramus sandwichensis savanna* seems to exist in ornithological literature as revealed by its orthography. Wilson distinctly refers to the city of Savannah as the locality where he states he first discovered the species (A. O., III, 55) and he so spells its name in the English title. Its specific name, however,

he gives as "savanna." In our current literature this last appears as the method of spelling the bird's name in English, which is clearly misleading. In its general application "savanna" might be very appropriate in view of the species' habitat, but Wilson intended it otherwise, and "Savannah sparrow" is the proper form of the English name.

The term "evening" in the vernacular of *Hesperiphona vespertina* as given to the species by Cooper (Annals N. Y. Lyceum Nat. Hist., I, 220) conveys, as does the scientific name, the idea of the west or the place of sunset.

Geothlypis trichas was called by Bartram "the olive colored yellowthroated wren" (Travels, 292). Of the bird's present English name I find the following interesting reference in Edward's Gleanings (V, 57): "J. Petiver, in his Gazophylacium, plate vi, has given the figure of a bird, which I believe to be the same with this; for which reason I continue the name he has given it * * * '*Avis Marylandica gutture luteo*, the Maryland yellowthroat. This the Rev. Mr. H. Jones sent me from Maryland.'" Edwards later received the bird from Bartram with a drawing "very neatly and exactly done, by Mr. William Bartram, of Pennsylvania, who hath enabled me to give a further account of this bird, for he says it frequents thickets and low bushes by runs (of water, I suppose, he means) and low grounds; it leaves Pennsylvania at the approach of winter, and is supposed to go to a warmer climate."

To Wilson we owe the place names of five of our species of warblers—the Kentucky, Connecticut, Tennessee, Nashville, and Cape May—from the State or locality of the first capture by him of the species in question. John Cassin named a species of Vireo "Philadelphia" after the city in the neighborhood of which he obtained his type specimen.

Thryothorus ludovicianus obtained its vernacular through Bartram—"(regulus magnus) the great wren of Carolina" (Travels, 291). This Wilson transposed into "Great Carolina wren."

The "Blackburnian warbler" is so called by Pennant and Latham, and was named in honor of Mrs. Hugh Blackburn, of London.

A number of our birds acquired their names in the first half of the last century in honor of certain persons known to their describers, as Lincoln's, Henslow's, LeConte's, and Harris's sparrows; Townsend's, Audubon's, Swainson's, and Bachman's warblers; Lewis's woodpecker; Clark's nutcracker; Steller's and Woodhouse's jays, and many others of early and recent date.

"Louisiana," as applied to the species of tanager (*Piranga ludoviciana*), and the water thrush (*Seiurus motacilla*) refers to the

region embraced in the Louisiana Purchase, not to the present State of that name. "Florida," "Canada," "California," "Hudsonian," and other regional names have in like manner been applied to certain species, as "Florida jay," "Canada jay," "Canadian warbler," "California woodpecker," Hudsonian chickadee," and so forth.

The matter as presented in the foregoing sketch does not pretend to list all of the species and varieties of North American land birds. It is only a sketch or outline of a most attractive subject and was written partly for the purpose of gathering together what knowledge we have of the history and origin of our more familiar bird names.

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GREAT BROWN BEAR OF THE ALASKAN PENINSULA (URSUS GYAS MERRIAM). NATIONAL ZOOLOGICAL PARK, WASHINGTON, D. C. WEIGHT MARCH 21, 1908, 1,050 POUNDS.

CONDITION OF WILD LIFE IN ALASKA.[a]

[With 1 plate.]

By Madison Grant.

The opening of the twentieth century found the game in the old territories of the United States well on the road toward the conditions that precede extinction. The bison had been practically gone for two decades. The mountain sheep had been exterminated throughout a very large part of its original range, and the number remaining in remote mountains was sadly reduced. The wapiti, while still living in herds numbering many thousand, was rapidly withdrawing to the vicinity of its last refuge, the Yellowstone Park. The prong-horn of the plains was disappearing with increasing rapidity, partly due to the increasing use of the barb-wire fences on its former ranges.

This rapid diminution of the game animals of the United States was, and is to-day, the inevitable consequence of the settlement and occupation of the best grazing lands. While there remain mountains where the game is relatively undisturbed, so far as the killing of individuals is concerned, and while these ranges in summer appear well adapted to sustain a large and varied fauna, their actual capacity to sustain life is limited to such animals as can there find sustenance during the heavy snows of winter.

Before the arrival of white men, the animals, which lived in the mountains during the summer, sought refuge in the sheltered valleys and foothills during the cold season. These favored localities, however, were at once occupied by settlers, and the game was deprived of its winter feeding grounds. In my opinion, this has done more in recent years to exterminate the large animals of the West than the actual shooting of individuals.

During the closing years of the nineteenth century the American people had obtained no little experience in game protection, and had embodied it in Federal statutes and the game laws of the various

[a] Reprinted by permission from the Twelfth Annual Report of the New York Zoological Society, 1907. New York, January, 1908.

States. Of all the regulations established for the preservation of wild life, the most practical and effective have been found to be, first, the prohibition of hide and head hunting; second, the prohibition of market hunting; third, and most important of all, the establishment of sanctuaries where game could roam and breed absolutely undisturbed. The most conspicuous example of such refuges is the Yellowstone Park, the unquestioned success of which is admitted on all sides.

At the end of the century, the gold discovered in the extreme northwest of Canada and in Alaska brought these territories suddenly before the public eye. Here was a district of enormous extent, lying at the extreme limit of the continent, and populated by a large and varied fauna, which was practically undisturbed. During the last ten years thousands of prospectors and miners have gone into Alaska, and in many places worked havoc with the game. On the whole, however, the destruction of the game has not yet gone far enough to permanently injure the fauna of the region, provided the matter of protection is taken in hand scientifically and in the immediate future.

We have in Alaska a gigantic preserve. In it there are not only several species rich in the numbers of their individual members, but also certain species which in point of size appear to be the very culmination of their respective genera, as, for example, the giant moose. The brown bear group of southern Alaska certainly contains the largest bears in the world, not even excepting the great fish bear of Kamchatka or the extinct cave bear of Europe. The largest known wolves are found in northern Alaska, and a wolverine of exceptional size has been recently described. When this great game region was first opened up immediate legislation was needed to protect the animals from the deliberate onslaught of hide hunters in southeastern Alaska; of head hunters, who attacked the moose, sheep, and caribou of the Kenai Peninsula, and of the market hunters generally throughout the coast regions. A game law, which certainly proved effective in making it difficult for sportsmen to hunt in Alaska, was passed, and a revision of this statute is now before Congress. It is not the intention to discuss in this paper the details of the proposed legislation, beyond saying that the measure is proposed by the friends of animal life in Alaska, and has the support of the best interests in that Territory.

The general principles of game protection applicable to the situation in Alaska are simple. It should be clearly understood that the game of Alaska, or of any other region, does not belong exclusively to the human inhabitants of that particular region, and that neither the white settlers nor the native inhabitants have any inherent right to the game other than that conferred by law. The interest of the

entire people of the United States, and to some extent that of the civilized world, is centered in the continued existence of the forms of animal life which have come down to us from an immense antiquity through the slow process of evolution. It is no longer generally conceded that the local inhabitants of any given district have a divine commission to pollute the streams with sawdust, to destroy the forests by axe or fire, or to slaughter every living thing within reach of rifle, trap, or poisoned bait. This must be thoroughly understood in advance. The game and the forests belong to the nation and not to the individual, and the use of them by the individual citizen is limited to such privileges as may be accorded him by law. The mere fact that he has the power to destroy without interference by the law does not in itself confer a right. The destruction of game is far more often effected by local residents than it is by visiting sportsmen, but the chief evil doer, and the public enemy of all classes is the professional hunter, either Indian or white, who kills for the market. Worse still, perhaps, is the professional dealer in heads and antlers, who employs such hunters to provide game heads for the decoration of the banquet halls of the growing class of would-be sportsmen, who enjoy the suggestion of hunting prowess conferred by a selected collection of purchased heads, mixed in with those of their own killing.

However efficient the game laws may be in limiting the killing to a given number of individuals, and to certain seasons of the year, or, better still, to the adult males of certain species, the only permanently effective way to continue in abundance and in individual vigor any species of game is to establish proper sanctuaries, as thoroughly controlled as the Yellowstone Park, and these must contain both summer and winter ranges. In such areas no hunting or trapping, nor perhaps even dogs, should be allowed; and in them the game will then retain its native habits and breed freely, while the overflow would populate the adjoining districts. This principle has been applied in East Africa with brilliant success, where a protected strip of land on either side of the Uganda Railway is now absolutely swarming with game.

Such preserves should be set aside in Alaska, while land is yet of little value. Districts should be selected where there is but little, if any, mineral wealth; and there are abundant areas of that description in Alaska. Certain islands should also be utilized, particularly in southeastern Alaska. Beyond doubt such refuges will be ultimately established, but it is to be hoped that it can be done before the game has been decimated and the forests cut down or burned.

Another element in game protection is the relation of the Indian to the wild game. This problem is not as serious in Alaska as it is in parts of British Columbia and the Canadian Northwest, and is settling itself by the rapid decline of the Indian population. Indians,

after they have been in contact with white men, certainly are extremely destructive to animal life. An Indian with a gun will shoot at anything he sees until his ammunition is gone. They seem to be entirely devoid of any idea of economy in slaughtering, even though they know that they are certain to suffer from starvation as a result of their indiscriminate waste of game. Any legislation, therefore, that gives Indians privileges superior to the whites is not based on scientific but on sentimental considerations.

To exempt Indians from the limitation of game laws in a district partly inhabited by white men, simply puts the white hunter at a disadvantage, and always results in a contempt for the law on the part of the latter. If an Indian is allowed to hunt freely during the closed season, he is usually employed by whites for market hunting. The game he kills finds its way to the white man's market rather than to the teepees of the tribe, or is used as food by the Indian's dogs, with the ultimate result that the food supply of the entire tribe is killed off for the benefit of a few hunters.

The Indians of Alaska have, in the abundance of salmon, a food supply which is available throughout the most of the district, and are consequently not entitled to any special privileges. Alaska is, and for a long time should remain, the ward of the Federal Government—however distasteful such a course may be to some of its inhabitants. It is peculiarly the duty of the Federal Government to preserve and control the wild game of this national domain, because the people of the United States as a whole are the ones most interested in its preservation. It is to Congress, rather than to the residents of Alaska, that we must look for the enactment and enforcement of suitable laws, and to avail of the last great opportunity to preserve our native fauna on a large scale. We no doubt in the future shall restore game and perhaps forests to many districts now stripped of both, but in Alaska we have our last chance to preserve and protect rather than to restore.

The claim made by many western communities, that local state laws are sufficient, is being daily disproved by the inability of several States to control the small game supply left within their own borders. Colorado is a notable example of the rapid diminution of game under state control, where female deer and fawns are now being killed under the laws of the State. In Canada, British Columbia prides itself on the efficiency of its game laws, but the game is rapidly vanishing there, although in the eastern portion of that province it is the Stoney Indians, rather than white hunters, who are the chief destroyers.

From the point of view of game conditions, Alaska is divided into two entirely distinct regions. First the coast region, from Portland Canal along the base of the mountains northward and then westward to and including the Aleutian Islands. The second region comprises

the interior beyond the mountains, and is coextensive with the region drained by the Yukon River and its various branches.

The conditions in these two regions differ widely, and practically all the sportsmen who go to Alaska hunt in the coast region. Those who cross into the interior are apt to confine their shooting to the headwaters of the Yukon in Canadian territory.

The game on the coast between Portland Canal and Mount St. Elias consists principally of bear and the small Sitka deer. There is an abundance of goat on the mainland close enough to salt water to be easily reached.

To reach moose, caribou, or sheep from the southeastern coast requires a journey over the mountains into British Columbia, which is seldom attempted, except from Fort Wrangell at the mouth of the Stikeen River.

West of the St. Elias Alps and around Cook Inlet the principal game animals are the giant moose and white sheep of the Kenai Peninsula, the caribou and bear of the Alaska Peninsula, and the bear of some of the large islands, notably Kodiak. It is in this district that the game laws require close attention and rigid enforcement.

In the vast interior the strict enforcement of game laws is not so important, because the entire region drained by the Yukon is covered with heavy forests, and the population is largely confined to the waterways.

Black bear, lynx, and moose are everywhere abundant, but seldom seen along the Yukon River. Sheep are accessible from points on the upper Yukon, notably at Eagle, and caribou occasionally cross the river in herds.

The game laws for this district should aim principally at the prevention of slaughter on a large scale for market purposes, and of hide and head hunting. There are very few sportsmen, and the miners and prospectors in the interior are difficult to control.

Wolves.—Wolves are abundant in Vancouver Island and throughout the interior. In the north, around the region drained by the Porcupine River, they assume very large dimensions, some skins measuring nearly 6 feet from nose to tip of tail; and a large percentage of these wolves are black. Coyotes have pushed north from the American boundary as far as White Horse, at the headwaters of the Yukon River.

Foxes.—Red, cross, silver, and black foxes occur in the interior. The two latter command enormous prices, in some cases as high as $1,000 for one skin. These animals are being killed off by the use of poison in the hands of white men, and many more are destroyed than are recovered. The natives are afraid to use poison, owing to several tragedies which have occurred from its careless handling.

Along the Arctic and Bering Sea coast white foxes abound, and blue foxes are found from the mouth of the Yukon River southward, their center of abundance being Nelson Island, in Bering Sea, near the mouth of the Kuskokwim River.

Bear.—Bear are extremely abundant in Alaska, especially on the Pacific coast. Their great numbers are probably due to the fact that they have an abundant food supply in the great schools of salmon that ascend the rivers. Before the arrival of the salmon, these bear, like the grizzlies of our own Rockies, fed on spermophiles and grass. During the salmon season they are easily found and killed by hunters, and as this occurs during the summer season, their fur is of very little value. The period of the salmon run, in fact the entire summer, should be made a closed season for bear throughout this district. Owing to the recent decline in the price of bear skins these splendid animals have been hunted rather less than formerly.

The black bear occur in Vancouver and Queen Charlotte islands, but, as far as I know, do not occur in any of the large islands north. They are, however, found along the mainland of the southeastern coast, and found everywhere throughout the interior in the timbered region. The blue or glacier bear is found rarely around the glaciers of the Mount St. Elias region.

Grizzlies occur in considerable numbers along the mainland of the coast as far north as Skagway, and are found in relatively small numbers throughout the interior. There are very few grizzly bear on the Seward Peninsula, and I was unable to get any skulls or to obtain any definite data concerning them. This bear may prove an interesting type if a sufficient series of specimens could be obtained.

There is a huge bear found on the large islands around Juneau and Sitka which has been described as a separate species, and its numbers are indicated by the fact that about 75 animals, the majority being of this species, are killed annually around Juneau.

The brown bear group extends from this point westward along the south coast of Alaska, out into the Alaska Peninsula. Several species have been described, but they can all be safely grouped together under the common designation of Alaska brown bear. They extend far up the Copper River, but I could not obtain any definite record of the occurrence of members of this group north of the mountain region and in the area drained by the Yukon.

Polar bear occur quite abundantly north of Bering Straits. Occasionally they are found on the Seward Peninsula, and occur as far south as St. Matthew Island, in the middle of Bering Sea.

Caribou.—Caribou of several species are found more or less numerously throughout Alaska, and occur in herds around the upper Yukon, with localities of especial abundance, such as the head of Forty Mile River. An examination of the antlers found at

various points, from the upper Yukon River to the sea, would indicate an almost complete transition of antler type from the woodland (Osborn) caribou, to the barren ground (Grant) caribou. A further study of the caribou of this region will ultimately lead to a merging of the various species. The work of Charles Sheldon, who is now studying sheep in the Mount McKinley district, has broken down the specific distinction of the sheep in Alaska in the same way.

That caribou were formerly very abundant on the Seward Peninsula is proved by the abundance of bleached skulls and cast antlers, apparently about 20 or 25 years old. The cause of their disappearance is as yet an unsolved problem. The possession of firearms by the natives, first obtained from whalers, is by some considered as the cause, and by others epidemic. The natives themselves claim that about a generation ago the winter cold continued throughout an entire year, and all the caribou perished in consequence. All these explanations leave much to be desired, as there is an abundance of caribou in the wooded district at the eastern end of the peninsula, and the explanation of the fact that in the course of all these years the caribou have not wandered back to their old feeding grounds remains a mystery. A few scattered individuals at the very most are all that have been seen since the founding of Nome, seven or eight years ago.

Domestic reindeer have been introduced into Alaska successfully, and form a valuable resource for the natives. I, however, saw nothing of them beyond the fact that their meat forms a part of the menu in the various restaurants at Nome.

Moose.—Moose occur everywhere throughout Alaska within the timbered region, but seldom leave the shelter of the woods. They extend close to the Arctic Ocean in the north, and occasionally wander far out on the Alaska Peninsula. The giant moose occurs on the Kenai Peninsula, but it is probable that this animal is only an outlying member of the type species, which in that district, for some unknown reason, produces antlers of extraordinary size and complexity. A few instances of moose with antlers of great size are known in the interior, but it is a matter of doubt whether or not in bodily size the Kenai Peninsula moose excels that of his kin in the interior or in the Yukon territory.

Mountain sheep.—Sheep occur everywhere in the mountain regions throughout Alaska, being especially abundant in the country around the upper Yukon and around Mount McKinley, extending thence as far south and west as the Kenai Peninsula. They also occur on the upper Porcupine River, but the great Yukon Valley in its lower reaches is without sheep.

Mountain goat.—Goat occur throughout the mainland from the American boundary north, but are never found, as far as I know, on any of the islands lying close along the coast in southeastern

Alaska. In size and abundance the mountain goat appears to culminate in the region around the White Horse Pass, where they are very abundant. They can still be seen within a half day's march of Skagway. They occur in abundance around the St. Elias Alps, and extend as far west as the head of Cook Inlet. I only heard of one doubtful case of Kennedy's goat, the horns of which have been described as lyrate.

Walrus and whales.—Walrus are found every winter and spring in the Bering Sea, and many are killed at that season by the natives for the ivory, which sells at a dollar a pound. The walrus formerly extended down to the Alaska Peninsula and Aleutian Islands, but the rookeries there have been destroyed. This great mammal should receive absolute protection in the entire Bering Sea region, except on the Pribilof Islands, where only a few are annually killed by the natives.

Whales and porpoises occur in great abundance along the inside passage between Puget Sound and Lynn Canal and are interesting and harmless. There are now two plants on Vancouver Island very profitably engaged in killing whale of all sizes and converting them into fertilizer. A new plant has just been established near Juneau, where whales are especially abundant. It would be an easy matter to protect these animals, especially with the cooperation of the Canadian authorities, throughout the inland passages and oceanward as far as the 3-mile limit. Protective legislation of this sort should be urged.

Fossils.—In any review of the present game conditions of the vast territory comprised within the district of Alaska and the Canadian territory of the Yukon, a few remarks on the former occurrence of related forms are not without interest.

Bones of large extinct mammals, more or less fossilized, occur in abundance throughout the entire valley drained by the Yukon River from Dawson down, and in the valleys of the Colville and Porcupine rivers, and in still greater abundance on the Seward Peninsula, that projection of Alaska which reaches to within 60 miles of Siberia. Throughout this enormous area remains of the mammoth and bison occur in such numbers as to indicate former herds of great size. We find also a smaller number of remains of horses, sheep, and at least two species of musk ox, together with a deer closely related to our wapiti. Teeth of mastodon, although very rare as compared with those of the mammoth, indicate the former existence of that animal. It is perfectly evident that in times comparatively recent, from a geological point of view, perhaps from ten to twenty-five thousand years ago, Alaska had a fauna of large mammals not altogether dissimilar to existing animals of North America and northern Asia. The mastodon and mammoth, of course, no longer exist on this con-

tinent, but the latter is little more than a hairy relative of the Indian elephant, thoroughly fitted to meet boreal conditions, and the horses in Alaska were probably not unlike the wild Prjevalsky horses of Asia to-day.

The ancient Alaskan deer were probably related to the wapiti, which swarmed over our American plains within the memory of living man, and the fossil remains of caribou and moose do not indicate any great departure from the living forms of those animals.

Sheep still occur abundantly in Alaska, and the musk ox, while no longer found in Alaska, inhabits the no less inhospitable regions of the Barren Grounds of North America and the land masses lying still farther north.

Bison skulls are quite common, and indicate an animal much larger, but probably ancestral to our living buffalo. The history of the American bison, which migrated in summer as far north as the Saskatchewan and southward in winter to the Mexican border, suggests that it is quite possible that these animals did not habitually spend the winter in Alaska, but on the approach of the cold season migrated southward to warmer climates, or crossed into Siberia on the former land connection over what are now Bering Straits. If this hypothesis be correct, the climate of Alaska during the Pleistocene and recent periods may not have radically differed from the climate of to-day.

The extension of placer mining in Alaska, when conducted in a more systematic manner than at present, will undoubtedly bring to light other forms of large mammals, most probably types related to those already mentioned, together with the remains of carnivorous types.

RECENT DISCOVERIES BEARING ON THE ANTIQUITY OF MAN IN EUROPE.

[With 18 plates.]

By George Grant MacCurdy, Yale University.

INTRODUCTION.

Every ten years our Government takes a census. This happens to be the year in which it is done. It is also good policy for a science, especially if it is a relatively new one, to take a periodical account of stock. The science of prehistoric anthropology need have no fear of the satisfactory outcome of such a test at this time. I have been asked to be the census taker for the European field, and consider myself fortunate, not only in the field, but also in the period to be covered. Nowhere else has the prehistoric, the whole problem of man's antiquity, been studied with such thoroughness and with such happy results. Of the nearly one hundred years since prehistoric archeology began to take shape and to grow into what is now becoming a real science, no decade has shown a more satisfactory record than the one just closed. To its achievements the present paper is devoted.

How are we to measure the growth of the decade in question? The correct result requires a knowledge not only of what is now known but also of what was known in 1900. The annual output in the way of publications is one of the best gauges of activity, of the rate of progress in a given subject. Ten years ago the prehistoric output was well provided for in the journals dealing with anthropology in general, in the proceedings of periodical congresses, the transactions of local societies, and occasional special publications. These channels continue to be utilized in increasing ratio, which ordinarily would meet the requirements of a healthy, steady growth. But they have not sufficed. New and more highly specialized journals have sprung into existence, new prehistoric societies and congresses have been organized, and special publications financed. At this moment I do not recall a single purely prehistoric European journal of importance

dating back to 1900. Of those founded since then, there should be mentioned: L'Homme Préhistorique (Paris), a monthly founded in 1903; La Revue Préhistorique (Paris), a monthly founded in 1906; Praehistorische Zeitschrift (Berlin), founded in 1909; Mannus, Zeitschrift für Vorgeschichte, Organ der Deutschen Gesellschaft für Vorgeschichte (Würzburg), founded in 1909. In December, 1903, the Société Préhistorique de France was founded. It publishes a monthly bulletin; also in 1906 a handbook appeared, Manuel de Recherches Préhistoriques, and since 1905 has held a congress annually, each compte rendu of which forms a large volume of about a thousand pages.

In addition to these new channels, there should be mentioned certain special publications made possible through the generosity of patrons of the science, either private individuals or learned societies. One of these, the joint work of de Villeneuve, Verneau, and Boule, and entitled "Les Grottes de Grimaldi [a] (Baoussé-Roussé)," was due to the initiative of Prince Albert I. of Monaco. The latter is at present promoting a new and important project, which might be styled a paleolithic survey of northern Spain. The work is in charge of a committee consisting of Hermilio Alcalde del Rio, P. Lorenzo Sierra, Abbé Henri Breuil, Abbé Jean Bouyssonie, and Dr. Hugo Obermaier. The report of last summer's campaign [b] is highly gratifying and gives assurance of another publication worthy to rank with that on the caverns of Grimaldi. The Academie des Inscriptions et Belles-Lettres has also become a patron of prehistoric archeology, generously supporting from its funds the joint explorations of French caverns by Cartailhac and Breuil.

This much increased literary output presupposes a corresponding activity in the field, the museum, and the study. A record of the explorations in the field alone would far surpass the limits of this paper. The results have been so comprehensive, so cumulative in their effect, that only the alert have been able to keep pace with the progress. It has been a period of intensive study as well as of generalization. The careful scientific exploration of new stations has led to a revision of old data and often the re-exploration of old localities.

A list of the more notable achievements would include such items as Rutot's contributions to our knowledge of a pre-Chellean industry; those of Penck relating to man and the glacial period; the discovery of paleolithic human remains at Krapina,[c] Mauer (near Hei-

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[a] Two quarto volumes, Monaco, 1906.

[b] H. Obermaier. Der diluviale Mensch in der Provinz Santander (Spanien). Praehistorische Zeitschrift, vol. 1, 183, 1909.

[c] Station discovered in 1899, but not published comprehensively till 1906.

delberg), Le Moustier, La Chapelle-aux-Saints, Combe-Capelle, Le Pech de l'Azé, and La Ferrassie; the studies of Breuil, Cartailhac, Capitan and others relating to paleolithic mural paintings and engravings; Commont's recent explorations at the classic station of Saint-Acheul; those of Martin and Giraux at La Quina; the researches of Szombathy, Hoernes, and Obermaier in Austria-Hungary, those of R. R. Schmidt [a] and of Wiegers in Germany, and of Bächler in Switzerland. Mention has already been made of the work done in the caverns of Grimaldi and that begun in northern Spain, both under the generous patronage of the Prince of Monaco.

To enumerate all the important stations recently discovered, even of the paleolithic period alone, would require more space than is at my disposal here. There is therefore need of limiting this study chronologically as well as geographically. Excepting the bare mention of quite recent paleolithic discoveries by S. J. Czarnowski [b] in the caverns of Russian Poland, the countries to be included are France and Belgium in the center, with Switzerland and parts of Germany and Austria-Hungary on the east, and Spain to the south. We shall not even cross the channel, as we might well do, for paleolithically England has much in common with France and Belgium, and English students of the period in question have by no means been idle of late.

The time element must also be reduced. The original table of relative chronology provided for an age of stone, of bronze, and of iron. For the present let us ignore the last two. This leaves the stone age, at first applied to the neolithic only, then divided into paleolithic and neolithic, and finally into eolithic, paleolithic, and neolithic. It is a case of the first being last and the last first in more senses than one, for during the past decade there have developed what may well be styled an eolithic school as well as a paleolithic school. Students of the neolithic on the other hand, while particularly active, must still await a more favorable moment for correlation, for crystallization of data. By common consent, then, we shall eliminate the neolithic from the present discussion, with only a passing reference to its place and divisions in the table of relative chronology.

As for the eolithic school, I endeavored five years ago to sum up its work in a paper entitled "The Eolithic Problem." [c] Since then investigations have been carried on almost continuously. Attempts were made to explain away the origin of eoliths by the invocation of flint mills as factories for their wholesale production, but such

[a] E. von Koken and R. R. Schmidt have in preparation a large work to be called "Die paläolithischen Kulturstätten Deutschlands."

[b] Paleolit na zboczu Gory smardzewskiej. Kosmos, vol. 31, Lemberg, 1906.

[c] American Anthropologist, n. s., vol. 7, 425–479, 1905.

attempts seem to have ended in failure. This subject was discussed in my vice-presidential address[a] before section H of the American Association for the Advancement of Science at the New York meeting in 1906. The recent discoveries of eoliths on the plateau of Hautes-Fagnes and at Boncelles, near Liège, by de Munck and Rutot, have an important bearing on this whole subject. At Boncelles eoliths are said to be found in undisturbed middle Oligocene deposits, which is the lowest horizon yet recorded for them.

The fact that the Tasmanians when they became extinct in 1876 were still in a culture stage corresponding to the eolithic has done much to strengthen the thesis of that school. In this connection should be mentioned the discovery by Franz de Zeltner in Haute Senegal of a quite recent industry with eolithic facies. Rutot also finds in Belgium that a neolithic epoch, to which he has given the name "Flénusian," is characterized by a similar industry.

But eoliths were introduced here only to be retired from the stage in order that more space might be given to the doings of the paleolithic school. I can not dismiss them, however, without first referring to Verworn's[b] rule of the one-sided marginal working of a flake or chip. No single character is a sufficient basis for declaring that a given stone object is or is not an artifact. Each specimen should be subjected to a systematic diagnosis, as is a case of fever, for example, by a physician, says Verworn. In observing a number of paleolithic or neolithic scrapers that are made from flakes which are retouched on one side only, one finds that the direction from which the retouching took place is almost always oriented in the same manner with respect to the sides of the flake. If one calls the under or bulb side of the flake the front and the outer side the back, one sees that the blows or the pressure which produced the marginal working was executed almost always from the front toward the back, that the tiny scars left by the chipping begin at the margin and extend over the back. The chipping is therefore visible only from the back; only in rare cases does one find the opposite orientation of the chipping.

What is the meaning of this? There is too much method in it to be the result of chance. There is even more than mere method. By following the rule as expressed in figure 1 *a–c*, we arrive at a tool that is utilizable. The edge produced by the chipping is straight, as seen in figure 1 *c*. On the other hand, if the opposite method of chipping is followed we arrive at a meandering irregular edge-line that is good for nothing from a practical standpoint (fig. 2 *c*). In rare instances the back of the flake may be more regular than the front.

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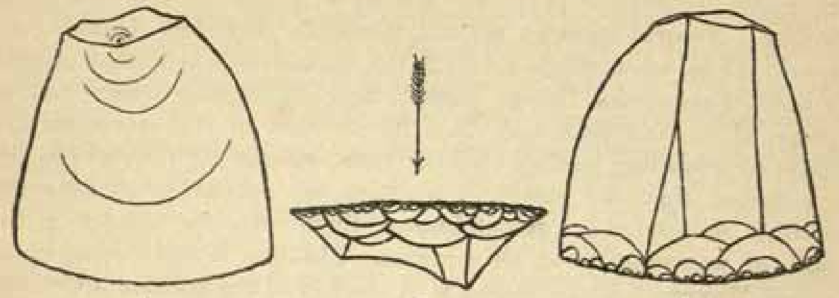
[a] Some phases of prehistoric archeology. Proc. Am. Ass. Adv. Sci., vol. 56, 1907.

[b] Max Verworn. Ein Objectives Kriterium für die Beurteilung der Manufaktnatur geschlagener Feuersteine. Zeit. für Ethnol., vol. 40, 548, 1908.

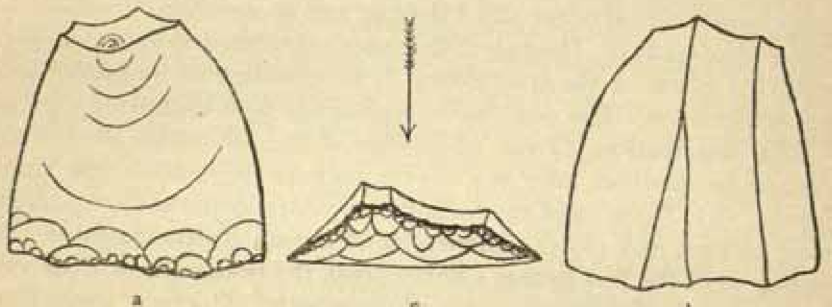
In that case the chipping is done from the back toward the front, as one might expect; a fact which strengthens the theory that the chipping is intentional and not accidental.



a c b

FIG. 1.—Flint flake with one-sided marginal chipping that follows the rule, viz, done from the front toward the back, thus securing an edge every point of which is in the same plane; (a) front, (b) back, (c) looking toward the edge.

Professor Verworn made a tabulation to show the percentage of specimens that follow the rule and of those that do not. He chose



a c b

FIG. 2.—Flint flake with one-sided marginal chipping opposed to the rule, viz, done from the back toward the front, thus producing an irregular edge that is practically useless; (a) front, (b) back, (c) looking toward the edge. After Verworn, Zeit f. eth., Vol. 40, p. 550, 1908.

two series universally recognized as artifacts, comparing them with each other, and later with a series of eoliths from Puy-de-Boudieu (Cantal). His results follow:

Locality.	Total number of pieces examined.	Number that follow the rule.	Number opposed to the rule.
		Per cent.	*Per cent.*
Vézère Valley (Dordogne)	686	654=95.3	32=4.7
Tasmania	92	88=95.7	4=4.3
Puy-de-Boudieu (Cantal)	121	115=95	6=5

This table is as eloquent as figures alone can be. We are forced to the conclusion that the general rule of one-sided marginal chipping, beginning at the edge and extending over the back, is the expression of a distinct definite purpose. We know the reason for it, namely, utility. Natural agencies are not moved by any such definite purpose. Thus, when we find flint flakes, no matter where, that possess a bulb of percussion; when, further, these flakes show series of chippings all on one side, and when 95 per cent of the specimens are chipped according to the rule laid down, we can not then escape the conclusion that the pieces in question are artifacts. Among the eolithic industries at present known, there are only two where the bulb of percussion is at all common. The first is the Cantalian of upper Miocene age, the second is at the top of the eolithic series, the so-called Mesvinian at the summit of the lower Quaternary.

Before definitely lopping off the first and third divisions of the stone age, it would be well to note their position and relative weight in the chronological scale. A table of classification in harmony with the teachings of both Rutot and Penck is reproduced in plate 1. It will be seen that the eolithic probably begins with the middle Oligocene,[a] reappears in the Miocene and Pliocene, and is carried up through the lower Quaternary. The paleolithic, once considered as commensurate with the whole of the Quaternary, is now limited to its middle and upper horizons. The neolithic is confined to post-Quaternary times.

The contributions to our knowledge of the paleolithic during the decade in question may for convenience be grouped under three heads: (1) Those relating to finds in valley deposits; (2) cavern explorations, and (3) the discoveries of human skeletal remains. As examples of the first group, I have chosen the researches of Commont at Saint-Acheul (France) and of Szombathy, Hoernes, and Obermaier at Willendorf (Austria-Hungary).

VALLEY DEPOSITS.

The housing and transporting required by modern civilization have led to the discovery of the culture levels attained by our paleolithic forebears. At Saint-Acheul the deposits of the Somme Valley have been exploited since 1771 at least. They yield not only material for building purposes, but also sand for foundries and flint for road metal. The first discovery of a paleolithic industry at Saint-Acheul was made by Doctor Rigollot in 1854, following on and inspired by Boucher de Perthes's discoveries at Abbeville. Then came Gaudry, Prestwich, and Evans, all now dead. Explorations at Saint-Acheul have been carried on for the past twenty-five years by d'Acy. The most active investigator on the ground at present is V. Commont, whose systematic work there covers a period of nearly ten years.

[a] The writer spent a day at Boncelles but failed to find an eolith.

This table is as eloquent as figures alone can be. We are forced to the conclusion that the general rule of one-sided marginal chipping, beginning at the edge and extending over the back, is the expression of a distinct definite purpose. We know the reason for it, namely, utility. Natural agencies are not moved by any such definite purpose. Thus, when we find flint flakes, no matter where, that possess a bulb of percussion; when, further, these flakes show series of chippings all on one side, and when 95 per cent of the specimens are chipped according to the rule laid down, we can not then escape the conclusion that the pieces in question are artifacts. Among the eolithic industries at present known, there are only two where the bulb of percussion is at all common. The first is the Cantalian of upper Miocene age, the second is at the top of the eolithic series, the so-called Mesvinian at the summit of the lower Quaternary.

Before definitely lopping off the first and third divisions of the stone age, it would be well to note their position and relative weight in the chronological scale. A table of classification in harmony with the teachings of both Rutot and Penck is reproduced in plate 1. It will be seen that the eolithic probably begins with the middle Oligocene,[a] reappears in the Miocene and Pliocene, and is carried up through the lower Quaternary. The paleolithic, once considered as commensurate with the whole of the Quaternary, is now limited to its middle and upper horizons. The neolithic is confined to post-Quaternary times.

The contributions to our knowledge of the paleolithic during the decade in question may for convenience be grouped under three heads: (1) Those relating to finds in valley deposits; (2) cavern explorations, and (3) the discoveries of human skeletal remains. As examples of the first group, I have chosen the researches of Commont at Saint-Acheul (France) and of Szombathy, Hoernes, and Obermaier at Willendorf (Austria-Hungary).

VALLEY DEPOSITS.

The housing and transporting required by modern civilization have led to the discovery of the culture levels attained by our paleolithic forebears. At Saint-Acheul the deposits of the Somme Valley have been exploited since 1771 at least. They yield not only material for building purposes, but also sand for foundries and flint for road metal. The first discovery of a paleolithic industry at Saint-Acheul was made by Doctor Rigollot in 1854, following on and inspired by Boucher de Perthes's discoveries at Abbeville. Then came Gaudry, Prestwich, and Evans, all now dead. Explorations at Saint-Acheul have been carried on for the past twenty-five years by d'Acy. The most active investigator on the ground at present is V. Commont, whose systematic work there covers a period of nearly ten years.

[a] The writer spent a day at Boncelles but failed to find an eolith.

		Geological periods.	Glacial and interglacial epochs.	Fauna.	Human remains.	Cultural epochs.	Type stations.	
		Recent.	Postglacial.	Existing fauna.	Neolithic races. Ofnet.	Omalian. Robenhausian. Campignian. Flénusian. Tardenoisian. Azylian (transition).	Omal, Belgium. Robenhausen, Switzerland. Le Campigny (Seine-Inférieure). Flénu, Belgium. Fère-en-Tardenois (Aisne). Mas d'Azil (Ariège).	Neolithic.
Quaternary.	Upper.	Flandrian (loess).	Daun Stage. Gschnitz Stage. Bühl Stage.	Reindeer. Bison.	Cro-Magnon, Grimaldi.	Upper Magdalenian. Middle Magdalenian. Lower Magdalenian. Upper Solutrean. Lower Solutrean. Upper Aurignacian. Middle Aurignacian. Lower Aurignacian. Upper Mousterian. Middle Mousterian. Lower Mousterian.	La Madeleine (Dordogne). Solutré (Saône-et-Loire). Aurignac (Haute-Garonne). Le Moustier (Dordogne).	Upper Paleolithic.
		Brabantian (loess).	Würm glacial (Wisconsin).	Equus caballus.	Placard. Grimaldi (Negroid). Combe-Capelle, La Chapelle-aux-Saints, Krapina, Spy, Neandertal, La Ferrassie, Homo mousteriensis.			
	Middle.	Hesbayan (Sand loess).	Riss-Würm interglacial.	Ursus spelaeus. Elephas primigenius.				
		Campinian (Old Diluvium).	Riss glacial (Illinoisan).	Rhinoceros tichorhinus.	Bury Saint-Edmunds.	Upper Acheulian. Lower Acheulian. Chellean. Strépyan.	Saint-Acheul (Somme). Chelles (Seine-et-Marne). Strépy, Belgium.	Lower Paleolithic.
	Lower.	Mosean (Old Diluvium).	Mindel-Riss interglacial. Mindel glacial (Kansan).	Rhinoceros merckii. Elephas antiquus.	Homo heidelbergensis.	Mesvinian. Maffiean. Reutelian.	Mesvin, Belgium. Maffle, Belgium. Reutel, Belgium.	Eolithic.
Tertiary.	Pliocene.	Upper.	Günz-Mindel interglacial.	Elephas meridionalis.		Saint-Prestian.	Saint-Prest (Eure-et-Loir).	
		Middle.	Günz glacial (Pre-Kansan).					
		Lower.				Kentian.	Kent, England.	
	Miocene.	Upper.		Hipparion, Dinotherium.		Cantalian.	Puy-Courny (Cantal).	
		Middle.						
		Lower.						
	Oligocene.	Upper.						
		Middle.				Fagnian (doubtful).	Hautes-Fagnes, Belgium.	
		Lower.						

RELATIVE CHRONOLOGY OF THE STONE AGE.

Commont has recently made two important discoveries: (1) A very productive station at rue Cagny, and (2) an ancient paleolithic workshop at the base of the Tellier gravel-pit. In 1906 an excavation for a factory site was made near the first pits that produced so many Chellean and Acheulian implements for the early explorers. It covered an area of 30 by 55 meters. Here Commont found in three months' time 540 implements of the Chellean and Acheulian types and 500 various objects, such as flakes, nuclei, and small implements, made from chips. It is indeed rare that so many specimens have been found in valley deposits covering such a small area.

In the workshop near the base of the Tellier gravel-pit, Commont found (1) many flint nodules prepared for chipping (débitage) and showing traces of the beginning of chipping, (2) a quantity of flint cores (nuclei) of all dimensions, (3) hammerstones of various forms, for the most part only slightly used, (4) 5,000 flint chips, (5) large flakes prepared for the production of special types of implements, (6) small implements derived from the large flakes, and (7) large implements of various forms, some only partly finished or broken in the process of manufacture. The patina of the flints of this workshop is a white mat, different from that of the Acheulian above. At the top of the same deposit that covered the workshop, Commont found a series of implements without patina, made of black (flint) or grey flint, that looked as fresh as if they had been made yesterday. The fauna of this deposit includes *Elephas antiquus*, large horse, *Bos*.

Section of the Tellier quarry: (1) Lower sands and gravels, rude industry, eolithic and Strépyan facies; (2) red sands, paleolithic workshop showing transition from Chellean to Acheulian I; (3) upper part of limon rouge (red clay), Acheulian II with white patina; (4) thin layer of white sands (base of ergeron) replacing the usual flinty layer (cailloutis), Mousterian industry, and small Acheulian implements with bluish patina; (5) lower part of brick earth, Magdalenian industry; (6) at the top of the brick earth, neolithic.

The deposits of the Tellier pit are 10 meters thick, their base being about 44 meters above sea level. The section is the most complete and instructive one at Saint-Acheul, especially in respect to the upper layers, in these even surpassing the famous section at the exploitation Helin, near Spiennes, Belgium. In fact, each section not only confirms, but also supplements the story told by the other. In each, all the Quaternary epochs except the Brabantian are represented. A section of one will suffice therefore for both. I have chosen for illustration (fig. 3) the exploitation Helin explored by Rutot in 1902. In the Helin section the lower Quaternary is represented by two distinct eolithic horizons—the Maflean and Mesvinian. Above these come the paleolithic horizons in regular order—

Strépyan, Chellean, and Achuelian I. But the deposits in which one might expect to find the Mousterian, Aurignacian, Solutréan, and Magdalenian are either sterile or absent. In the Tellier section at Saint-Achuel, we find not only the eolithic, Strépyan, Chellean, and Acheulian I industries in regular section, but also Acheulian II, Mousterian, and Magdalenian in stratigraphic position, the only industries absent being the Aurignacian and Solutréan.

Fortunately for the science, other valley deposits supply the industries that are missing from Helin and Saint-Acheul. Among the paleolithic stations of lower Austria, those situated in the loess at Willendorf, left bank of the Danube, about 20 kilometers above Krems, are exceedingly productive. Until 1908 only two stations

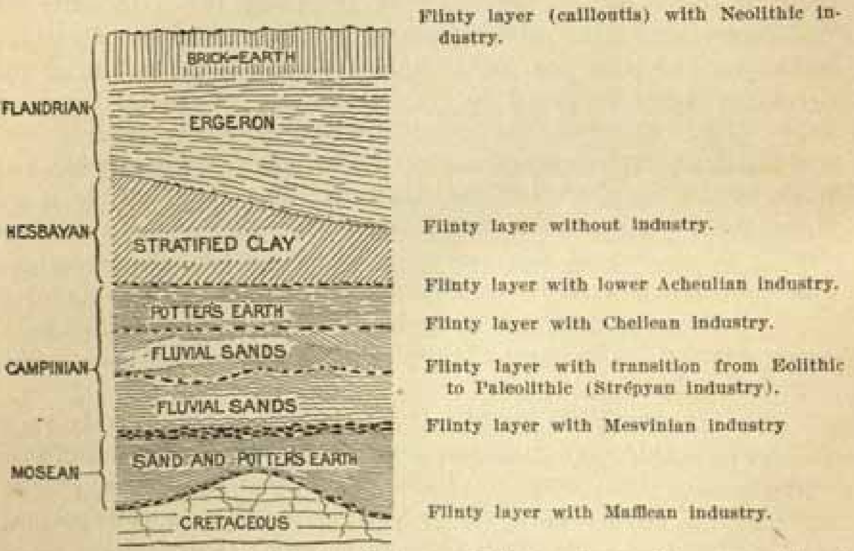


FIG. 3.—Section of the Exploitation Helin, near Spiennes, showing the superposition of the Quaternary deposits and industrial horizons; lower terrace of the valley of the Trouille (after Rutot).

were known, the Grossenstein brick works to the south and the Ebner brick works north of the village. Recently the opening of a railroad from Krems to Grein uncovered seven more stations in the vicinity of Willendorf. One of these is near the Grossenstein brick works; a second, explored in 1908 by Drs. H. Obermaier and J. Bayer, seems to be the continuation of the Ebner station. This second station is at present the most important of all. Here nine superimposed culture layers were determined. The loess deposits at this station are about 18 to 20 meters thick.

The culture horizons are situated from 2 to 8 meters below the surface. They are recognized by a brownish color and the presence of charcoal as opposed to the light yellow color of the rest of the loess.

Each layer varies in thickness from 10 centimeters to 30 or 40 centimeters. In section the thicker parts appear like nests and are marked by the presence of hearths. About these hearths are found bones and stone implements in large numbers. These artifacts and bones are not confined to the culture layers only, but here and there occur in the alternating layers. Seven meters below the lowest culture layer, and about 3 meters above loess bottom, there were found a hornstone chip with traces of utilization (possibly an eolith) and a fragment of bone.

The lowest (first) culture-bearing layer is characterized by a very crude industry made of materials not utilized in the upper layers. Charcoal and a few bone fragments also occur. Fauna: Reindeer and bison.

Second layer: Varieties of quartz and jasper; also Danube River stone used as hammer-stones, a poor quality of flint, and incomplete examples of the lower Aurignacian type. Fauna: Reindeer, bison, wolf.

Third layer: Industry similar to that of second layer in respect to forms as well as the kinds of materials used, and characterized by the appearance of the keel-shaped scraper.

Fourth layer: Abundance of small keel-shaped scrapers, whitish-gray patinated hornstone; bone points, both blunt and sharp; a stag antler with end hollowed out for insertion of a stone implement. Fauna: Mammoth, reindeer, stag.

Fifth layer: Rich in well-fashioned hornstone implements. Especially noteworthy are the hornstone points (à tranchant rabattu). Fauna: Mammoth, reindeer, stag.

Sixth, seventh, and eighth layers: Hornstone points (à tranchant rabattu). In the seventh layer an Aurignacian bone point with cleft base. Appearance of the forerunners of the Solutréan laurel-leaf point, pieces of reindeer horn that served as haftings for stone implements. Fauna: Mammoth, horse, reindeer, cave lion, wolf.

Ninth layer: Rich and beautiful stone industry of the upper Aurignacian types. Points with lateral notch at the base. The most important piece of all was a female statuette of stone—the so-called Venus of Willendorf (pl. 2, fig. *a*). The piece was found in the yellow loess 25 centimeters below a charcoal stratum belonging to the ninth layer and near a hearth of this layer. Szombathy, Bayer, and Obermaier were all present when the discovery was made. The figure is 11 centimeters high and complete in every respect. It is carved from fine porous oölitic limestone. Some of the red color with which it was painted still adheres to it. It represents a fat pregnant woman with large pendent mammæ and large hips, but no real steatopygy. It corresponds closely in form to the Venus of Brassempouy, an ivory figurine of Aurignacian age from the grotte du

Pape (Landes). The hair is kinky (negroid), the face left unchiseled. The arms are much reduced, the lower arms and hands being represented only in slight relief. The knees are well formed, but below the knees the legs are much shortened, although provided with calves. The entire figurine is proof that the artist was a master at representing the human form and that here he intended to emphasize those parts most closely associated with fecundity. The only suggestion of apparel or ornament is a bracelet on each wrist. The fauna of this horizon includes the mammoth, horse, reindeer, stag, and fox. All nine layers are Aurignacian, with a transition to Solutréan at the top. It was my good fortune to be in Vienna the week the Venus of Willendorf arrived, and, after the museum staff, to be the first archeologist to examine the specimen.

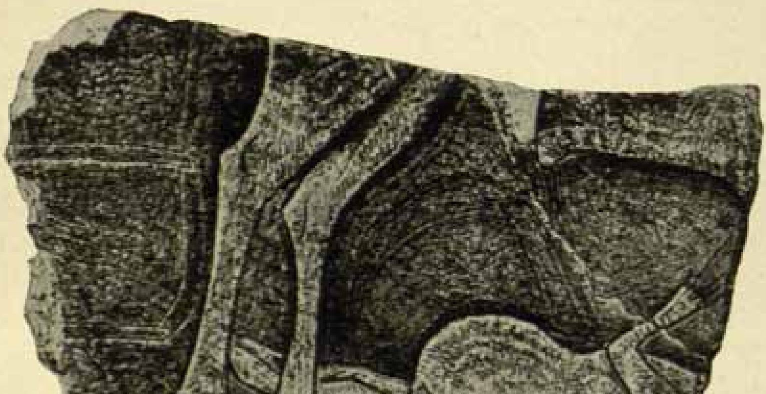
In addition to the Venus of Brassempouy (pl. 2, fig. *b*), the Piette collection includes other female figurines in the same style and from a corresponding horizon. One of these, also from the grotte du Pape, is said to have served as a poinard handle (pl. 3, fig. *a*). The blade formed by the prolongation of the back is broken. Presumably the figure never had been supplied with head and arms. Another example, found in the cavern of Mas-d'Azil (Ariège), is a female bust carved from the incisor of a horse (pl. 3, fig. *b*). This piece is of special importance because of the chiseling of the features, which were lacking in the headless specimens from Brassempouy and also are not differentiated in the Venus of Willendorf. Piette would place in this or an intermediate group the bas relief from Laugerie-Basse, carved on a reindeer palm and representing a human female near the feet of a reindeer (pl. 2, fig. *c*). The skin being almost completely hidden beneath a hairy coating indicated by incised lines, there was no need of apparel. Ornaments, however, are not lacking. Besides bracelets recalling those worn by the Venus of Willendorf, there is a necklace. Curiously enough, in the same Aurignacian layer at Brassempouy that furnished the adipose type with pendent breasts were found figurines belonging to a distinctly different class, representing a slender, probably superior race. The best single example of this class is the femme à la capuche (pl. 4). The long slender neck calls for a body and legs to match, and these are seen in other figures from the same horizon.

The discovery by Prof. Otto Schoetensack of a human lower jaw in the lower Quaternary sands at Mauer, near Heidelberg, rightly comes in the category of valley deposit finds. We have chosen, however, to reserve it for the general discussion of human remains.

A combination of the three stations—Helin, Saint-Acheul and Willendorf—not only gives us every paleolithic horizon, the transitional Tourassian or Asylian alone excepted, in stratigraphic position, but also determines their position with respect to the eolithic below

a.

b.



c.

FIG. a. VENUS OF WILLENDORF. ⅔. AFTER SZOMBATHY, KORRESP.-BL., 40, P. 87, 1909.
FIG. b. VENUS OF BRASSEMPOUY. ½. AFTER PIETTE, L'ANTHR., 6, PL. 1, 1895.
FIG. c. WOMAN AND REINDEER FROM LAUGERIE-BASSE, L'ANTHR., 6, PL. 5, 1895.

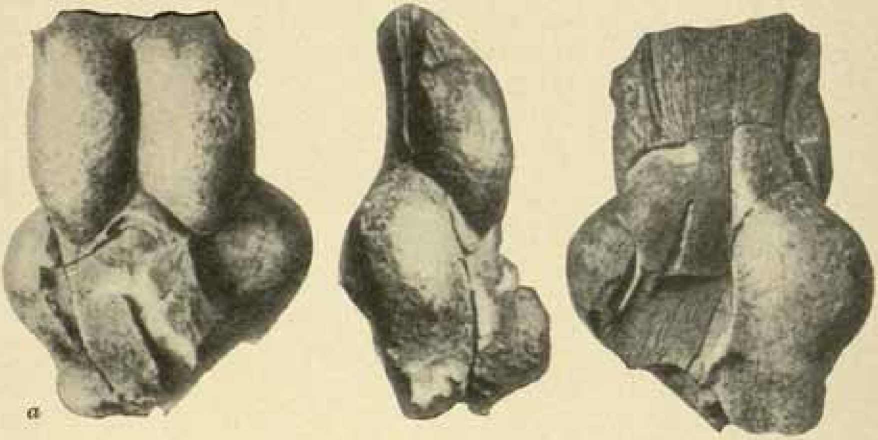
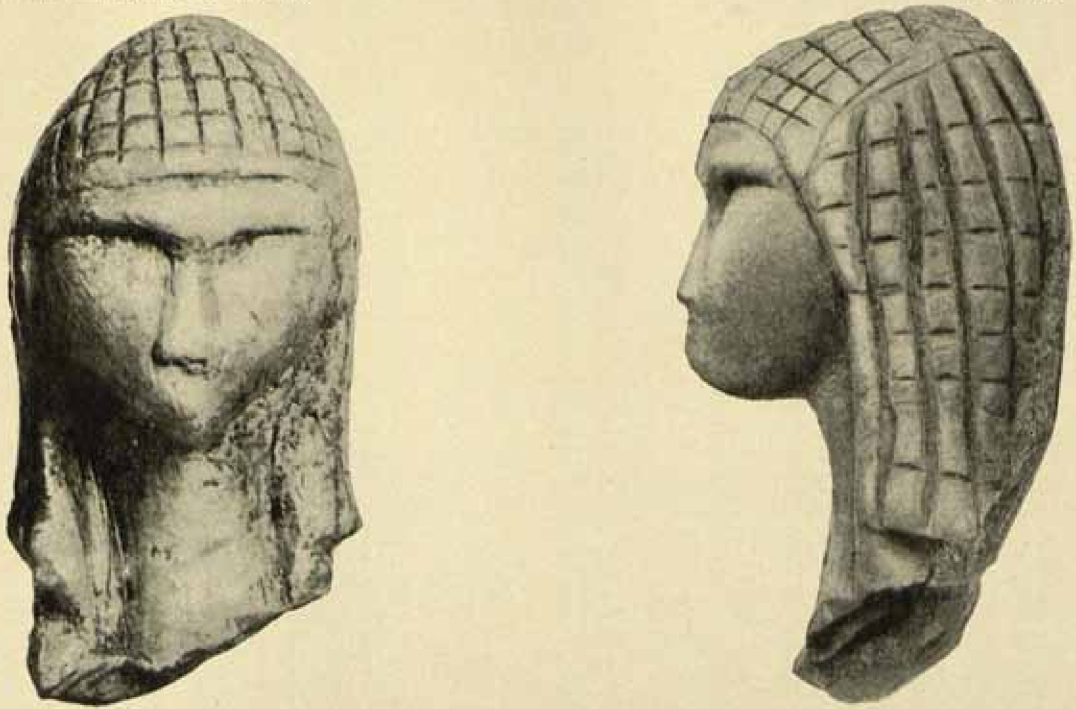


FIG. *a*. FEMALE TORSO, FROM BRASSEMPOUY. $\frac{1}{1}$.
FIG. *b*. FEMALE BUST, FROM MAS D'AZIL. $\frac{1}{1}$. AFTER PIETTE, L'ANTHR., 6, PL. 4, 1895.



HOODED FEMALE FIGURINE (FIGURINE À LA CAPUCHE), FROM BRASSEMPOUY. ENLARGED. AFTER PIETTE, L'ANTHR., 6, PL. 6, 1895.

and the neolithic above. This is the sort of evidence on which the science of prehistoric European archeology rests.

CAVERNS AND ROCK-SHELTERS.

Turning to the paleolithic caverns and rock-shelters, we find confirmatory evidence, although there is no direct stratigraphic relation between the superimposed cavern deposits and those of the river valleys. The chasm, we believe, is safely bridged, however, by the combined evidence of faunal and industrial remains. The results accumulated in the past decade of cavern exploration have been even more remarkable than those due to the investigation of valley sites. Like the researches of Commont at Saint-Acheul, much time has been given by cavern explorers to regions and even stations already well known. As examples there may be cited the caverns of Grimaldi, Le Moustier (Dordogne), and Altamira, Spain.

Rock-shelters and caves seem to have been employed as habitations before the close of the Acheulian epoch and continued to be so used thereafter throughout the paleolithic. A study of their floor deposits reveals a succession of culture levels corresponding to those found in valley deposits and classed as upper paleolithic.

The rock-shelter of La Quina (Charente), already mentioned, deserves more than a passing notice. Known since 1872 and often visited by archeologists bent on increasing their collections, La Quina came into the possession of Dr. Henri Martin in 1905, since which time he, with the help of friends, including M. Louis Giraux,[a] has carried on excavations that have led to important results.

Beginning at the bottom the section is composed of the following: (1) Alluvial sands deposited by the Voultron, a tributary of the Gironde, at the summit of which are found certain elements of an industry with Acheulian facies; (2) two clay deposits, the lower sandy and of a greenish tint, the upper dark. The contact between these is the so-called couche à ossements utilisés, which is also rich in a pure Mousterian stone industry; (3) a barren layer formed by débris from the one-time overhanging cliff; (4) vegetal earth.

Particular attention is called to the utilized bones, a subject treated in part 1 of a quarto memoir in preparation by Doctor Martin.[b] The traces of utilization are bunched incisions usually nearly transverse to the long axis of the bone. The bones and parts of bone thus marked belong to five categories: (1) The lower extremity of the humerus of the horse and certain bovidæ; (2) the first phalanx of

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[a] The Yale University Museum is indebted to M. Giraux for a gift collection from La Quina, comprising stone industry as well as utilized bones.

[b] Recherches sur l'évolution du Moustérien dans le gisement de La Quina (Charente). 1r fasc.: Ossements utilisés. In 4°, Schleicher Frères, 1907.

the horse; (3) first phalanges of the bison and other ruminants; (4) metacarpals and metatarsals of the horse and reindeer; (5) fragments of the shafts of long bones. In some cases the bone resembles a veritable miniature chopping block. In every instance it would offer a solid support for an object to be cut, scraped, or chipped, as the case might be.

Similar incisions could have been produced by pressing a flint chip or flake against a fresh bone at the proper angle to produce the marginal chipping so characteristic of the stone industry at the station in question, as has been noted by M. A. de Mortillet. Since Martin's discovery at La Quina, bones utilized in similar fashion have been found by Favraud at Petit-Puymoyen, and Pont-Neuf (Cha-

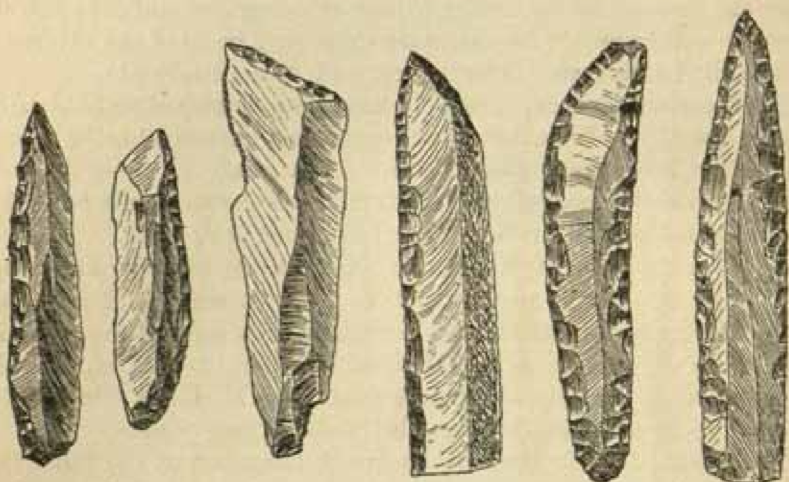

Fig. 4.—Flint implements, from the Aurignacian horizon in the cavern of Les Cottés (Vienne). ½. After Breuil, Rev. de l'Ecole d'anthr. de Paris, Vol. 16, p. 56, 1906. R. de Rochebrune collection.

rente), also by Dr. Eugène Pittard at the Mousterian station of Rebières (Dordogne). Petit-Puymoyen is of Mousterian age, while Pont-Neuf is Aurignacian.

The rehabilitation of the Aurignacian epoch and the determination of its stratigraphic position between the Mousterian and Solutréan instead of between the Solutréan and Magdalenian, where it had been placed for a brief period by G. de Mortillet,[a] is one of the special recent contributions to the credit of cavern explorers, Cartailhac and Breuil suggesting that the old name be revived. Once and for a long period rejected by the builders it has suddenly become one of the chief corner stones in the temple of classification. Its

[a] Compte-rendu, Acad. des Sci., Paris, vol. 68, March 1, 1869.

presence is reported from many localities both in loess deposits and in caverns.

Aurignacian industry is characterized by blade-like flint flakes with one end chipped obliquely and the back worked down (rabattu) for its entire length; flakes chipped along both margins and producing in some instances hour-glass forms; the appearance of two types of bone implements, (1) scrapers terminating in an oblique edge and (2) points with cleft base; the beginnings of sculpture, engraving, and painting, and, according to Rutot at least, the dawn of ceramic art. In respect to fauna, this is the epoch in which the reindeer first becomes prominent. The cave bear, horse (abundant), hyena, and mammoth are also well represented. The direct superposition

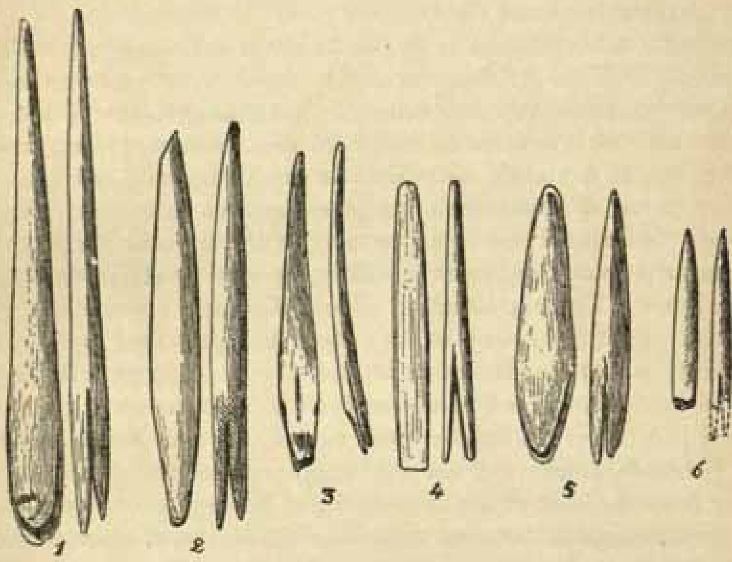

Fig. 5.—Points with cleft base, from the Aurignacian horizon, cavern of Les Cottés (Vienne). ½. Material, ivory and reindeer horn. After Breuil, Rev. de l'Ecole d'anthr. de Paris, Vol. 16, p. 54, 1906. R. de Rochebrune collection.

of the Aurignacian on the Mousterian is seen to good advantage in the caverns of Grimaldi, at Pair-non-Pair (Gironde), Spy (Belgium), Chatelperron (Allier), La Quina (Charente), and Les Cottés (Vienne). On the other hand, the superposition of the Solutréan on the Aurignacian has been noted at a number of stations including: Cro-Magnon, Combe-Capelle, Le Ruth and Laussel (Dordogne), Solutré (Saône-et-Loire), Lacoste II near Brive (Corrèze), grotte du roc, commune of Sers (Charente), Sirgenstein (Württemberg), Ofnet (Bavaria), and Carmago and Hornos de la Peña, both in the Province of Santander, Spain.

By reason of its bearing on the relation between cavern culture and the glacial period, one of the most important paleolithic discoveries

in recent years is that made by Herr Emil Bächler, director of the Natural History Museum in St. Gallen, Switzerland. The Alpine region had not been considered seriously as a field for paleolithic research, since the latter period closed before the retreat of the glaciers to anything like their present extent. It is true, man might have penetrated into the Alps during an interglacial period, but the evidences of his presence would have been destroyed by the succeeding glaciation. Two stations in Switzerland of the Magdalenian epoch have been known for years, viz., Schweizersbild and Kessierloch, but these are north of the Rhine in Canton Schaffhausen.

It remained for Herr Bächler to make the discovery, some four years ago, of a station of late Mousterian age; not in a valley, or even the foot-hills, but in the Säntis Mountains, which lie between the lakes of Constance and Zürich.

The station in question is on the Ebenalp (above Appenzell) at a height of 1,477 to 1,500 meters. It consists of two caverns, with southeastern exposure, that enter the precipitous face of the rock, and one of which penetrates backward and upward, giving access to the top of the mountain as well as to the Weissbach valley lying to the northwest. The caverns are reached by foot-path from Weissbad, the most frequented one being by way of the gap that separates the Bommenalp from the Ebenalp. This gap was produced by faulting which left the Ebenalp standing about 300 meters above its neighbor. The last part of the way is very steep but protected by a railing. It would, in fact, be absolutely broken at one point were it not for a wooden bridge anchored to the vertical face of the rock. This is at a point just below the first or lower cavern. It is probable, therefore, that paleolithic man did not reach the caverns from this side, but rather from the back of the mountain and by way of the upper cavern. The communication between the two is by means of a narrow ledge. (See pl. 8, fig. *a*.)

These caverns have been known since 1621, and there is a legend to the effect that at a much earlier date they were inhabited by wild men. The little pilgrimage chapel of Wildkirchli that gives its name to the place was founded by Dr. Paulus Ulmann (1613–1680), priest at Appenzell. The chapel is in the lower cavern, and in the upper cavern where the hermit house once stood there is now the Wildkirchli Inn. The last hermit died in 1851, since which time Wildkirchli has been rather a belvedere for mountain climbers than a place of religious pilgrimage. The views are certainly superb and well repay the toilsome ascent. A place so full of the spirit of the past and of natural charms could not well escape the romancer, as witness the last chapters of the historical novel, Ekkehard, by the celebrated German writer, Viktor von Scheffel.

As early as 1861 Rütimeyer announced the presence of bones of *Ursus spelæus* and *Capra* (*ibex* and *rupicapra*) in the floor deposits of Wildkirchli. Before that date the hermits used to pick up bones of the cave bear and sell them to the pilgrims. Bächler began his researches which led to the discovery of a pure Mousterian industry during the winter of 1903–4, and continued them during the two following winters. Winter is the best time to work, as the caverns are then dry, relatively warm, and free from visitors.

The deposits are about 5 meters thick and cover an area of several hundred square meters, so that the amount still to be excavated is much greater than that already done. About 99 per cent of the bones found are of the cave bear, the number of individuals represented by the finds to date being approximately 200. These remains have been found practically at all levels save in the layer at the top, which has a thickness of one-half meter. Mousterian implements are found in the same horizons as the faunal remains. They are made of quartzite and flint; also of cave-bear bone. The quartzites were picked up in the Weissbach Valley several hundred meters below and carried to the caverns, there to be worked into tools. Some of the better-formed implements are made of a greenish flint that must have been brought a long distance by paleolithic man. Both stone and bone implements are of crude workmanship.

In company with Herr Bächler I spent some hours studying the sections and searching for animal remains and artifacts. We were successful in finding two bone implements and one chipped quartzite. Teeth and fragments of bones were counted by the dozen. These were chiefly of the cave bear. Remains of the cave lion, the cave panther, badger, marten (*Mustela martes*), ibex, chamois, stag, marmot, otter, and hermit crow have been noted.

The deposits are not indurated and may be worked with as much rapidity as is consistent with careful observation. They consist of materials that have fallen from the ceilings. They can not be called stratified, and yet more or less definite horizons may be distinguished on account of the relative fineness of the deposits and the variations in color.

What is the age of the industry-bearing deposits of Wildkirchli? In order to arrive at a just estimate one must have a knowledge not only of prehistoric times, but also of the ice age. According to Penck[a] there were four glacial epochs (with alternating interglacial epochs). These have been named after four streams of southern Germany in the foothills of the Alps—Günz, Mindel, Riss, and Würm glacial epochs, respectively, beginning with the oldest. Penck

[a] See table of relative chronology (pl. 1).

has gone even further and determined three well-defined stages in the final retreat of the Würm glaciation. The stages correspond to temporary advances during the period of retreat. Such stages have left their traces so distinctly in the region about Innsbruck that local names have been applied to them—Bühl, from Kirchbühl, at an elevation of 500 meters; Gschnitz at 1,200 meters; and Daun at 1,600 meters, the latter, of course, being the most recent.

The barbaric races with which the Romans had to contend had a knowledge of iron. It is estimated that the bronze age had its beginning some 3,500 years ago. The Alps were then either inhabited or visited throughout their extent by man. We find, for example, bronze weapons in the Flüela pass of the upper Engadine. The Flüela pass was invaded by ice of the Daun stage. The latter, therefore, antedates the bronze age. Prehistoric copper mines have been discovered at two localities in the Austrian Alps. One of these lies at the southern foot of the Übergossene Alp, near Salzburg, at a height of 1,500 meters. Neolithic implements were found in the old shafts. Now this locality (Mitterberg) is near the timber line, and a slight depression of this would render it difficult to establish smelters there. The other copper mine is southeast of Kitzbühel in the Tyrol, at a height of 1,900 meters. This mine also must have been occupied later than the Daun stage, at which time the region lay very near the snow line and was uninhabitable.

Even the whole neolithic period in Switzerland is younger than the Daun stage, whose snow-line lay 300 meters lower than to-day. The minimum time, therefore, that separates us from the Daun stage must be at least 7,000 years.

A very long interval of time separates us from the closing epoch (Magdalenian) of the paleolithic period. For we find on the borders of Lakes Constance and Geneva animal remains of the Magdalenian epoch in terraces that are 20 to 30 meters above the present level of these lakes. Magdalenian industry is found in Switzerland well within the area covered by the Würm glaciation. But such stations have not yet been found within that covered by the Bühl stage. It may be taken for granted, therefore, that the Magdalenian industry is not older than, but may be contemporaneous with, the Bühl stage, which corresponds, by the way, to the Champlain stage in North America.

The rock-shelter of Schweizersbild was occupied by paleolithic man after the Würm glaciation had retreated across the Rhine from Canton Schaffhausen. Here 25,000 stone implements have been found by Nüesch; also many bone implements and some engravings, one being of the mammoth. The paleolithic layers were covered in turn by successive deposits belonging to the neolithic bronze and Roman periods. Taking the thickness of the deposit left since Roman times

as representing 2,000 years, the time required for the whole series of deposits is estimated at 24,000 years. The total time elapsed since the maximum advance of the Würm glaciation is still longer, 30,000 years being none too high an estimate for it.

When could Wildkirchli have been inhabited? It lies within the region of glaciation. It could not have been occupied during the Würm glacial period, because it is at a height of 1,500 meters, while the snow line of the Würm glaciation was only 1,200 meters. It is self-evident that man could not have taken up his abode above the snow line. Even during the Bühl stage of the glacial retreat the snow line was still as low as 1,500 meters. Man could have come there only after the Bühl stage. But after the Bühl stage we have a different fauna and flora; so that man must have inhabited Wildkirchli before the last (Würm) glacial epoch, that is to say during an interglacial (Riss-Würm) epoch with climatic conditions similar to those of the present day.

During the last glacial epoch the Wildkirchli caverns were filled with ice or snow, and hence no deposits of any kind were formed. The sterile layer one-half meter thick at the top of the floor deposits represents the accumulation since the close of the glacial period. If we allow 30,000 years for post-Würmian times we must allow as much more for the last glacial epoch. Thus to reach the Riss-Würm interglacial period and man's occupancy of Wildkirchli caverns would mean going back about 100,000 years. We have here an atypic late Mousterian, or perhaps lower Aurignacian, industry.

An interesting feature in the development of our knowledge of cavern life is that pertaining to paleolithic mural decorations. These were first discovered in the cavern of Altamira, province of Santander, Spain, explored in 1879 by Sautuola. They were, however, not accepted as authentic. About ten years later Léopold Chiron reported mural decorations in the cavern of Chabot (Gard), but the discovery was received with the same skepticism as that which befell the earlier announcement of Sautuola. With the discovery by Émile Rivière, in 1895, of wall engravings in the cavern of La Mouthe (Dordogne), the tide was finally turned in favor of their authenticity. Thereupon other caverns were searched and revealed similar phenomena. In 1906 François Daleau announced the discovery of wall engravings at Pair-non-Pair (Gironde), and the following year Félix Regnault found frescoes on the cavern walls of Marsoulas (Haute-Garonne). Since 1900 discoveries of this class are to be numbered by the dozen, and the literature has been enriched by more detailed accounts of the cavern decorations discovered prior to the date in question.

The cavern of Altamira, situated near Santillana, is a series of grand halls united by corridors. The entry is modern, being formed

in consequence of a cave-in. The vestibule leads to a very large hall divided into two chambers by a mass of fallen rock. The chamber to the left is 40 by 10 meters. The one on the right leads to the series of halls and corridors. At the close of the Quaternary a cave-in at the entrance had effectually sealed the cavern. The fauna is that of the cave bear.

The paintings and engravings are found in all parts of the cavern, especially in the first chamber to the left after entering. The beauty, size, and degree of preservation of these works of art are admirable. Some of the engravings are deeply cut; others are gently incised by the aid of a sharp point. The greater part of these decorations, however, were executed in color, either black or red or both. The most remarkable are those in polychrome of the left chamber near the entrance. While some of the decorations represent animal figures, others are incomprehensible signs and symbols. They do not all date from the same epoch. The deeply-cut figures of the left chamber recall those of Chabot, Pair-non-Pair, and La Grèze. Mural art at Altamira admits of grouping under four categories: (1) Deeply incised engravings and line drawings (dessins au trait) in black; (2) black or red figures; (3) fine engravings, and (4) polychrome frescoes.

Line-drawings and figures in black are abundant along the corridors. The ceiling of the left chamber has many traces of black line-drawings (pl. 5, fig. *a*) generally in bad state of preservation. Some of the figures in black are shaded in (modelés), and in this respect are quite equal to the polychrome figures.

The second layer of paintings includes the black or red frescoes which are seldom combined in the same figure with engravings.

Fine engravings are numerous and often made over the black line-drawings, that is to say, were more recently executed.

The polychrome frescoes are remarkable for vigor, exactitude and the command of colors—red, brown, black, and yellow—which mix and grade into numerous tints. A group of twenty-five of these is seen on the ceiling of the left chamber. Some are older than others. In the later figures, black contours and engravings combined play an important rôle. The surface to be included in the field of the projected figure was washed and scraped. A black line was traced fixing the contours. The necessary colors were then added. In many cases, one sees divers touches of the brush, each marking a tuft of the mane or the dewlap (pl. 5, fig. *b*), while the large colored surfaces were covered with a thinner mixture of color, graduated by washing or gouache. This work accomplished, the artist often retouched the figure, washing or scraping, removing the color in places to secure the lighter effects or to detach the limbs folded on the body. Spots for decoration were often chosen that give, without much extra effort, the effect of a colored bas relief. The frescoes

FIG. *a*. HEAD OF A HORSE, DRAWN WITH A BLACK CRAYON. CAVERN OF ALTAMIRA (SPAIN). FIRST PHASE. ½. AFTER BREUIL.

FIG. *b*. BISON FROM THE CAVERN OF ALTAMIRA (SPAIN), PAINTED IN POLYCHROME. FOURTH PHASE. AFTER BREUIL, C. R., CONGR. INTERN. D'ANTHR. ET D'ARCH. PRÉHS., 1, P. 384, MONACO, 1906.

vary in size from 1.50 to 2.50 meters and represent the bison, wild boar, deer, horse, etc. Since Altamira, a dozen other caverns with decorated walls have been found in the Province of Santander: El Haza and Covalanas near Rameles, region of Rio Asón (paintings); Sotarriza, Cueva negra (paintings) and Venta de la Perra (engravings), all three at Molinar de Caranza, Rio Asón; Salitre at Ajanedo, environs of Santander with Aurignacian and Magdalenian paintings; Castillo, at Puente-Viesgo (paintings and engravings), El Pendo, near Escobedo (engravings) and Santien, at Puente-Arce (paintings), all in the region of Rio Pas; Hornos de la Peña, at San Felices de Buelna (paintings and engravings), Clotilde, at Santa Isabel (engravings) and Meaza, at Comillas (paintings), in the environs of Torrelavega. In addition to these, the able committee so generously supported by the Prince of Monaco located some fifteen caverns, in which no frescoes and wall engravings were found, and four paleolithic stations other than caverns.

In 1903, Juan Cabré noticed for the first time animal figures painted on walls of a rock-shelter at Cretas, south of Calaceite, called Roca del Moro. In 1906, after having heard of the publication of Alcalde del Rio on the caverns of Santander, he called the attention of archeologists to the figures he had seen three years previously. Breuil[a] heard of the place through a publication of Santiago Vidiella,[b] and visited it in 1908 for the purpose of study. The grotto is 10 meters long by 2.5 meters wide. The floor deposits are barren, but on the slope there are flint flakes of the Magdalenian type and no trace of the neolithic. On the protected wall of the rock shelter were found the handsome frescoes which have been removed to prevent their being destroyed by curious visitors. The removal was successfully made in spite of the hardness of the rock.

The painted frieze comprised three deer, a bull, and a small creature undetermined. All are in dark red, the color having penetrated well into the rock. The figures of the deer were outlined by delicate engraving. One of these is represented as in the act of rising (se levant de son gite), the attitude being full of grace and natural elegance (pl. 6, fig. *a*). In this figure and all those of the deer at Cretas there is a curious disposition of the antlers. The upper parts are represented as seen from the front, while the lower parts are in profile. This is also true of figures of the deer at Cogul, Lérida (Catalonia), and in France among the drawings of the reindeer in the cavern of Portel (Ariège).

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[a] L'Abbé H. Breuil et Juan Cabré Aguila. Les peintures rupestres du bassin inférieur de l'Èbre. L'anthr., vol. 20, 1, 1909. I. Les rochers peints de Calapata à Cretas (Bas Aragon).

[b] Boletin de hist. y geogr, del Bajo Aragon, mars-avril, 1907.

On leaving the Roca del Moro at a distance of 200 meters, Breuil chanced to see in another rock shelter a figure painted red. He leaped from his horse and clambered up to the spot to find a companion figure in black and near these, two deer in red and black and three other smaller figures (wild goat) in black. This discovery caused the explorers to change their plans so as to include a reconnaissance tour of the whole province. After three months, Cabré reported that he had found nine other localities with paintings or engravings in open shelters[a] (à l'air libre). A tenth situated to the south of the province has been discovered and it looks, says Breuil, as if we might have the satisfaction of seeing Quaternary art clasp hands by the way of Gibraltar with the rock paintings and engravings of northern Africa.

A Catalonian rock-shelter near Cogul, south of Lérida in the province of the same name, is adorned with frescoes that furnish interesting additional data concerning paleolithic art. These frescoes known for ages were formerly attributed to the Moors. The researches of Breuil prove them to be of Magdalenian age. They form five groups, two of which are shown in plate 6, figure *b*. Both of these are hunting scenes. Above and to the left is a hunter in the act of striking down a stag after having already killed one. The drawing is highly stylistic without obscuring the real meaning of the ensemble. The dead stag lies on his back with all four feet in the air. The group at the right is a combination of stylistic and realistic art, the figure of the bison being similar to figures of that animal in a number of French and Spanish caverns. But the bison emigrated from southwestern Europe before the close of the Quaternary; the Cogul frescoes are therefore Magdelenian. Another remarkable group in this rock shelter represents nine women surrounding one man. The latter is executed in the style of the hunters reproduced in figure *b*. The female figures are somewhat more realistic and are readily distinguished by skirts reaching to the knees and by pendent breasts. While the presence of feminine skirts gives to the scene a modern air, the art as a whole is more closely related to the paleolithic than to that of any succeeding epoch.

The explorations of French caverns have more than kept pace with those in Spain. Confining ourselves chiefly to caverns with mural decorations those of the Dordogne are perhaps the most important, the largest group being in the Vézère Valley. The calcareous formation, cleft by the Vézère and its tributaries, is composed of Cretaceous beds approximately horizontal and of varying degrees of hardness (pl. 7); so that overhanging rocks often shelter horizontal galleries and niches. Again subterranean streams have left meandering caverns, some of them several hundred meters in length. These as well

[a] This province has a very dry climate.

FIG. *a*. RED FRESCO REPRESENTING A STAG IN THE ACT OF RISING (THE COLOR HAS DISAPPEARED FROM THE DOTTED PORTIONS). ROCK SHELTER OF CALAPATA AT CRETAS (LOWER ARAGON). AFTER BREUIL AND CABRÉ AGUILA, L'ANTHR., 20, 1909.

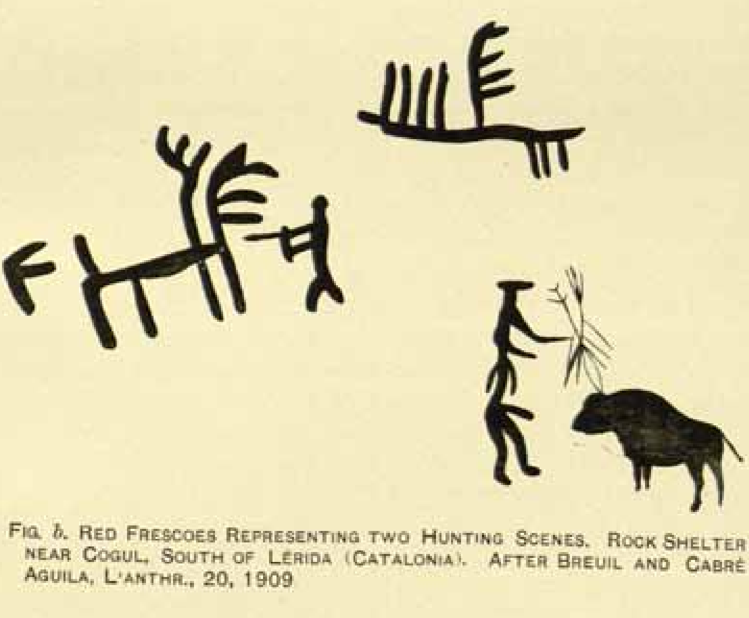
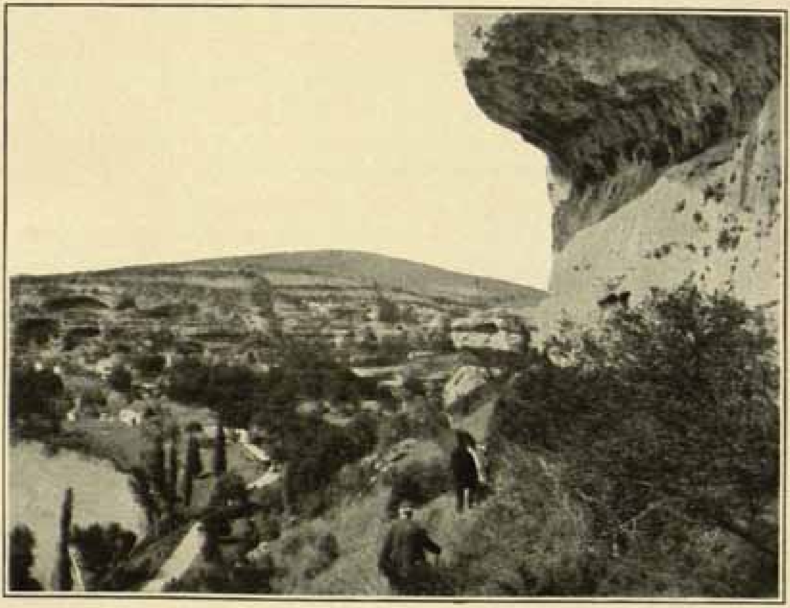


FIG. *b*. RED FRESCOES REPRESENTING TWO HUNTING SCENES. ROCK SHELTER NEAR COGUL, SOUTH OF LÉRIDA (CATALONIA). AFTER BREUIL AND CABRÉ AGUILA, L'ANTHR., 20, 1909



LES EYZIES IN THE BACKGROUND; THE VÉZÈRE RIVER ON THE LEFT (DORDOGNE).

(Photograph by G. G. MacCurdy.)

as the rock-shelters and open shallow caves, formed through atmospheric agencies, were inhabited by early man. Some were enlarged or modified and occupied during the middle ages. At a safe height in the roc de Tayac, one such that withstood successive sieges in the fourteenth and fifteenth centuries is at present used as a restaurant and appropriately named "au Paradis."

The earlier explorations at Les Eyzies, Cro-Magnon, Gorge-d'Enfer, Laugerie-Basse, Laugerie-Haute, La Madeleine, and Le Moustier are so well known that they are mentioned only in passing. After so long a series of important discoveries, it might well be supposed that the archeological possibilities of the region had been exhausted, yet some of the most important treasures still remained locked in the recesses of the less easily accessible and little known subterranean caverns which penetrate the hills to great depths. The entrances to these caverns are small and invisible from the valley below. Some indeed were completely stopped by hillside débris, leaving no outer trace of their existence. It is not strange that they escaped immediate notice. They were neglected until the early nineties, when Rivière removed some of the floor deposits in the cavern of Les Combarelles that yielded many flint implements, and especially fine bone needles. In 1895, he began work in similar deposits in the cavern of La Mouthe. One day, after penetrating to a considerable depth, he and his companion, the son of Berthoumeyrou, the innkeeper, sat down to rest. In lighting a cigar, the extra light of the match added to the feeble candle light and placed at the proper angle revealed to one of them what had not been observed before—an engraving on the wall. The discovery was duly announced and marked the beginning of a new epoch in cavern explorations.

The mural decorations at La Mouthe occur in four groups or panels. The first panel is about 93 meters from the entrance. The second, 4 meters farther on, is called the "Hall of the Bison." Seven animals are represented on an area 5.02 meters by 2.6 meters. The third and fourth panels are 113 and 130 meters, respectively, from the entrance.

In 1899, Rivière was so fortunate as to find a stone lamp in the floor deposits of this cavern at a point about 17 meters from the entrance. The pick of the workman broke the lamp into four pieces, of which three were immediately recovered. Rivière and two of his men searched for the missing fragment an entire day, but without success. The shallow bowl contained some carbonized matter, an analysis of which led M. Berthelot, the chemist, to conclude that lard was used for lighting purposes. On the base there is an engraving of a wild goat's head and horns. A figure exactly like this was found on the third mural panel already mentioned. This was the fourth lamp to be found in French caverns. The first and second were from the cavern of Monthier (Charente), and the third from the cavern of

Coual (Lot). The necessities of men dwelling in dark caverns would be likely to lead to the invention of artificial light, which light made it possible for them to depict the frescoes and engravings on the walls of their abodes.

The past ten years have witnessed a succession of remarkable discoveries by Messieurs Capitan, Breuil, Bourrinet, Ampoulange, and Peyrony, in the caverns of Les Combarelles, Font-de-Gaume, Bernifal, Teyjat, La Grèze, and La Calévie.

The Combarelles cavern has a total length of 234 meters, is from 1 to 2 meters wide, and high enough to admit of walking upright for most of the way. The engravings begin at a point about 118 meters from the entrance, and occupy both walls for a distance of 100 meters.

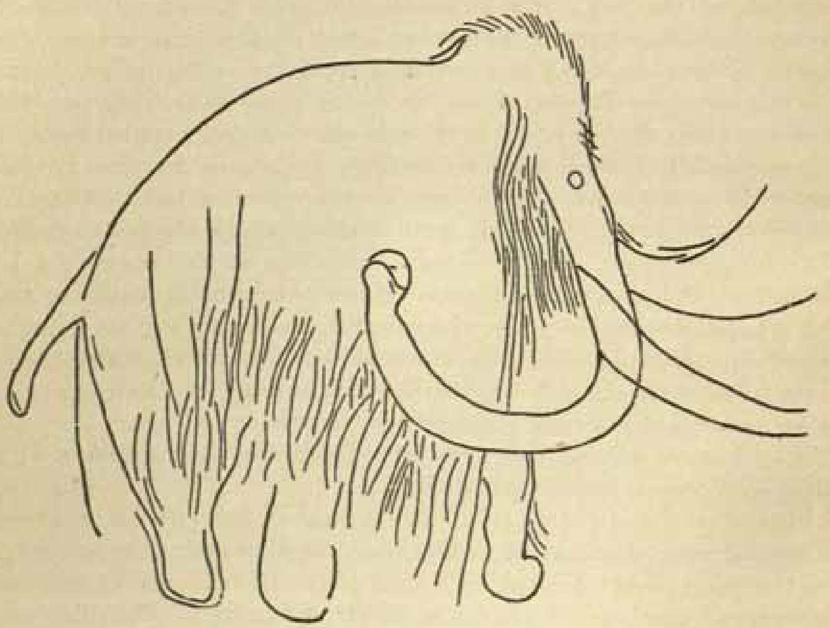


FIG. 6.—Engraving of a mammoth. Cavern of Les Combarelles (Dordogne). Second phase. ½. After Capitan and Breuil.

Some of the figures are deeply incised, others are mere scratches. In some, the effect is heightened by the application of a dark coloring matter (oxide of manganese). Portions of the walls are covered by a coating of stalactite thick enough in places completely to hide engravings, while in others the more deeply incised figures are still visible. On areas devoid of incrustations, the figures are fresh and distinct. The artist sometimes had recourse to champlevé; sometimes natural prominences were utilized to add relief to the figures. Of the 109 engravings of various animals on the walls at Les Combarelles there are some forty equine figures, occurring either singly or in groups, and fourteen of the mammoth. One of the latter is reproduced in figure 6. The mural engravings belong precisely to the

same school of art as the relief and incised figures from the floor deposits of the shallow caves and rock-shelters, so well known through the works of the earlier investigators. This statement applies equally to all the caverns thus far explored.

The cavern of Bernifal was first explored in 1903. It was discovered by accident. The original entrance near the base of an escarpment is completely obstructed by earth and stones. The present artificial entrance is at a point where the ceiling of the cavern comes close to the surface of the wooded sloping upland. The descent into the cavern is almost vertical, and made by means of an iron ladder about 3 meters long. There is a joint in the ladder, the upper portion of which may be inclined and locked so as to secure the interior against vandalism.[a] Within are three large chambers united by rather narrow corridors. The first is 22 meters long, with high ceiling and a maximum breadth of 8 meters. The others are not quite so large. The beautiful stalactites overhead have been left undisturbed. Most of the engravings are to be found in the second chamber. They are cut rather deeply into the calcareous walls, and generally coated over with a thin, hard layer of stalactite. Twelve groups, numbering in all 26 figures, have been recognized. These include geometric triangular signs in addition to various animal figures—reindeer, mammoth, horse, bison, and antelope. Some are simply engraved, others are painted with red ocher and manganese. Many are probably wholly hidden beneath thick mural incrustations. Tectiform signs, the significance of which is unknown, were also met with at Les Combarelles and Font-de-Gaume.

The Font-de-Gaume frescoes and engravings were discovered in 1901 by Capitan and Breuil with the assistance of M. Peyrony, the school principal of Les Eyzies. The entrance is some 20 meters above the valley and near the top of the escarpment (pl. 8, fig. *b*).

A passage about 65 meters long, and much restricted in places, leads to an ample gallery 40 meters in length, 2 to 3 in breadth, and 5 to 6 in height. A majority of the paintings—and Font-de-Gaume is especially rich in paintings—occur on the walls of this gallery and in a little side chamber farther on (fig. 7, no. 16). The latter contains 13 remarkable figures, in color, of the bison and a group of reindeer (pl. 9). The coloring matter was red ocher and manganese, either mixed so as to give various intermediate shades or used separately. Both these materials are found on top of the neighboring plateaus. The dimensions of the figures vary from 2.70 meters down to 0.20 meter. Some are on regular surfaces, while others include natural prominences in such a way as to give the effect of relief. They are veritable frescoes, the whole figure often being covered with

[a] Most of the prehistoric monuments of France are now the property of the Government and are protected by the enactment and enforcement of wise laws.

paint. Engraving and fresco are usually associated in the same figure. The coloring matter was, in some cases, applied after the engraving; while in others the process was reversed. Again some figures are a piecework of engraving and fresco. Some are engraved

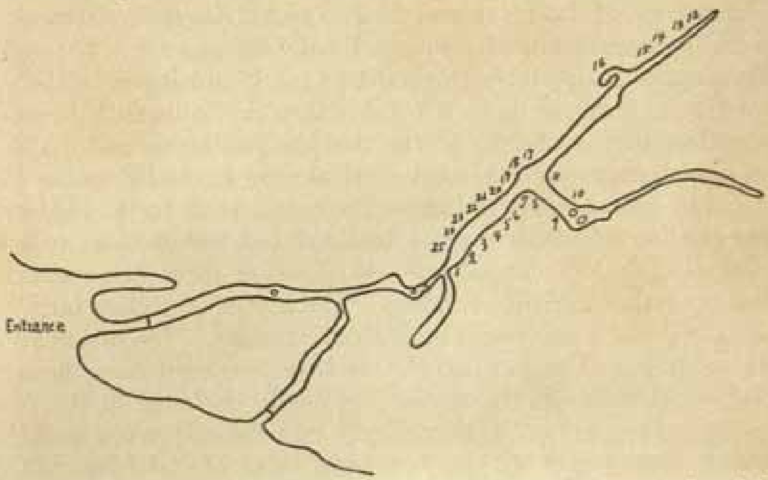


FIG. 7.—Floor plan of the cavern of Font-de-Gaume (Dordogne). The numbers indicate the position of the engravings and paintings on the walls.

only. In certain cases the outlines of the animal are simply traced by a single stroke of the brush or pencil, usually in black. Where the contours are filled in, various tints from black to red are usually employed. The outlines are seldom marred by blotches or evidences of an uncertain stroke.

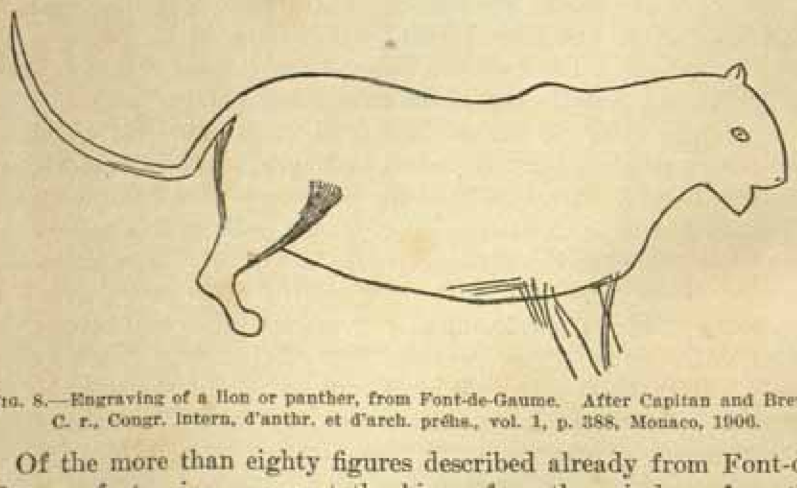


FIG. 8.—Engraving of a lion or panther, from Font-de-Gaume. After Capitan and Breuil, C. r., Congr. intern. d'anthr. et d'arch. préhs., vol. 1, p. 388, Monaco, 1906.

Of the more than eighty figures described already from Font-de-Gaume, forty-nine represent the bison, four the reindeer, four the horse, three the antelope, two the mammoth, one the stag, one *Felis leo*, one the wolf (see pl. 10), one *Rhinoceros tichorhinus* (see pl. 10), six various signs. A number have not yet been determined.

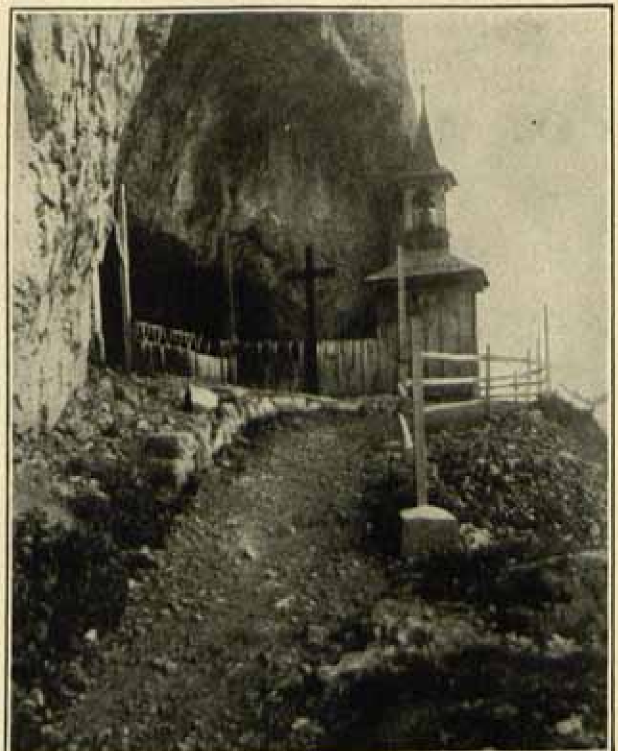


FIG. *a*. ENTRANCE TO THE LOWER CAVERN OF WILDKIRCHLI, CANTON APPENZELL, A STATION OF MOUSTERIAN AGE AT A HEIGHT OF 1,477 METERS.

(Photograph by G. G. MacCurdy.)

FIG. *b*. ENTRANCE TO THE CAVERN OF FONT-DE-GAUME (DORDOGNE).

(Photograph by G. G. MacCurdy.)

FIG. *a*. UNFINISHED POLYCHROME PAINTING OF TWO REINDEER, SHOWING HOW PAINTING WAS COMBINED WITH ENGRAVING. CAVERN OF FONT-DE-GAUME (DORDOGNE). FOURTH PHASE. $\frac{1}{10}$. AFTER CAPITAN AND BREUIL.

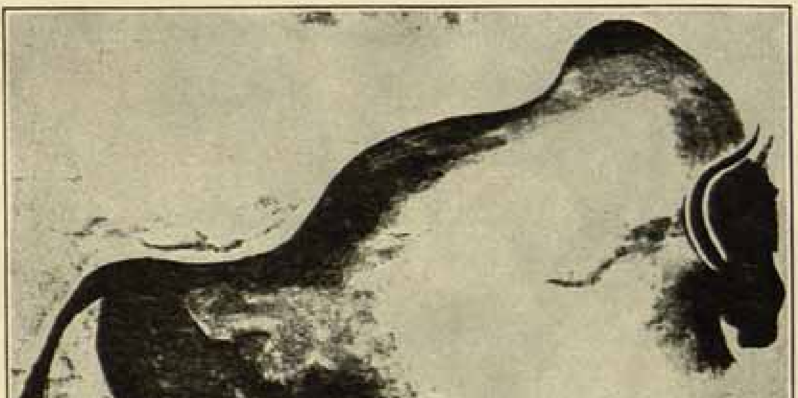


FIG. *b*. POLYCHROME PAINTING OF A BISON. CAVERN OF FONT-DE-GAUME (DORDOGNE). FOURTH PHASE. $\frac{1}{10}$. AFTER CAPITAN AND BREUIL.

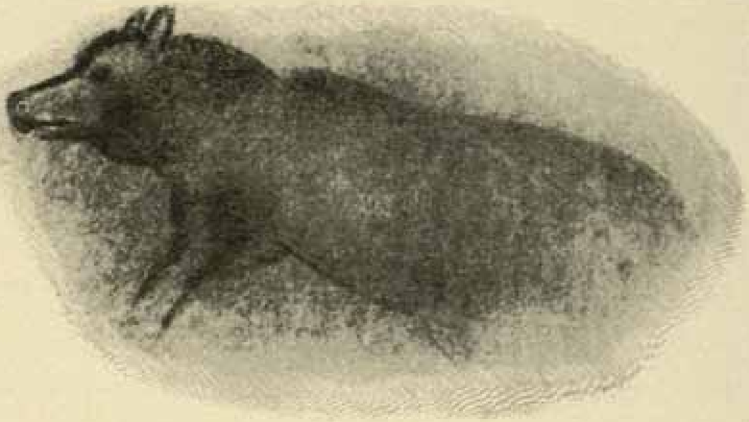


FIG. *a*. POLYCHROME FRESCO OF A WOLF, FROM FONT-DE-GAUME. AFTER CAPITAN AND BREUIL, C. R., CONGR. INTERN. D'ANTHR. ET D'ARCH. PRÉHS., 1, P. 390, MONACO, 1906.

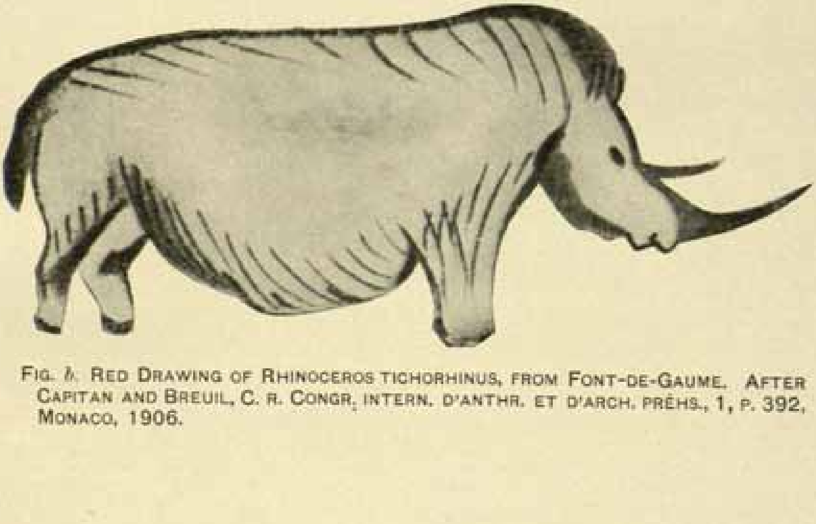


FIG. *b*. RED DRAWING OF RHINOCEROS TICHORHINUS, FROM FONT-DE-GAUME. AFTER CAPITAN AND BREUIL, C. R. CONGR. INTERN. D'ANTHR. ET D'ARCH. PRÉHS., 1, P. 392, MONACO, 1906.

In their various explorations Messieurs Capitan, Breuil, and Peyrony have collected about a hundred drawings of the mammoth. Those of the bison, horse, and reindeer are also numerous. On the other hand representations of *Ursus*, *Felis*, and *Rhinoceros* are rare. The engraving of *Ursus spelæus* on a piece of schist found in the floor deposits of the cavern of Massat (Ariège) has been known since 1867. A similar figure is to be seen on the cavern walls of Les Combarelles, and other fine examples occur on the walls of the cavern at Teyjat (see fig. 12). An engraving of *Felis* on a pebble from the cavern of Gourdan (Haute-Garonne) was recently published by Piette. Two mural engravings of *Felis* are known; one at Les Combarelles and the other at Font-de-Gaume, at the end of the cavern. In the latter the entire animal is represented, being characterized by the form of the head, the general aspect of the body, the long, lifted tail and short paws. The animal is probably *Felis leo*, var. *spelæa*, since it is figured somewhat larger than are the four horses forming part of the same group or picture (fig. 8).

One of the most interesting animal representations on the cavern walls of Dordogne is a drawing in red of *Rhinoceros tichorhinus* (pl. 10 *b*), found at Font-de-Gaume near the group that included an engraving of the cave lion, i. e., at the end of the cavern. The figure is not only complete but also exact. The two horns are faithfully indicated, the anterior notably longer and larger than the posterior. The only other representations of the woolly rhinoceros are an indifferent engraving on a piece of stone found in the cavern of Gourdan and recently published by Piette, and one likewise on stone from the grotte du Trilobite at Arcy. The coating of long hair is equally well characterized. The technique points to an archaic phase in the development of Quaternary art. Near this figure is the head of another rhinoceros, also traced with an ochre crayon.

The cavern of Font-de-Gaume opens on a narrow valley tributary to that of the Beune and near their junction. The well-known rock-shelter of Les Eyzies lies across the valley of the Beune. It is visible from Font-de-Gaume, appearing like a black spot on the face of the great escarpment, and only 800 meters distant. M. Peyrony[a] suggests that the two prehistoric communities may have been closely united. His recent researches at Les Eyzies tend to confirm this view.

The shallow cave of Les Eyzies, overlooking the Beune near its junction with the Vézère, opens on a sort of natural platform about 35 meters above the bed of the stream. The opening of the cave is wide and high enough to admit the light to its greatest depth, which is 12 meters. The greatest width is 16 meters. It has a southern

[a] Le Dr. Capitan, l'Abbé Breuil et Peyrony. Nouvelles observations sur la grotte des Eyzies et ses relations avec celles de Font-de-Gaume. Compte rendu, Congrès préh. de France, 1905, p. 137.

exposure, is dry and habitable. Font-de-Gaume was never a place of residence, as is indicated by the absence of floor deposits. About the only objects found there are a few broken gravers with edges dulled in executing the wall engravings, a few pieces of ochre and manganese and one handsome ochre pencil. Why should the artists make residence of a dark subterranean cavern, when by going a short distance they could have an ample shallow cave or rock-shelter facing the south and warmed and lighted by the sun? Such a shelter is Les Eyzies, and the enormous quantities of refuse taken from its floor at various periods testify to its use as a place of habitation by generation after generation.

The rock-shelter of Les Eyzies has furnished unusually large quantities of ochre of various tints. Most of the pieces have been scraped to produce a colored powder which was mixed with grease or some liquid, thus forming a paint. In order to pulverize and thoroughly mix the coloring matter, mortars were used. An interesting series of these mortars from Les Eyzies forms a part of the famous Christy collection in the British Museum. Very few mortars have been found in neighboring stations. Besides, ochre pencils exactly like the one from Font-de-Gaume have been found in the rock-shelter of Les Eyzies. Sometimes a flat piece of ochre is cut in the form of a triangle, each angle serving in turn as a pencil point. Some of these pencils are perforated to be suspended, and might well be supposed to form a part of the outfit of the artists who drew in color figures such as that of the two-horned rhinoceros previously mentioned.

It may be that the artists who made their home at Les Eyzies decorated its walls also. Exposure would have obliterated these decorations long ago, as it did those at La Grèze, which were not protected by the floor deposits. Lucky it was for present-day lovers of art and archeology that their troglodyte forebears had the good sense to seek at Font-de-Gaume a more permanent gallery for their masterpieces.

The cavern of La Calévie belongs in the Vézère group and is situated on the left side of the Petite Beune, some 500 meters below Bernifal. The cavern, which has two entrances, is 15 meters wide by 7 or 8 meters deep. Near the entrance are two engraved figures of the horse, one of them recalling the work at Les Combarelles. As the latter is Magdalenian, this is probably Magdalenian also. The other is in the style of Pair-non-Pair, which is well dated, because there the upper Aurignacian floor deposits cover the mural figures.

The rock shelter of La Grèze is only 6 kilometers above Les Eyzies, on the right bank of the main fork of the Beune. Fortunately some of its wall engravings have been protected by the floor deposits. As the latter contain an industry of Solutréan age, both the authenticity

and the age of the engravings are established in the same manner as at Pair-non-Pair. An engraving from La Grèze representing the first phase in the development of parietal decoration is reproduced in figure 9.

Before leaving the caverns of the Vézère Valley it should be noted that recent discoveries there have not been confined to mural art alone. The classic station of Les Eyzies is only one of many rock-shelters in the same cliff. To the east of it only a few rods and at the same level is the station of Peyrille, yielding an industry with lower Magdalenian facies. A short distance to the west of the Grotte

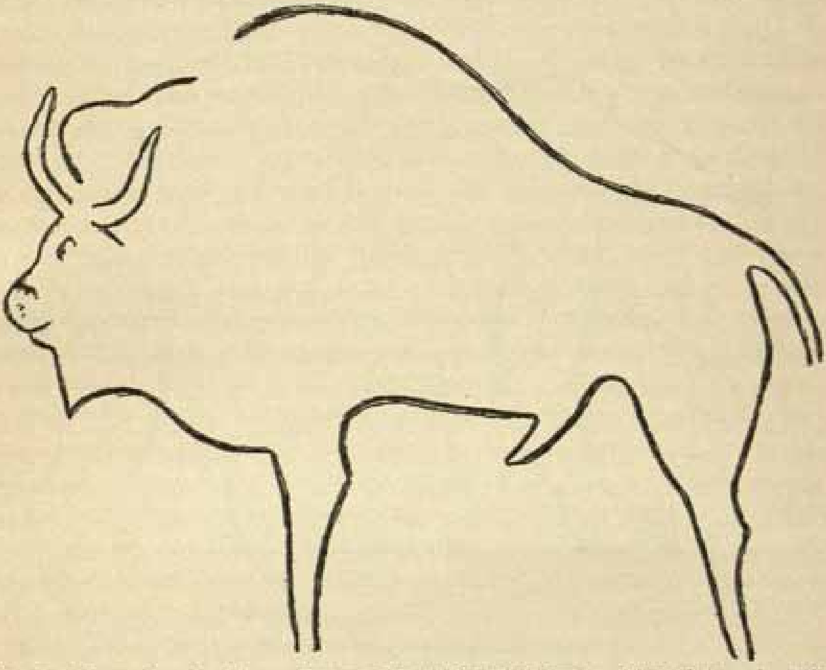


FIG. 9.—Engraving of a bison. Cavern of La Grèze (Dordogne). First phase. ⅓. After Breuil.

des Eyzies and at a slightly higher (2.50 meters) level is the rock-shelter of Escalifer, with lower Mousterian industry. A few meters still farther to the west and on the same level as Escalifer is the rock-shelter of Audi, with a superposition of Aurignacian on Mousterian. Some 5 or 6 miles to the east of this group of stations is the rock-shelter of Laussel near a chateau of the same name and also near the rock-shelter of La Grèze. Explored originally by E. Rivière in 1894, new excavations were made by Doctor Lalanne in 1908. The Laussel section revealed in stratigraphic position a succession of layers, including Acheulian, Mousterian, Aurignacian in two separate horizons, and Solutréan.

The station of La Micoque, some 2 kilometers to the northwest of Les Eyzies, although discovered in 1895, should be mentioned in this connection because of recent excavations by Hauser and others. Cartailhac and Hauser believe it to have been protected originally by an overhanging rock. According to Rutot it was always, as it now appears to be, a station in the open. The industry is Mousterian, with traces of a ruder paleolithic facies at the bottom and Aurignacian at the top.

One of the latest additions to the long list is the rock-shelter of Le Rut, about half a mile below the celebrated station of Le Moustier and on the same side of the Vézère River, excavated in 1907 by D.

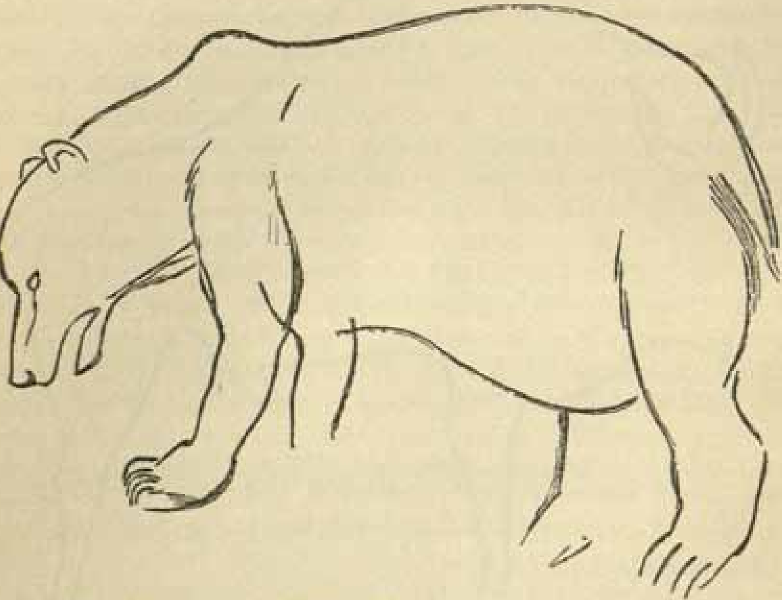


FIG. 10.—Engraving of *Ursus spelaeus*, from the cavern of La Mairie, Teyjat. After Capitan and Breuil, C. r., Congr. intern. d'anthr. et d'arch. préhs., vol. 1, p. 391, Monaco, 1906.

Peyrony. The section at Le Rut overlaps and supplements that of Laussel. It begins with the middle and upper Aurignacian, above which are added three Solutréan horizons and one Magdalenian.

Other regions of the Dordogne have not been neglected. The cavern of La Mairie and the rock-shelter of Mège, both at Teyjat, are near Javerlhac, a railway station on the line between Nontron and Angoulême. Some twenty years ago M. Perrier du Carne found in La Mairie cavern Magdalenian implements and five remarkable engravings on stone representing the horse and the bison. In 1903 three groups of engravings (fig. 10) were discovered on the walls of the cavern, and during the same year the rock-shelter of Mège in

the immediate neighborhood was first explored. Here there is only one archeological horizon—middle Magdalenian, corresponding to the lower culture level at La Mairie. It is rich, however, both in fauna and industrial remains. The latter is characterized by the harpoon with a single lateral row of barbs, the type that was abundant at Gourdan, Raymunden, and Bruniquel (Plantade). In 1908 M. Bourrinet found at Mège a so-called bâton de commandement of stag horn (pl. 11), covered with engraved animal and semi-human figures. The piece is the large basal prong of *Cervus elaphus*, about one-third of a meter in length. Of the two perforations, one is nearly round and the other, which is near the point, is elliptic. Practically the entire surface was scraped and engraved with figures, including the head of a doe, serpents, swans, semi-human forms, a horse, and a colt. The engraving of the horse is among the most painstaking and complete paleolithic representations of that animal (fig. 11). The elliptic hole in the bâton cuts the left hip of the horse on one side and its right hind foot on the other, as indicated by the dotted lines. The short erect mane projecting forward beyond the ears is characteristic and the anatomy of the head, neck, and shoulders is faithfully rendered, even to the fossa above the eye. The heavy line back of and below the eye is the zygomatic arch; the two parallel lines below it, reaching nearly to the corner of the mouth, mark the position of subcutaneous organs and do not represent a bridle. According to both Cartailhac and Breuil, there is no evidence that the horse was domesticated in paleolithic times. Marcel Baudouin notes a striking similarity between paleolithic representations of the Quaternary horse and a race of small horses still living on the Île d'Yeu (Vendée). This race by reason of its isolation[a] has perpetuated its primitive type: Large pendent belly, short head and neck, and erect mane.

The cavern de La Mairie has furnished some interesting bits of evidence bearing on the authenticity of parietal decorations. In the floor deposits are two Magdalenian horizons with a sterile layer between. Wall engravings were left by the first occupants. In the course of time, with the loosening of plaques of stalagmite, some of these engravings were removed. A small fragment of this sort bearing the tail and hip of a bison was found in the lower layer. Later a larger fragment with the rest of the bison was found in the sterile deposit that covers the lower archeological horizon (middle Magdalenian). The two pieces united are seen in figure 12. Other blocks of stalagmite were found to enclose engravings and when properly split disclosed their negative imprints. The feet of a horse that are

[a] The Île d'Yeu was a part of the mainland until near the close of the Quaternary.

missing from one wall engraving were found in the upper Magdalenian floor deposit, proving that the drawing in question was at

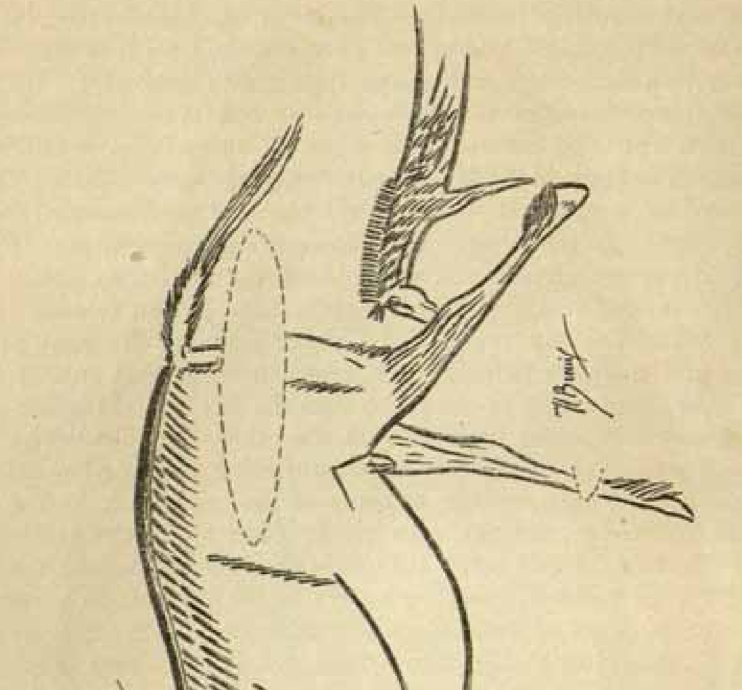


Fig. 11.—Engraving of a horse. Detail from the ornamented stag horn prong (see pl. 11) found at Teyjat. ½. After Breuil.

least as old as the deposit enclosing it, and may have dated from the first occupation of the cavern.

BASAL PRONG OF STAG HORN, PERFORATED AND COVERED WITH ENGRAVINGS, ONE OF WHICH REPRESENTS THE HORSE (SEE FIG. II). FROM THE ROCK SHELTER OF MÈGE AT TEYJAT. AFTER CAPITAN, BREUIL, BOURRINET, AND PEYRONY, REV. DE L'ÉCOLE D'ANTHR. DE PARIS, 19, 1909.

If further evidence were needed to establish the authenticity of paleolithic mural decorations, one need only cite the cavern of Pair-non-Pair where rude deeply incised engravings were revealed on the walls only after the floor deposits of upper Aurignacian age that covered them had been removed. The engravings, therefore, are not only authentic, but dated as well. The same sort of evidence was furnished at La Grèze. There the parietal engravings were covered by floor deposits of Solutréan age.

The excellent preservation of these parietal works of art is due in many cases to the accidental sealing up of the caverns toward the close of the Quaternary. This was the case not only at Altamira,

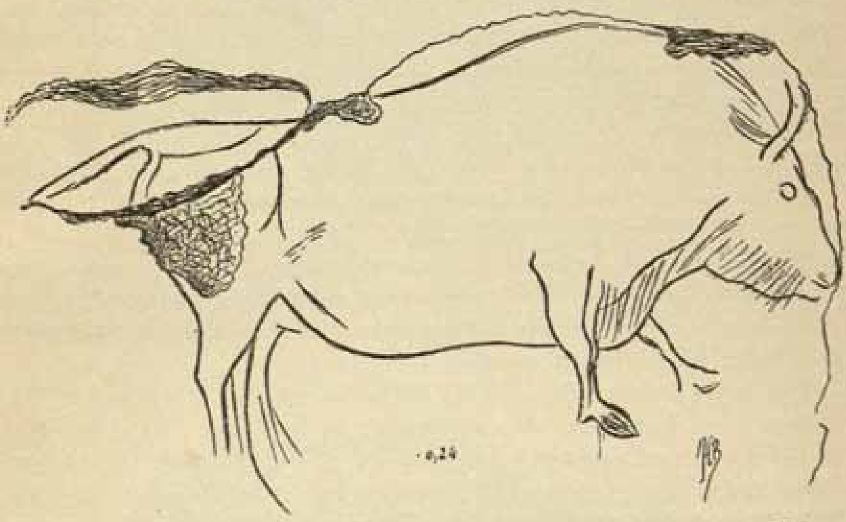


FIG. 12.—Bison engraved on two fragments of stalagmite that were found some distance apart in the lower layer of the floor deposits at the cavern of La Mairie, Teyjat. After Breuil, Rev. de l'Ecole d'anthr. de Paris, vol. 18, p. 172, 1908.

but also at Marsoulas (Haute-Garonne) and Teyjat. That frescoes and engravings are not found on the walls near entrances that were never sealed, but do occur at safe distances from the cavern mouths, is at least negative proof of their antiquity. For the first 60 meters at Font-de-Gaume, one finds no mural art (see fig. 7), and the anterior barren stretch is still greater at Les Combarelles, La Mouthe, and Niaux.

Judged by its parietal art, the cavern of Marsoulas (Haute-Garonne) is a connecting link between Altamira and the Périgord, Gironde, and Gard group of caverns. Marsoulas had been explored from 1880 to 1884 by the Abbé Cau-Durban, who discovered Solutréan and Magdalenian hearths in its floor deposits. At that time he saw certain red outlines on the walls, but supposing they could not date from paleolithic times he did not mention them. The dis-

coveries at La Mouthe led to Félix Regnault's successful search in 1897 for mural art at Marsoulas. In 1902, through a subvention of the Académie des Inscriptions et Belles-Lettres, Cartailhac and Breuil began their study of the cavern which opens on an affluent of the Salat. About the close of the Magdalenian epoch, the anterior part of the Marsoulas cavern was filled by a fall of earth and stone, thus accounting for the complete absence of neolithic culture and the good preservation of the wall decorations.

The principal figures number fourteen and comprise six horses, six bison, one wild goat, and one deer. Of the more than one hundred partial figures, a majority represent the bison. Here, as elsewhere, are found problematical figures that might be construed as caricatures of man. The details of a fine polychrome bison, painted over a partially effaced series of figures in black, are exactly similar to those in the polychrome frescoes of Altamira and Font-de-Gaume.

One curious figure of a bison (pl. 12, fig. *a*) is done in a peculiar technique. The head was first engraved, then painted reddish brown, the horns remaining without color. The entire body was filled in with dots or small spots carefully arranged, as if done with the point of a brush. At Marsoulas there are at least three distinct layers of wall decorations, probably dating from the Aurignacian, Solutréan, and lower Magdalenian epochs.

The large caverne des Forges at Niaux (Ariège) is about 4 kilometers from Tarascon. On account of its size Niaux has for a long time been looked upon as a sort of show place. In 1886 Doctor Garrigou noted the presence of drawings on the walls of this cavern. They were rediscovered in 1906. This is another one of the caverns being explored by Cartailhac and Breuil, at the expense of the Académie des Inscriptions and by authority of the Administration des Eaux et Forêts.

The narrow entrance is 100 meters above the Vic-de-Sos, a tributary of the Ariège. The cavern has a total length of 1,100 meters. The best specimens of mural art, including fine drawings and engravings, are in the rotunda at a distance of 772 meters from the entrance. They are grouped on the ceiling as well as the sides. Figures of the bison, thirty in number, predominate. The horse, wild goat, and stag are also represented. The drawings are outlines in a single color, usually black, in which style of art Niaux excels. The medium is presumably a mixture of charcoal and oxide of manganese, to which grease or oil may have been added. It was applied with a brush. Nearly half the animals are represented as having arrows (pl. 12, fig. *b*) sticking in their sides. It is suggested that these may be votive figures symbolizing the hunter's hopes for success in the chase. Both drawings and engravings are wonderfully well pre-

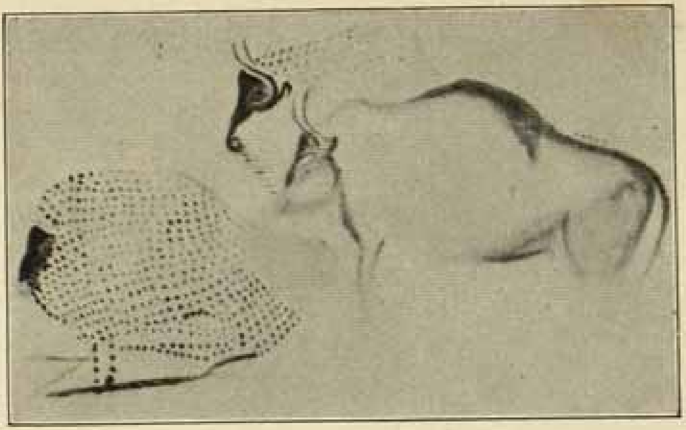


FIG. *a*. BISONS, THE ONE ON THE LEFT IN RED, THE OTHERS IN BLACK. SHADING OF TWO IN QUINCUNX. CAVERN OF MARSOULAS (HAUTE-GARONNE). AFTER CARTAILHAC AND BREUIL, L'ANTHR., 16, P. 439, 1905.

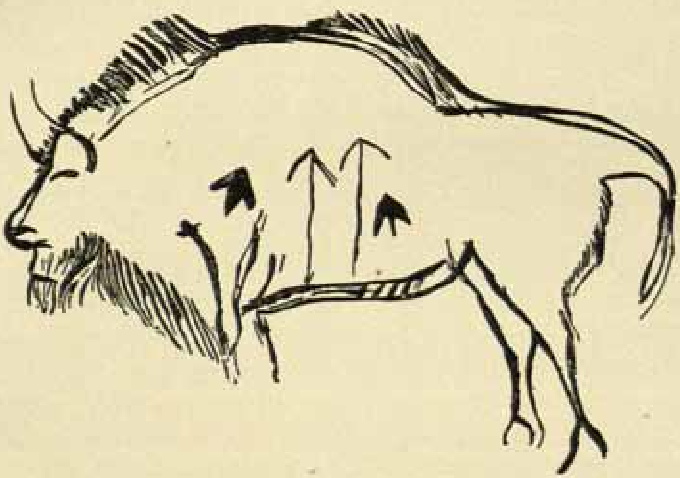


FIG. *b*. LARGE BISON WITH FOUR ARROWS IN ITS SIDE (THE TWO LATERAL ONES ARE IN RED). CAVERN OF NIAUX (ARIÈGE). ABOUT $\frac{1}{15}$. AFTER CARTAILHAC AND BREUIL, L'ANTHR., 19, P. 29, 1908.

served by reason of their distance from the entrance, the absolute calm, and the uniform temperature of air and walls.

One of the striking features about paleolithic art is its realism. This is especially true of the phases leading to the period of its highest development. Recent investigations confirm in the main Piette's views as to the evolution of Quaternary art, although the successive stages overlap more than he had supposed. Sculpture appeared in the lower Aurignacian, but continued without interruption through the Solutréan and to the middle of the Magdalenian—a much longer period than Piette had in mind. Although beginning but little earlier than engraving, sculpture came to full fruition first. Engraving, on the other hand, developed more slowly at first, not reaching its zenith till the middle Magdalenian, when it supplanted sculpture.

The sculptor's problem is in many respects the simpler, his opportunity of success greater. Not confined to a single aspect of his model, he has as many chances of succeeding as there are angles from which to view his work. The engraver or painter, on the other hand, must seize the likeness at the first attempt or else fail. His model was almost always an animal form, generally a quadruped. The most striking, as well as the most complete, single aspect of a quadruped is its profile. This happens to be the view that can be most easily represented on a plane surface.

In dealing, however, with the human form the problem is more complex. So far as the head is concerned, the profile presents fewer difficulties and at the same time is quite as characteristic as the front view. With the body it is just the reverse, the view from the front being the most complete and characteristic as well as the easiest to manage. This element of complexity in a given aspect of the human form must have confused the primeval engraver and painter not a little, although it was not of such a nature as to disturb the sculptor. Herein may lie the reasons why the latter chose as models man and four-footed animals indifferently, while the former's predilections for quadruped forms were so pronounced. At any rate, the fact is that a large majority of paleolithic engravings and practically all the paintings are animal profiles. The earliest ones are in absolute profile, thus simplifying the problem of representing the legs without materially detracting from the general effect.

By degrees more freedom entered into the execution of the figures and more or less successful attempts were made at bringing out details of anatomy by means of incised lines or color or both. The artist, however, retained his predilection for profiles. Attempts at rendering any other aspect are rare even in the Magdalenian. One of the most creditable efforts is the front view of a reindeer incised on a piece of reindeer horn (fig. 13). That the artist was ignorant,

however, of the laws of perspective is painfully evident. This specimen is from the lower Magdalenian horizon of the cavern of Gourdan (Haute-Garonne).

In the same layer at Gourdan was found another fragment of reindeer horn with panel engravings that are of more than passing interest (fig. 14). That the dorsal view presented difficulties perhaps even greater than those of the front view is seen in the upper left-hand panel. The model in this case was a bovidian. This was a daring artist who sought difficulties he was unable to overcome. Neither was he afraid to acknowledge failure if such it was considered at the time, for his signature appears in two places—above the left horn and opposite the left shoulder. The adjoining panel with fish (pike) in profile is also signed in two places, but by another artist, whose signature, composed of an oval pit with four smaller ones above it, is not unlike a four-pointed coronet. Of the two lower panels only the one on the right is adorned. The principal figure is that of a small antelope running. The body is in profile, while the head is turned from the beholder. The posterior convexity at the base of each ear is indicated, as it was also in the bovidian of the upper panel. The head of a horse viewed from in front is seen just above the antelope. The front view of the head alone presents fewer difficulties than that of the entire animal, as is attested by engravings on a wand from the middle Magdalenian deposits of the rock-shelter of Mège (Dordogne). The artist's representation of a deer's head was so successful that it was repeated with slight variations four times on the shaft of the slender wand (fig. 15). Many representations of the front view are so diagrammatic as to be scarcely recognizable. Some of the processes that lead to conventionalism are simply short cuts to the artist's goal, the goal being to convey a given impression. This can often be done better by evading difficulties than by meeting them. The paleolithic artist

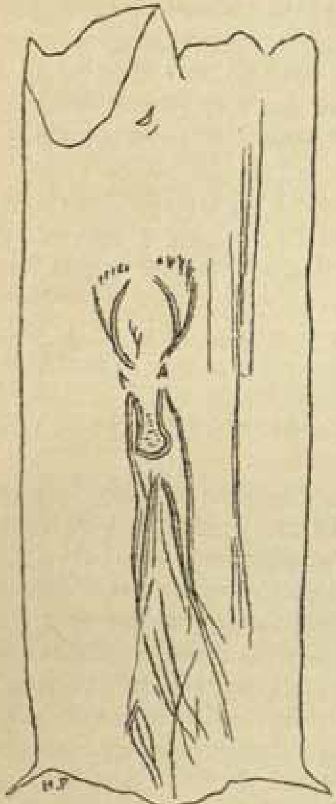


FIG. 13.—Reindeer viewed from in front, engraved on reindeer horn. From the lower Magdalenian deposits, cavern of Gourdan (Haute-Garonne). After Piette, L'anthr., vol. 15, p. 159, 1904.

soon found this to be true especially of the front and dorsal views. Even his favorite profiles did not escape the universal tendency particularly when they dealt with groupings or herds of animals. An excellent example was recently discovered in the cavern of La Mairie at Teyjat (Dordogne). It represents a herd of reindeer (fig. 16). The three in the lead are fairly well differentiated as is also one at the rear. The space between is filled in by cross-hatching similar to that on the bodies of the leaders, representing therefore the undifferentiated bodies of those in middle of the herd. Above rises a forest of horns. These being the most characteristic feature of the animal are exaggerated as if to make up for the artist's sacrifice of detail with respect to body and limbs. The entire group is delicately incised on the radius of an eagle that was found in the upper Magdalenian layer of the cavern floor.

Fig. 14.—Panel engravings on a piece of reindeer horn. Lower Magdalenian, cavern of Gourdan (Haute-Garonne). After Piette, L'anthr., vol. 15, p. 163, 1904.

A work of art similar to the foregoing but engraved on a fragment of stone and representing horses instead of reindeer was found many years ago in the cavern of Chaffaud (Vienne). The surface

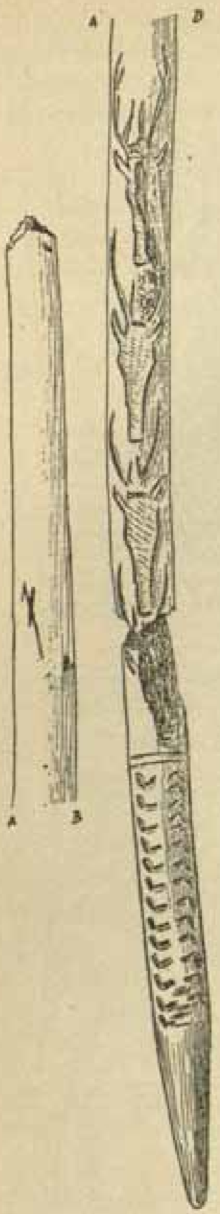


FIG. 15.—Front view of the deer's head, repeated four times on the shaft of a wand. Middle Magdalenian, rock-shelter of Mège (Dordogne). After Breuil, Rev. de l'Ecole d'anthr. de Paris, vol. 16, p. 209, 1906.

of the stone is divided into two panels—an upper and a lower. Each panel is filled by a herd of galloping horses—seventeen in one group and eighteen in the other. In both panels the horse at each end is completely traced. Those in between are represented by contour lines of the heads, necks and forefeet only, giving the effect of an orderly compact squadron of cavalry in action. The original is said to have disappeared but Cartailhac[a] has reproduced it in negative from an estampage.

From the beginning of the Magdalenian epoch, symbolism began to play an important rôle in paleolithic art. According to Piette, symbols are figures or images employed as signs of objects; therefore they represent words. In the process of time the words were divided into syllables, the syllables into letters; the same signs have designated successively words, syllables, and letters. Among the earliest paleolithic symbols are the dotted circle, the lozenge and the spiral or sigmoid scroll. The first is supposed to be a sun symbol. It reappears as an Egyptian hieroglyph, also on dolmens and menhirs, on bronze age funerary urns and ornaments of the first iron age. The circle without the dot passed into the ancient alphabets and from them into modern alphabets. The lozenge was employed as an artist's signature. The spiral has flourished in all succeeding ages and like some other symbols may have developed independently in various ages and lands.

Piette distinguishes two successive systems of writing in the Magdalenian—the first hieroglyphic and the second cursive. He believes the latter was derived from the former, but admits that since symbols are creatures of convention they may have been from the beginning figures formed by geometric lines instead of being simplified images. An example of cursive writing dating from the Magdalenian epoch is given in figure 17. It is from the classic station of La

[a] L'anthropologie, vol. 14, 177, 1903.

Madeleine (Dordogne). The inscription is composed of eight signs, some of which resemble certain letters of the Phenician and ancient Greek alphabet, as well as Cypriote signs. While these may not have been real letters to the Magdalenians, they did become so in passing from a symbolic and phonetic stage combined to one purely phonetic.

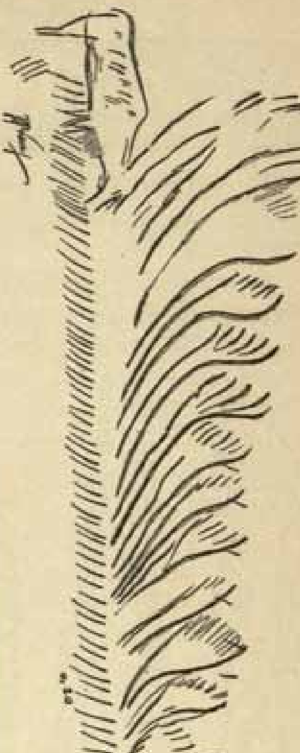


Fig. 16.—Herd of reindeer engraved on the radius of an eagle, from the cavern of La Mairie, Teyjat (Dordogne). After Breuil, Rev. de l'Ecole d'anthr. de Paris, vol. 18, p. 212, 1908.

The first sign resembles the Phenician guimel, the gamma of ancient and modern Greek and a sign in Asylian writing which dates from the epoch of transition between the paleolithic and neolithic. Allowing for some negligence in execution, the second sign is comparable to the Phenician alef, the alpha of ancient and classic Greek, and A of our own alphabet. The third character is the Phenician guimel, the gamma of primitive and classic Greek. The fourth sign is the same as the third, only reversed. This is also found in the Asylian. The fifth and sixth signs are alike; they are comparable to the letter l of the Lycian alphabet and of the classic Greek—the equivalent of the Cypriote sign go. The seventh sign, which is also found on one of the painted pebbles of Mas d'Azil, resembles the character ti, di, thi of the Cypriote alphabet. The eighth character bears some analogy to the Cypriote vi or yi.

Cursive writing was developed still further during the Asylian epoch (fig. 18), which is the connecting link between the paleolithic and neolithic periods. The transitional character of this epoch is revealed in both faunal and industrial remains. The fauna is composed entirely of species still living in temperate regions. Asylian culture is a heritage from the Magdalenian. It is characterized by

the appearance of flat, perforated harpoons (fig. 18) made of staghorn, that replaced two successive types of Magdalenian harpoons—the older with a single row of lateral barbs and the younger with two rows of lateral barbs. The stratigraphic position of the Asylian, reposing on the upper Magdalenian, is in harmony with the cultural and faunal elements. This is the horizon of the remarkable painted pebbles (fig. 18) found in the cavern of Mas l'Azil[a] (Ariège), that have thrown so much light on paleolithic systems of writing and their connection with subsequent systems. According to Piette we are indebted

FIG. 17.—Inscription, from the upper Magdalenian, La Madeleine (Dordogne). After Piette, L'anthr., vol. 15, p. 164, 1904.

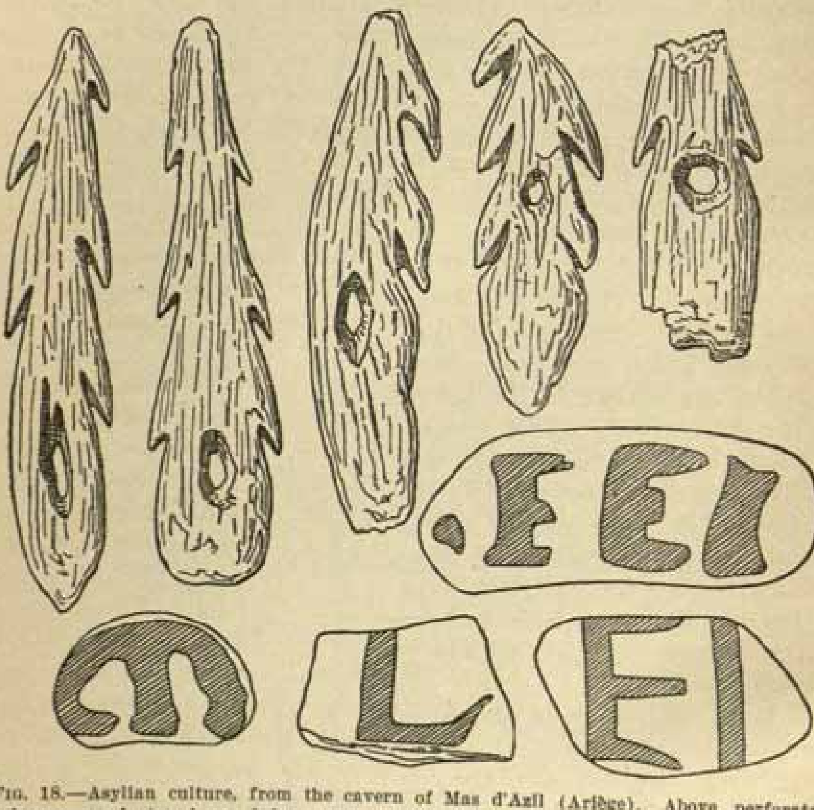


FIG. 18.—Asylian culture, from the cavern of Mas d'Azil (Ariège). Above, perforated harpoons of stag horn; below, pebbles with painted designs representing a cursive system of writing. After Hœrnes, Der diluv. Mensch in Europa, p. 79, 1903.

to the Asylian for at least a dozen symbols that have come down from the close of the Quatenary through the Phenician, Archaic

[a] Provincial form for Maison d'Asyle, whence Piette's name (Asylian) for the epoch.

and classic Greek, Latin and Lydian. Discoveries of the past few years have added appreciably to our knowledge of the Asylian. One of these at Ofnet (Bavaria) will be discussed in the following chapter.

HUMAN REMAINS.

The decade has witnessed the discoveries of skeletal remains of man that have added much to our knowledge of the races inhabiting Europe during the Quaternary. Because of the stratigraphic position in which it was found and of its somatological characters, the human lower jaw discovered by Dr. Otto Schoetensack[a] on October 21, 1907, in a sandpit near the village of Mauer, 10 kilometers southeast of Heidelberg, ranks as the most important single specimen. Mauer lies in the valley of the Elsenz, a tributary of the Necker. The human lower jaw was found in situ in the so-called Mauer sands, at a depth of 24.10 meters and 0.87 meter from the bottom of the deposit. The first 10.92 meters at the top of the sections are composed of loess, which is classed as upper Quaternary, while the Mauer sands forming the rest of the section are lower Quaternary. The loess itself represents two distinct periods, an older and a younger.

The horizon (fig. 19) from which the human lower jaw came has furnished other mammalian remains, including *Felis spelæa*, *Felis catus*, *Canis*, *Ursus arvernensis*, *Sus scrofa* var. *priscus*, *Cervus latifrons*, *Bison*, *Castor fiber*, *Equus*, *Rhinoceros etruscus*, and *Elephas antiquus*.

Schoetensack likens the fossil mammalian fauna of the Mauer sands to the preglacial Forest beds of Norfolk and the upper Pliocene of southern Europe. This is particularly true of *Rhinoceros etruscus*, and the horse of Mauer, which is a transition form between *Equus stenonis cocchi* and the horse of Taubach, both of which may be referred definitely to the Pliocene. The rest of the mammalian fauna belongs to the lower Quaternary.

The coexistence of man with *Elephas antiquus* at Taubach, near Weimar, gave Schoetensack special reasons for expecting to find human remains also at Mauer. The possibility of such a discovery had kept him in close touch for twenty years with the owner of the sandpit, Herr J. Rösch. The discovery was made by one of the workmen, with whom at the time were another workman and a boy. Schoetensack was immediately informed, and arrived the following day. The lower jaw was intact, but the stroke of the workman's

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[a] Der Unterkiefer des Homo Heidelbergensis aus den Sanden von Mauer bei Heidelberg: Ein Beitrag zur Paläontologie des Menschen, von Otto Schoetensack. Mit 13 Tafeln, davon 10 in Lichtdruck. Leipzig: Verlag von Wilhelm Engelmann, 1908.

shovel had caused the two halves to separate along the line of symphysis. It was discolored, and marked by incrustations of sand exactly as are all fossil bones from the Mauer sands. A limestone pebble was so firmly cemented to the left half of the jaw, covering the premolars and first two molars, that the crowns of all four stuck to the pebble when the latter was removed. Both the jaw and the pebble were marked by dendritic formations.

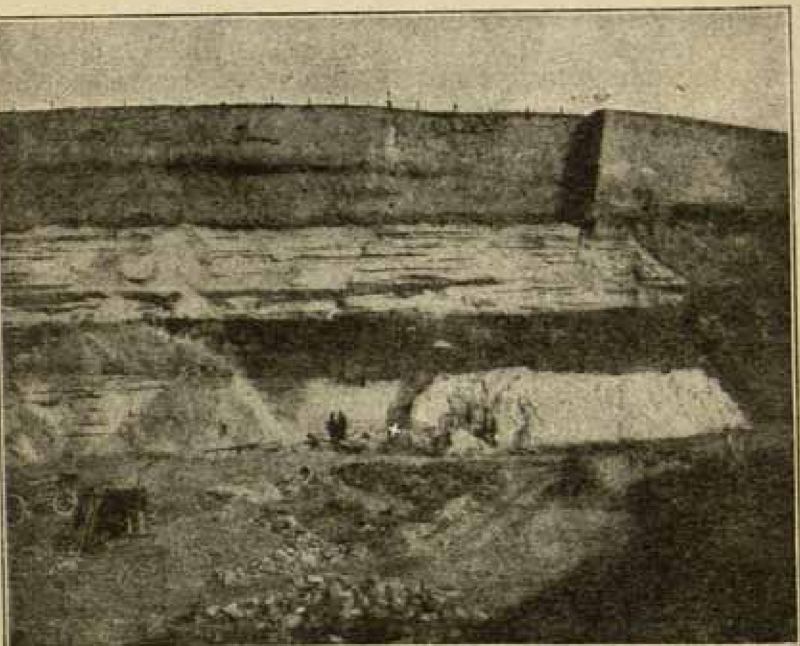

FIG. 19.—Sand pit at Mauer. The lower jaw was found at the spot marked with a cross. After Schoetensack, Der Unterkiefer des Homo Heidelbergensis, Taf. II, Leipzig, 1908.

Perhaps the first thing to attract one's attention is the absence of a chin (pl. 13). The region of the symphysis is somewhat gorilloid, while the ascending ramus suggests rather the gibbon. The teeth, however, have a distinctly human stamp, not only in their general appearance, but also in point of size—larger than the average, but smaller than in exceptional cases to be found among the Australians, for instance. One is impressed, in fact, by the relative smallness of the teeth as compared with the massive jaw in the case of *Homo heidelbergensis*. The alveolar arch is almost long enough, for example, to allow space for a fourth molar. I noted the same phenomenon in a collection of recent crania from Gazelle Peninsula, New Britain.[a] In one of these the alveolar arch of the upper jaw

[a] American Anthropologist, 1902, n. s., vol. 4, 474.

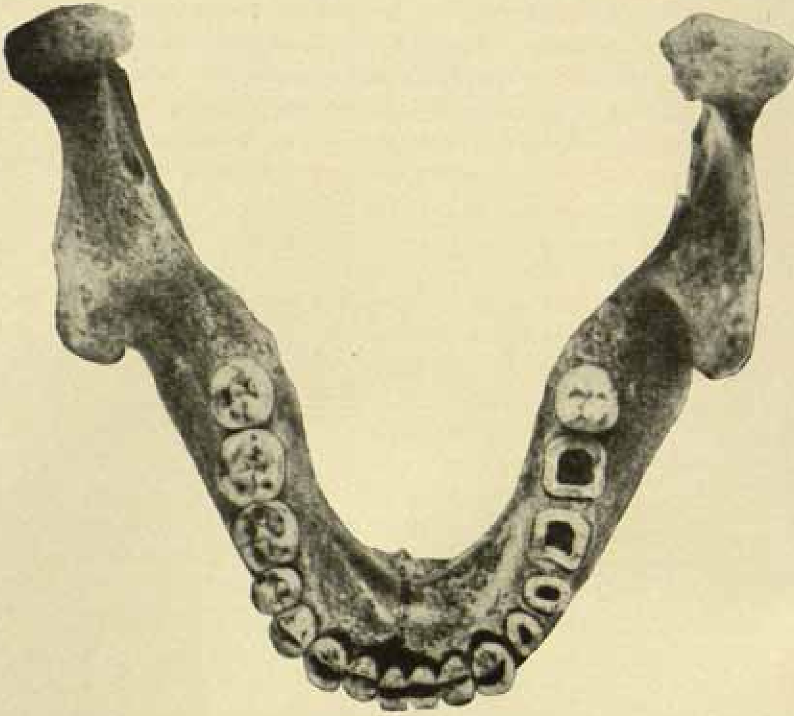

FIG. a. LOWER JAW OF HOMO HEIDELBERGENSIS. ABOUT ½.

FIG. b. LOWER JAW OF HOMO HEIDELBERGENSIS. AFTER SCHOETENSACK, DER UNTERKIEFER DES HOMO HEIDELBERGENSIS, LEIPZIG, 1908.

projects 12 millimeters beyond the third molar, while the average for the males is 8.6 millimeters. Respecting the series of lower jaws, I quote from my paper read in 1902: "The third molar is generally situated well in front of the ascending ramus of the lower jaw, when the jaw is so held as to bring the anterior margins of the rami in a line with the eye. With the jaw held in this position, the entire crown of the third molar can be seen in 13 out of a total of 18 cases."

The crowns of the teeth in the Mauer specimen are worn enough to show the dentine, proof that the individual had reached the adult stage. All the molars, except the third left, have five cusps. The tendency in recent man is toward a four-cusp type for the third molar, if indeed there be a third molar. The breaking away of the crowns of four teeth on the left side tended to facilitate the study of the pulp cavities and the walls. This study reveals the fact that the dentition of *Homo heidelbergensis* represents a youthful stage in the dentition of the modern European. That is to say, in the ontogeny of the latter, a stage representing adult dental characters when the race was young is now reached at the age of from 9 to 14 years. This is not an anthropoid character, but a primitive human character—another reason for leaving the anthropoids to one side in our search for the ancestral form and the origin of genus *Homo*.

A study of the corpus and ramus mandibulæ reveals at once a number of points of divergence from the modern European. The body is massive, and relatively long in proportion to the bicondylar breadth, its greatest height being in the region of the first and second molars. The basis mandibulæ, if applied to a plane, touches only on either side of the symphysis and near the angulus, forming three gentle arches—one median and short, called by Klaatsch incisura submentalis; and two lateral and long, to which might be given the name incisura basilaris. The latter is seen to good advantage also in the chimpanzee.

The ramus is characterized by unusual breadth, 60 millimeters as opposed to an average of 37 for recent examples. The angle formed by lines tangent to the basis and the posterior border of the ramus is 107°—smaller than the average. The processus coronoideus is exceedingly blunt, and the incisura mandibulæ correspondingly shallow. The condyloid process is noteworthy on account of the extent of articular surface, due to an increased antero-posterior diameter (13 and 16 millimeters), since the transverse diameter is relatively short. The neck constriction is very slight, approaching in this respect the anthropoid forms.

The first fossil lower jaw to attract world-wide attention on account of its primitive characters and association with remains of

the mammoth and rhinoceros, was that found in 1866 by Dupont in the cavern of La Naulette, valley of the Lesse, Belgium. It was only a fragment, but enough remained to demonstrate the complete absence of chin and the nature of the dentition. Its kinship with the man of Neanderthal, whose lower jaw could not be found, was evident. It tended therefore to legitimatize the latter, which hitherto had failed of general recognition. The fortunate association of skull with lower jaw came in 1886, when the remains of two individuals were discovered in the cavern of Spy, also in Belgium. In the same layer were found not only remains of the mammoth and the rhinoceros, but also an industry of the Mousterian type.

Among the human remains found in 1899 by Professor Gorjanovič-Kramberger at Krapina, there are parts of a number of lower jaws that bear the same racial characters as those of La Naulette and Spy. They were also associated with a Mousterian industry. Instead, however, of the *Rhinoceros tichorhinus*, as at Spy, there were remains of *Rhinoceros merckii*, an older type. This may be accounted for by the fact that *Rhinoceros merckii* would persist longer in the south than in the north.

That the lower jaws of La Naulette, Spy, and Krapina represent one and the same stage in the evolution of *Homo sapiens*, there is no longer any doubt. That this stage is intermediate between recent man and *Homo heidelbergensis*, a careful comparison of the specimens in question furnishes ample proof.[a] The lower jaw from Mauer is therefore pre-Neanderthaloid. That it also exhibits pre-anthropoid characters gives it a fundamental position in the line of human evolution. Doctor Schoetensack is to be congratulated on his rich reward for a twenty years' vigil.

The lower jaws of the Neanderthal, or so-called *primigenius*, type, mentioned above, were all found in cavern or rock-shelter deposits. These cannot be definitely correlated with river-drift and loess; hence we cannot measure the time that separates the man of Spy from *Homo heidelbergensis*. Judging from somatic characters alone, the time separating the two must have been considerable.

The Mousterian industry which is found associated with *Homo primigenius* occurs in deposits that mark the close of the middle Quaternary, and also in cavern deposits corresponding to the base of the upper Quaternary. It belongs to the transition from the Riss glacial period to the Riss-Würm interglacial period. At Wildkirchli, in the Alps, it is frankly interglacial, a station that probably belongs to the close of the Mousterian epoch.

The position of the Mauer lower jaw near the bottom of the old diluvium, and its association with the remains of *Elephas antiquus*

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[a] Spy approximates more closely the Mauer type than does Krapina.

HOMO PRIMIGENIUS, OR MOUSTERIENSIS, FROM THE CAVERN OF LE MOUSTIER (DORDOGNE).

(Photographs by O. Hauser.)

and *Rhinoceros etruscus*, suggest for it a place at least as far back as the lower Quaternary. But the industry of the lower Quaternary is eolithic, the evolution of the Chellean type not taking place until the middle Quaternary. One would expect to find Maflean industry in the horizon of *Homo heidelbergensis* and this, according to the latest report, is what Professor Schoetensack has succeeded in doing.

During the summer of 1908, Herr O. Hauser found part of a human skeleton, including the skull, in the classic station of Le Moustier itself. This station, belonging to a wonderful series of paleolithic sites in the valley of Vézère, France, has been known since the explorations of Lartet and Christy, 1863–1865. Hauser very wisely delayed the removal of the human remains from the cavern of Le Moustier until after the arrival of a party of German anthropologists, including Professor Klaatsch, of Breslau, the party going direct from the German Anthropological Congress held at Frankfurt during the first week in August.

Hauser's discovery was made in the lower cave at Le Moustier, and includes not only an almost complete skull (pl. 14, figs. *a*, *b*) but also various parts of the skeleton of a youth of about 15 years. At this age, sex can not be determined from the bones alone. The race characters also are not so distinct as they would be at full maturity; but they point unmistakably to the type of Neandertal, Spy, and Krapina—the so-called *Homo primigenius* which now also becomes *Homo mousteriensis*. It was a rather stocky type, robust and of a low stature. The arms and legs were relatively short, especially the forearm and from the knee down, as is the case among the Eskimo. Ape-like characters are noticeable in the curvature of the radius and of the femur, the latter being also rounder in section than is the case with *Homo sapiens*. In the retreating forehead, prominent brow ridges, and prognathism it is approached to some extent by the modern Australian. The industry associated with this skeleton from Le Moustier is that typical of the Mousterian epoch.

A discovery of paleolithic human remains was made on August 3, 1908, by the Abbés J. and A. Bouyssonie and L. Bardon, assisted by Paul Bouyssonie, a younger brother of the first two. It is in many respects one of the most satisfactory, particularly on account of the pieces being so nearly complete. The locality is the village of La Chapelle-aux-Saints, 22 kilometers south of Brive, in the department of Corrèze, which forms a part of one of France's celebrated cavern belts, including Dordogne, Charente, and Gironde to the west.

The discovery at La Chapelle-aux-Saints was made in a cavern a short distance from the entrance. It includes not only human bones, but also stone implements and the remains of the reindeer, *Bison*, *Equus*, *Capra ibex*, *Rhinocerous tichorhinus*, fox, bird.

That this may have been a burial is suggested by the disposition of the human remains which seemed to lie in a rectangular pit sunk to a depth of 30 centimeters in the floor of the cavern. They were covered by a deposit intact 30 to 40 centimeters thick, consisting of a magma of bone, of stone implements, and of clay. The stone implements belong to a pure Mousterian industry. While some pieces suggest a vague survival of the Acheulian implement, others presage the coming of the Aurignacian. Directly over the human skull were the foot bones, still in connection, of a bison—proof that the piece had been placed there with the flesh on, and proof, too, that the deposit had not been disturbed. Two hearths were noted also, and the fact that there were no implements of bone, the industry differing in this respect from that at La Quina and Petit-Puymoyen (Charente), as well as at Wildkirchli, Switzerland.

The human bones include the cranium and lower jaw (broken, but the pieces nearly all present and easily replaced in exact position), a few vertebræ and long-bones, several ribs, phalanges and metacarpals, clavicle, astragalus, calcaneum, parts of the scaphoid, ilium, and sacrum. The ensemble denotes an individual of the male sex, whose height was about 1.60 meters. The condition of the sutures and of the jaws prove the skull to be that of an old man. The cranium is dolichocephalic, with an index of 75. It is said to be flatter in the frontal and occipital regions than those of Neanderthal and Spy.

Beyond the loss of teeth, due evidently to old age, the skull is so nearly intact as to make possible the application of the usual craniometric procedure, thus leading to a more exact comparative study than has been possible, for example, in all previously discovered paleolithic human skulls dating from the same period, not excepting even Spy and *Homo mousteriensis*. This is particularly true of the basi-occipital region, the upper jaw, and the face-bones (pl. 15). We are thus enabled to supplement our knowledge of Mousterion craniometry at several points and to correct it at others. This is the first case, for example, in which the foramen magnum has been preserved in human crania of the Mousterian type. It is found to be elongated, and is situated farther back than in modern inferior races. The character of the inion and its relation to the cranial base is revealed for the first time. There is no external occipital protuberance, but the linea nuchæ superior (torus occipitalis transversus) is well marked. The character of the surface in the nuchal region indicates that the muscles here were highly developed. The palate is relatively long, the sides of the alveolar arch being nearly parallel; that is to say, the palate is hypsiloid—one of the two characteristic simian forms. Boule also notes the absence of the fossa canina. The nose, separated from the prominent glabella by a pronounced depression,

FIG. *a*. SKULL OF THE FOSSIL MAN OF LA CHAPELLE-AUX-SAINTS, AFTER RESTORATION OF THE NASAL BONES AND JAWS. AFTER BOULE, L'ANTHR., 20, P. 267, 1909.

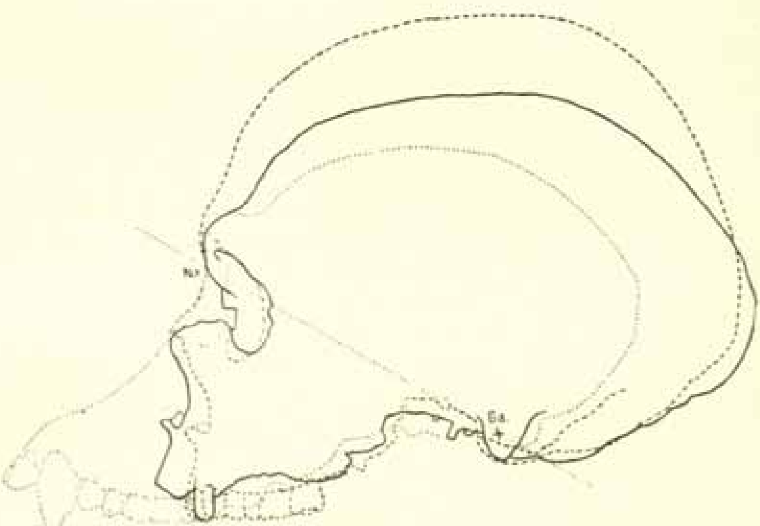


FIG. *b*. PROFILES OF THE CRANIUM OF A CHIMPANZEE, THE CRANIUM OF LA CHAPELLE-AUX-SAINTS, AND THAT OF A MODERN FRENCHMAN SUPERPOSED, AND WITH A COMMON BASI-NASAL LINE EQUAL IN LENGTH FOR EACH. BA, BASION; NA, NASION. AFTER BOULE, L'ANTHR., 20, P. 265, 1909.

is relatively short and broad. The lower jaw is remarkable for its size, for the antero-posterior extent of the condyles, the shallowness of the incisura mandibulæ, and the absence of chin.

Boule estimated the capacity of the Chapelle-aux-Saints skull according to the formulæ of Manouvrier, of Lee, and of Beddoe, obtaining results that varied between 1,570 and 1,750 cubic centimeters. By the use of millet and of shot an average capacity of 1,626 cubic centimeters was obtained. Judging from these figures the capacity of the crania of Neandertal and Spy has been underestimated by Schaaffhausen, Huxley, and Schwalbe.

By its cranial capacity, therefore, the Neandertal race belongs easily in the class of *Homo sapiens.* But we must distinguish between relative capacity and absolute capacity. In modern man, where the transverse and antero-posterior diameters are the same as in the skull of La Chapelle-aux-Saints, the vertical diameter would be much greater, which would increase the capacity to 1,800 cubic centimeters and even to 1,900 cubic centimeters. Such voluminous modern crania are very rare. Thus Bismarck, with horizontal cranial diameters scarcely greater than in the man of La Chapelle-aux-Saints, is said to have had a cranial capacity of 1,965 cubic centimeters.

The most remarkable thing about the astragalus is the special development of the articular surface for the lateral malleolus, development that recalls the condition in anthropoids and climbing mammals. This seems to indicate that, as among anthropoids, the foot of the man of La Chapelle-aux-Saints should repose on its external margin, also that the fibula was relatively more powerful than is the case among modern races.

The calcaneum is characterized by its shortness and especially by the large dimensions of the lesser process (sustentaculum tali). The latter in its proportions resembles that in the Veddahs and in anthropoids.

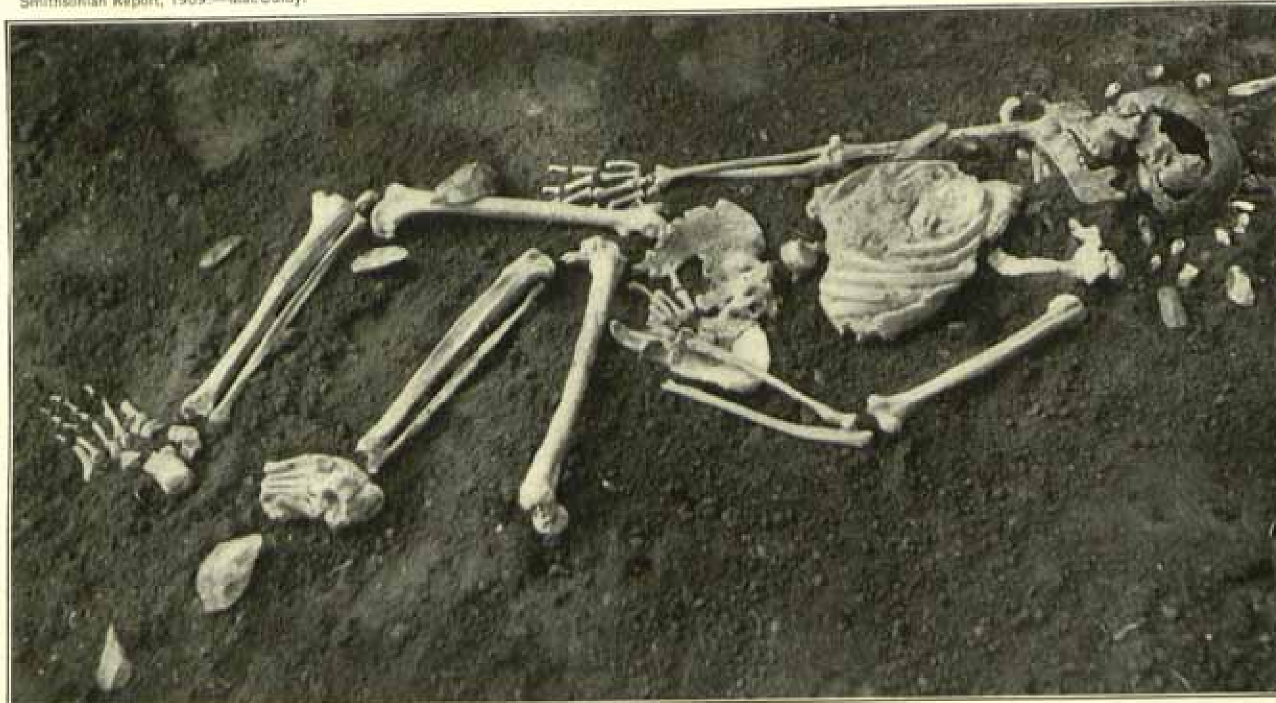
During the autumn of 1909 M. D. Peyrony, of Les Eyzies, had the good fortune to discover human remains of Mousterian age at two different localities in the department of Dordogne. The first find was made in a small cavern at Pech de l'Azé, 5 kilometers from Sarlat. Here in undisturbed upper Mousterian deposits was found the skull of a child five or six years old. About it were the numerous animal bones broken artificially, the teeth of the horse, deer, reindeer, and an abundance of Mousterian implements. The lower Mousterian deposit on which the skull rested contained fine implements of the Acheulian type.

M. Peyrony's second discovery was made September 17, 1909, in the rock-shelter of La Ferrassie near Bugue. The section at La Ferrassie comprises five archeological horizons, Acheulian, Mousterian,

and lower, middle, and upper Aurignacian. It was between the Acheulian and Mousterian deposits and at a depth of 3 meters that an almost complete human skeleton was found. Although in part crushed by the enormous weight of earth above, all the bones were in place with the exception of those of the right foot and hand, which had been displaced and partially destroyed, probably by some carnivore or rodent. The skeleton has been removed intact with care and, it is hoped, will soon be published in detail. Unlike the case of La Chapelle-aux-Saints, this was not an interment. The body was placed at one corner of the shelter and covered with branches or skins, perhaps a little earth, or all three of these combined. About the head and shoulders were three stones that might have served as weights. Gradually it was covered deeper and deeper by débris from the overhanging rocks and that left by succeeding Aurignacian populations. Its stratigraphic position is clearly defined. A more extended report as to its somatological characters is awaited with much interest. It should not only confirm but also supplement existing data bearing on the osteology of *Homo primigenius*, as did the remains from La Chapelle-aux-Saints.

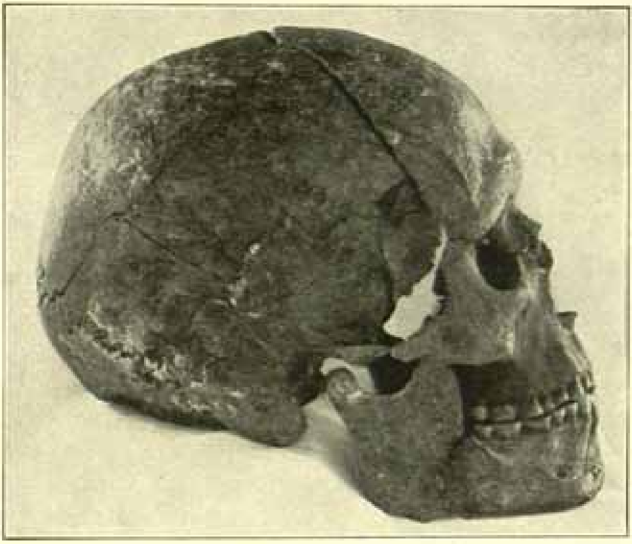
Thanks to persistent, painstaking, systematic explorations, the Dordogne seems destined to maintain its lead in matters paleolithic. Herr O. Hauser who made the important discovery of *Homo mousteriensis* at Le Moustier in 1908 has been also rewarded with a rich harvest in 1909. At Combe-Capelle, near Montferrand-Périgord, he found on August 26 an adult male skeleton of Aurignacian age. The type, however, is of a higher order than that of his *Homo mousteriensis*, the difference being greater than might be inferred from its stratigraphic position. The remains had been interred, the pit being sunk into a deposit of Mousterian age. The stone implements found with the skeleton about the head, arms, knees, and feet are Aurignacian. For this reason Klaatsch suggests the name *Homo aurignacensis hauseri*. A number of snail shells were also deposited with the dead, probably as ornaments. As was the case the previous year at Le Moustier, Professor Klaatsch, of Breslau, was called to Combe-Capelle to superintend the removal of the skeleton (pls. 16, 17).

Klaatsch classes *Homo aurignacensis hauseri* with the human remains from Brünn (Mähren) and Galley Hill, near London. All three skulls are long and narrow, markedly dolichocephalic. In so far as the fragmentary condition of the Galley Hill skeleton will admit of comparison the other skeletal parts agree in type. Klaatsch also notes certain resemblances to the much later Magdalenian race, as represented by the skeleton found twenty years ago at Chancelade, also in the Dordogne. Although of rather short and powerful build, Klaatsch believes this Aurignacian race did not evolve directly from



HOMO AURIGNACENSIS HAUSERI, FROM THE ROCK SHELTER OF COMBE-CAPELLE (DORDOGNE).

(Photograph by O. Hauser.)



SKULL OF HOMO AURIGNACENSIS HAUSERI.

(Photographs by O. Hauser.)

the Neandertal or Mousterian race. On the other hand, he believes it later developed into the Cro-Magnon and Chancelade types.

The caverns of Grimaldi (Baoussé-Roussé), between Mentone and Ventimiglia and on the Italian side of the international boundary, form one of the most compact groups of paleolithic caverns in all Europe.

Counting two small rock-shelters, the group includes nine stations, the most important being the Grotte des Enfants, La Barma Grande, Grotte du Cavillon and the Grotte du Prince. General attention was first called to this region many years ago by Rivière's discovery of a human skeleton in the Grotte du Cavillon—the so-called homme de Menton, now in the Natural History Museum, Paris. Later five skeletons in all were found at La Barma Grande, and two, of children, in the Grotte des Enfants, whence its name.

Interest in archeology and ownership of one of the caverns (Grotte du Prince), led the Prince of Monaco to provide for a systematic exploration of the Grimaldi cavern deposits hitherto undisturbed, beginning with the virgin Grotte du Prince. The work was placed in the hands of the Canon L. de Villeneuve, Prof. M. Boule, and Dr. R. Verneau. The Grotte du Prince proved to be rich in faunal remains. Not a single human bone was found, however, although as many as twenty-eight hearths were encountered. The age, therefore, of the skeletons previously found in the neighboring caverns still remained in doubt. Work was next begun (1900) in the Grotte des Enfants that had been only partially explored by Rivière. Here, as at the Grotte du Prince, the entire series of deposits was found to be Quaternary; the occupation of the cavern, however, is supposed to have begun and to have ended a little later than at the Prince's cavern.

The two layers at the bottom were characterized by a so-called warm or tropical fauna—*Elephas antiquus* and *Rhinoceros merckii.* All the succeeding layers contain the fauna of the reindeer. The explorers were rewarded by finding human remains at three distinct levels, all three being in the reindeer deposits. Beginning at the bottom, a common sepulture with an adult female and youthful male skeleton was encountered at a depth of 8.5 meters and resting directly on the deposits with the fauna of *Elephas antiquus.* On account of their accentuated negroid characters, these differ from all other Quaternary skeletons. To this type, which Verneau has called the Race de Grimaldi, attention has been called afresh by the Venus of Willendorf, a stone figurine recently discovered near Krems, Austria.

At a level of less than a meter above the common sepulture with negroid remains was found a male skeleton of the Cro-Magnon type. The fauna of the two horizons is precisely the same, and con-

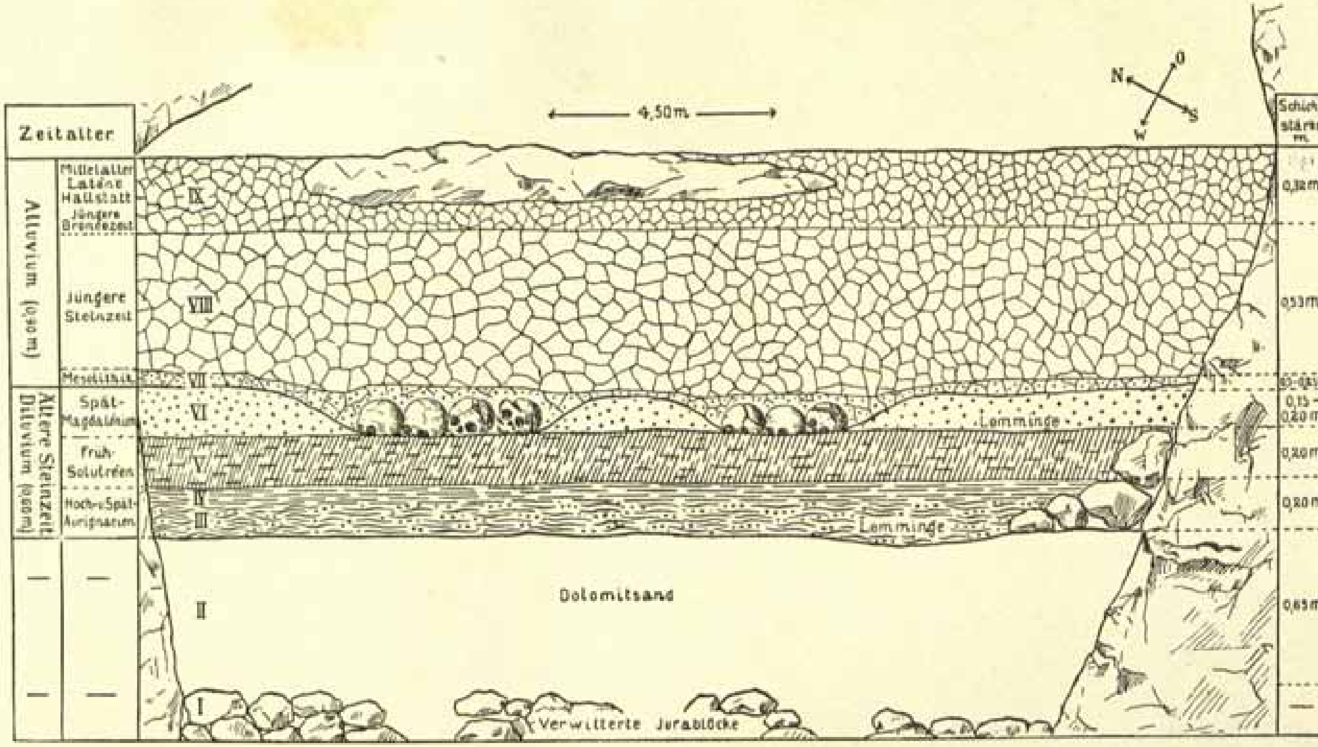
tinues to be uniform to the top of the section. The female skeleton, therefore, found by de Villeneuve at a depth of 1.9 meters from the surface is Quaternary, belonging probably to the close of the Magdalenian epoch. It has certain negroid characters, such as relatively long forearms and thighs. The slight parieto-occipital flattening suggests the Cro-Magnon type, while in some respects it is not unlike the neolithic dolichocephals.

The reindeer is associated with three successive cultural epochs—Aurignacian, Solutréan, and Magdalenian, respectively. All three epochs are probably represented at the Grotte des Enfants, in which case the negroid skeletons might be considered as of Aurignacian age. Immediately below were remains of *Elephas antiquus*. It may be recalled that at Krapina, the latter was associated with a Mousterian industry and skeletal remains of the *Homo primigenius* type.

The human skeletal remains from the Grotte des Enfants are all referable to the reindeer period, the transitional Asylian epoch not being represented there. Thanks to the researches of Dr. R. R. Schmidt[a] in the cavern of Ofnet, a number of human skulls dating from the Asylian have been brought to light. Stratigraphically, Ofnet is, after Sirgenstein, one of Germany's most important paleolithic stations. An instructive section of the deposits is reproduced in plate 18, taken at a point just inside the entrance to the cavern. On account of its great weight, the fallen stone at the top had protected this portion of the floor deposits from earlier exploitation. The first two layers are sterile. In the third and fourth, Schmidt found an industry typical for the middle and upper Aurignacian in association with an Equus fauna, including the lemming. The fifth layer marks the appearance of a pure early Solutréan culture, with a continuation of Equus fauna. The lemming reappears at the base of the sixth deposit, which is surmounted by a characteristic upper Magdalenian industry.

The horizon that interests us most is the seventh, called by Schmidt "Mesolithik," and coördinate with the Asylian. The layer is only about 5 centimeters thick except at two points where pockets are formed that reach to the level of the Solutréan deposit. The compact earth in these pockets was impregnated with red ochre, and in each was a circular group of human crania covered with powdered ochre. All the crania, twenty-seven in one group and six in the other, were placed so as to face the setting sun. A large majority in each group were skulls of females and children, there being in all but six male skulls. The burials of the heads without the bodies were made while the flesh was still on as the lower jaw and one or several cervical

[a] Die vorgeschichtlichen Kulturen der Ofnet. Bericht des naturwissenschaftl. Vereins für Schwaben und Neuberg (E. V.), 85, 1908.



SECTION THROUGH FLOOR DEPOSITS IN THE CAVERN OF OFNET, BAVARIA. AFTER R. R. SCHMIDT, ACHTUNDDREISSIGSTER BERICHT F. SCHWABEN UND NEUBURG (E. V.), 1908.

vertebræ were found in place with each cranium. The skulls of the females and children were accompanied by necklaces of perforated stag canines and shells (*Planorbis*). The skulls were neither burnt nor mutilated.

With the possible exception of a Tardenoisian flint point, there is nothing in this horizon to suggest the neolithic; no ceramics, no remains of domesticated animals, although the neolithic is well represented in the succeeding deposit. In respect to fauna and stratigraphy, it is Asylian. Two typical Asylian cultural elements—flat harpoons of stag horn and painted pebbles—are missing, however. Schmidt classes the industry as Asylo-Tardenoisian. The burial custom leans rather to the paleolithic. The use of ochre and of shell ornaments is common to a number of paleolithic burials: Asylian of Mas d'Azil; Magdalenian of Cro-Magnon, Laugerie-Basse, Grimaldi, and Placard; and Solutréan of Brünn (Moravia). The practice of burying the head alone seems to have been in vogue also at Gourdan, for there according to Piette one never finds any human bones except those of the cranium, lower jaw, and the first two or three cervical vertebræ.

Twenty of the Ofnet crania have been restored and are to be carefully studied by Doctor Schliz, who reports a mixture of the Mediterranean and the Alpine type. The Mediterranean influence on the physical type is not surprising, when viewed in the light of Ofnet's cultural resemblances to stations in southwestern Europe.

CONCLUSIONS.

The first explorer, the original discoverer on a world scale, was primitive man. He had covered the earth before the Europeans of to-day set for themselves the highly interesting task of rediscovering it and him. After some centuries, this self-imposed, instructive, and pleasure-giving problem is nearly solved. Superficially, at least, the earth has been compassed, the blank spots on the world map of to-day being few and comparatively small.

The conquest, however, has been largely one of two dimensions. Now that it is nearly over, we are left all the more free to focus the attention on a whole series of antecedent worlds. This is what Europe is at present doing. She is now bent on discovering the prehistoric worlds beneath her very feet. She has found that man's occupation of the earth has not only length and breadth, but also depth, and therefore admits of measurement in three dimensions instead of two. Surely here is more work for the pathfinder. That success will attend his labors, the discoveries of the past decade offer ample proof.

This survey of recent progress is made first of all from the standpoint of chronology. In the second place the evidence of man's antiquity has been arranged under three categories, derived respec-

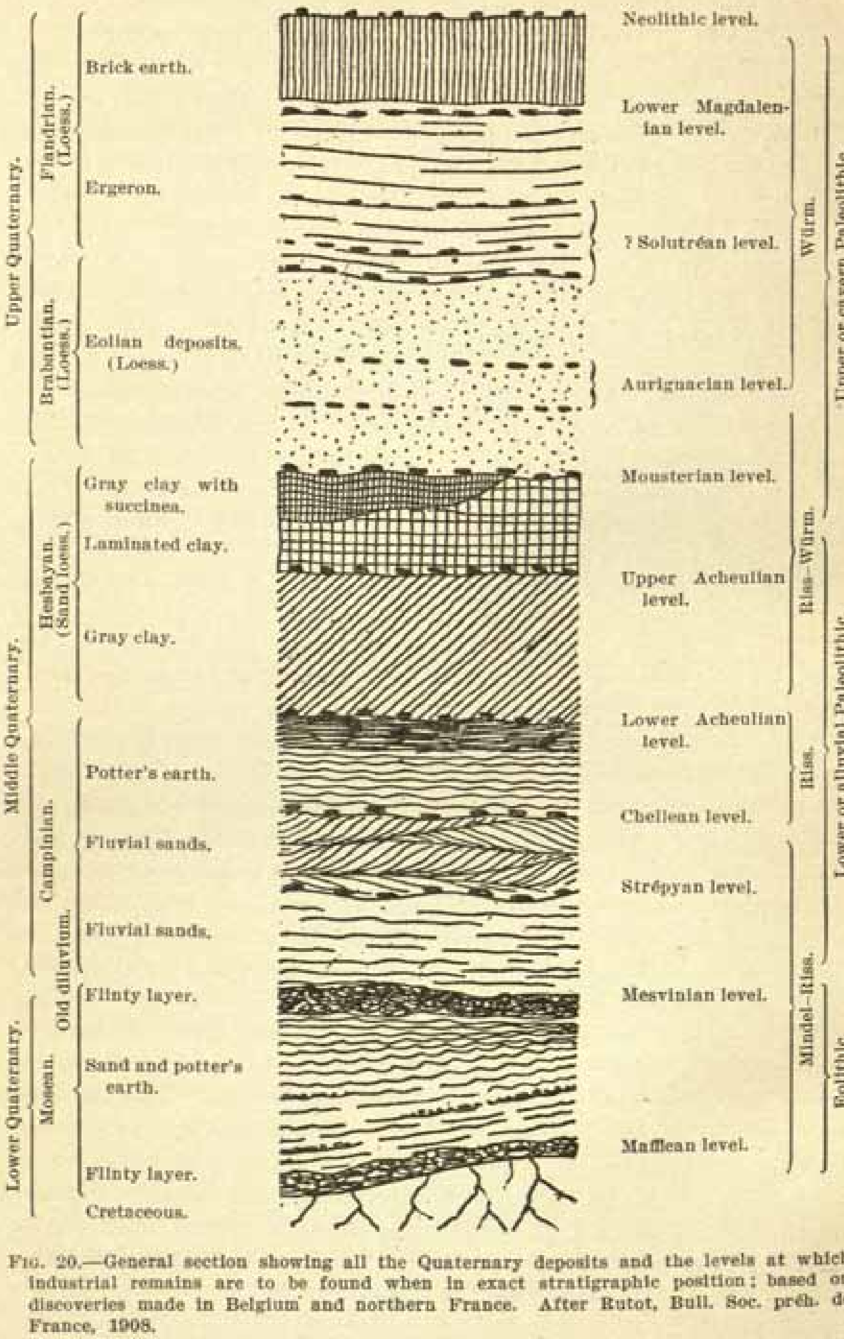


FIG. 20.—General section showing all the Quaternary deposits and the levels at which industrial remains are to be found when in exact stratigraphic position; based on discoveries made in Belgium and northern France. After Rutot, Bull. Soc. préh. de France, 1908.

tively from (1) valley deposits, (2) caverns and rock-shelters, and (3) human skeletal remains.

The older paleolithic horizons, the Strépyan, Chellean, and Acheulian are to be found in valley deposits beginning with the middle Quaternary. The younger paleolithic horizons are quite generally thought of as being restricted to caverns and rock-shelters. Thanks to the results of recent researches, such a view is no longer tenable. With a higher degree of precision and differentiation there is revealed the diluvial equivalents of the upper paleolithic series, Mousterian, Aurignacian, Solutréan, and Magdalenian.

As might be expected the nature of the industry in the upper diluvial series tallies with that of the cave deposits. Thus each category of finds supplements and confirms the other. The only regret of the archeologist is that the work of his predecessors could not be done over again in the light of the latest discoveries. Experimentation in any line presupposes a certain amount of waste. The coefficient of waste in archeological experimentation is unfortunately very high. The valley deposits are well-nigh inexhaustible. Much, therefore, may be expected of them. With caverns the case is different. The supply of those still untouched is limited; the list of those already wholly or in part excavated is long. Think of the Dordogne, Grimaldi, Kent's cavern, as once more virgin fields! The latter, for example, has contributed little toward a better definition of paleolithic chronology, yet judging from the published illustrations it contained practically every type of industry from the Acheulian to and including the Magdalenian.

In paleolithic studies the chief elements of control are stratigraphy, technology, and paleontology. These are all given a place in the table of relative chronology. Perhaps no better summary of the bearing of stratigraphy on the question of paleolithic man could be chosen than a composite section of nonmarine Quaternary deposits as they occur in the Paris Basin and in Belgium. I have chosen Rutot's combination of the three sections: Saint-Acheul (Somme), exploitation Helin at Spiennes, near Mons, and the Thiarmont quarry at Ecaussines, between Brussels and Mons (fig. 20). The section shows the stratigraphic relation not only of the paleolithic to the eolithic below and the neolithic above, but also, by means of a bracket, that portion of the diluvial series for which there are cavern equivalents. It should be recalled, however, that there is no direct stratigraphic relation between the cavern deposits and those of the valleys. At Saint-Acheul and Helin, industries occurred at all the horizons indicated except the Aurignacian and Solutréan. The deposits at Ecaussines corresponding to these two horizons are sterile. By going to Willendorff, in the Danube Valley, near Krems (or to the Rhine Valley), the diluvial cultural series can be completed, as has already been pointed out.

According to Rutot, the neolithic is wholly superficial, never being found in situ in the brick earth. Whether the latter is entirely barren of industry remains to be determined. As it was deposited by the last flood waters of the Quaternary, to find middle or upper Magdalenian industry near its base should create no surprise. At the other end of the series the paleolithic stops short of the lower Quaternary, the industry of the latter being purely eolithic.

Respecting technology, the various paleolithic types of implements are for the most part so familiar to students of the prehistoric that with one or two exceptions I have deemed it unnecessary to figure them (figs. 4 and 5). They admit of separation into two more or less distinct groups. The older, practically confined to the diluvial deposits, is represented by the Strépyan, Chellean, and Acheulian. The generalized type, common to all three horizons, is the almond-shaped implement chipped on both sides. The younger group, common both to the upper series of diluvial deposits and the caverns, includes the Mousterian, Aurignacian, Solutréan and Magdalenian horizons. Lithologically, it is composed largely of flint flakes that are chipped on one side only. The group is characterized also by the appearance of bone implements and the beginnings of the arts of sculpture, engraving, and painting. In this as well as the older group there is everywhere orderly development marked either by refinement of preexisting forms or the appearance of new ones. The result is that a given combination of cultural phenomena has its definite stratigraphic position. The two kinds of evidence are therefore in harmony.

Of the three elements of control, the least thoroughly mastered is paleontology. Some forms appear, disappear, and reappear. Some, again, persist in certain latitudes much longer than in others. *Elephas antiquus*, for example, and *Rhinoceros merckii* existed in France from the beginning of the Quaternary to the lower Acheulian epoch, having retreated from Belgium with the coming on of the Riss glaciation. Farther south, at Grimaldi, we find them contemporary with Mousterian man. Their successors, *Elephas primigenius* and *Rhinoceros tichorhinus*, appeared in Belgium as early as the Strépyan and persisted almost until the end of the Quaternary, as their remains have been found in the lower Flandrian deposits (ergeron).

The researches of Commont prove that at the beginning of the paleolithic there were two adjacent contemporary zoological provinces, (1) a northern, including England (for Great Britain and Ireland were then a part of the mainland), Belgium, and northern Germany with the fauna of the mammoth, and (2) a southern, including the greater part of the Paris basin and the valley of the Somme, where the fauna of *Elephas antiquus* still persisted. The fauna of the mammoth overran France in the Acheulian epoch, i. e., about the time that *Elephas antiquus* retreated toward the south. If these facts

are kept in mind, the apparent mélange of arctic and tropical types need no longer present insuperable difficulties. It will be readily seen, also, that in the table (pl. 1) no attempt has been made to give either the horizontal or the vertical range of a given species. Each dominant species simply appears once and in one of its favorite horizons.

With man the case is different. Already in the paleolithic he exhibited those universal tendencies for which he has ever since been famous. His horizontal range was over the whole of Europe not preëmpted by the glaciers and his vertical range covered the entire Quaternary. Fortunately, he can be traced not only by the presence of his own bones, but also by that of his industries. In fact, the bulk of the evidence rests on industrial remains, due in part, at least, to their indestructible character. The decade's discoveries of osseous remains, however, have added immensely to our knowledge of fossil man. The already familiar Neandertal type has become still better known through the finding of well-preserved specimens whose faunal and cultural associations are also more clearly defined than ever before.

New types have been discovered at various horizons, ranging from the Mafflean to the Asylian, giving a fairly comprehensive composite picture of human evolution from near the beginning of the Quaternary to its very close. Neandertal man seems to have been a direct descendant of *Homo heidelbergensis*, there being little evidence of somatological changes due to admixture of races until after the close of the middle Quaternary. The somewhat sudden appearance of a distinctly higher type in the Aurignacian epoch (Combe-Capelle) is a fact difficult to explain without recourse to the theory of an influx of new blood. Curiously enough, the appearance of this new race is signalized also by great cultural changes—the use of bone implements and the beginnings of sculpture, engraving, and painting. To this Aurignacian element, inherited by the succeeding Magdalenian races belongs much of the credit for the phenomenal art development of the upper paleolithic.

I have endeavored to trace the principal lines along which the science of prehistoric anthropology has been developing, lines that are yearly becoming more distinct. If hitherto they have seemed obscure, it has not been the fault of our ancestors who left their story upon each age in its turn, but is due rather to our slowness to discover the record and interpret it aright. I have also endeavored to show that in both discovery and interpretation the achievements of the past decade are not only highly creditable in themselves, but are also prophetic of a promising future.

YALE UNIVERSITY,
New Haven, Conn., April 6, 1910.

THE EUROPEAN POPULATION OF THE UNITED STATES.

The Huxley Memorial Lecture for 1908.[a]

By William Z. Ripley, Ph. D.,
Professor of Economics in Harvard University.

The population of Europe may, in a rough way, be divided into an east and a west. The contrast between the two may be best illustrated perhaps in geological terms. Everywhere these populations have been laid down originally in more or less distinct strata. In the Balkan States and Austria-Hungary this stratification is recent and still distinct; while in western Europe the several layers have become metamorphosed by the fusing heat of nationality and the pressure of civilization. But in both instances these populations are what the geologist would term sedimentary. In attempting a description of the racial problems of the United States your attention is invited to an entirely distinct formation which, in continuation of our geological figure, may best be characterized by the term eruptive. We have to do not with the slow processes of growth by deposit or accretion; but with violent and volcanic dislocation. We are called upon to traverse a lava field of population, suddenly cast forth from Europe and spread indiscriminately over a new continent. In Europe the populations have grown up from the soil. They are still embedded in it, a part of it. They are the product of their immediate environments; dark in the southern half, blonde at the north, stunted where the conditions are harsh, well developed where the land is fat. Even as between city and country, conditions have been so long settled that one may trace the results in the physical traits of the inhabitants. It was my endeavor in the "Races of Europe" to describe these conditions in detail. But in America the people, one may almost say, have dropped from the sky. They are in the land but not yet an integral part of it. The population product is artificial and exotic. It is as yet unrelated to its physical environ-

[a] Reprinted by permission from The Journal of the Royal Anthropological Institute of Great Britain and Ireland, London, vol. 38, July to December, 1908, pp. 221–240.

ment. A human phenomenon unique in the history of the world is the result.

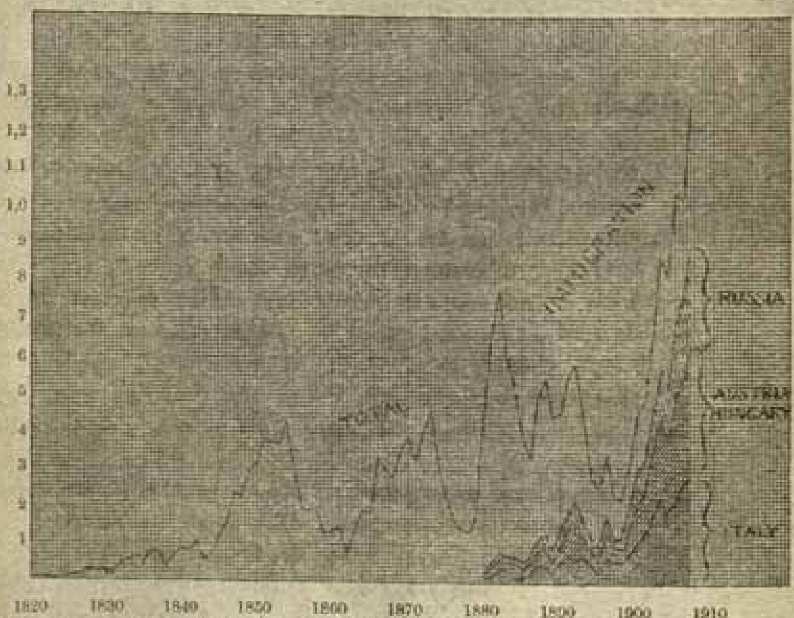
In the description of these conditions two great difficulties are at once encountered. One is the recency of the phenomenon; the other the paucity of precise physical data. As the first immigration to America on a large scale is scarcely more than half a century old, and in its more startling and violent aspects has lasted only half a generation, time enough has not yet elapsed to permit a working out of nature's laws. What evidences have we as to the effect of the new environment upon the transplanted peoples? It is amusing to read in the older books on ethnology, and even in the files of this learned body, of the undoubted effect of the American climate upon Europeans in tending to produce the black wiry hair, the bronze skin, and the aquiline features of the American Indians. Such conclusions are, of course, now understood to be a product, not of climate but of vivid imagination, somewhat overexcited, perhaps, by Buckle's "History of Civilization." Time is needed, not only to show the effect of the physical environment, but also to demonstrate the laws of inheritance which are certain to emerge from so heterogeneous a mix up of all the nations of the earth. Almost everything in fact lies in the womb of the future. We must be content at this time rather to indulge in speculation and prophecy than to revel in the more positive delights of somatological statistics. This is the field in which a great generalizing intellect like Huxley's would have been at its best.

The second difficulty in the study of racial conditions in the United States is the lack of precise physical data. This may be ascribed in large measure to the overwhelming insistency and importance of other allied concerns. This ethnic phenomenon, tremendous and important as it is for pure science, is for the moment overshadowed by others, social and political. The attention of students is compelled by the urgency of the problems presented by the affairs of men, rather than by their physical persons. Questions of living wages, of overcrowding of population in the great cities, of public health, of moral chaos, of political demoralization, are demanding immediate solution at the hands of science. And then again, in the purely anthropological field, there are the other inviting paths of study afforded by the presence of the negro and the disappearance of the aboriginal Indians. Both of these should be of absorbing interest to specialists, the former unfortunately, much neglected; but the latter, the study of the Indian, of immediate concern because whatever is to be done must be done at once. The day will indeed come when science will awake to the opportunities presented by the ethnic composition of the present white population of the United States, but that day is not yet here. And then, finally, it should be borne in mind by

way of excuse for the rather vague and general character of this address, that the United States lacks certain institutions, which have greatly facilitated the anthropological study of Europe. We have no great standing armies to be recruited year by year from all sorts and conditions of men. All military service is voluntary and for hire. The only data of this sort comes to us from the time of the civil war. Moreover still another supply of material is rendered difficult of approach by reason of the attitude of our people toward anything savoring of government paternalism. An attempt at a physical census of the school children of New York, like Virchow's great investigation in Germany, would probably lead to a violent outbreak of yellow journalism concerning the property rights of the individual in his offspring—an uproar which might even disturb the courts and the legislatures. Private initiative with the exercise of the greatest tact and diplomacy must alone be relied upon. For instance, a difficult and yet inviting field of study for the physical anthropologist is afforded by our mountaineers in Kentucky and Tennessee. A Simon-pure Anglo-Saxon stock is here isolated over a large area. Anticipating some years ago a vacation trip into these wilds, I took counsel as to modes of approach for physical measurements upon this rather inflammable human material, wherein blood revenge and the clan feud are still customary. This population has always enjoyed the proud distinction of being the tallest in the United States. By enlisting rivalry in a wholesale contest over the tallness of the men of Tennessee or Kentucky, I was told that one might, indeed, hope to fill one's saddlebags with statistics without endangering one's life in the attempt.

Judged solely from the standpoint of numbers the phenomenon of American immigration is stupendous. We have become so accustomed to it in the United States that we often lose sight of its numerical magnitude. About 25,000,000 people have come to the United States from all over Europe since 1820. This is about equal to the entire population of the United Kingdom only fifty years ago, at the time of our civil war. It is, again, more than the population of all Italy in the time of Garibaldi. Otherwise stated, this army of men would populate, as it stands to-day, all that most densely settled section of the United States north of Maryland and east of the Great Lakes; all New England, New York, New Jersey, and Pennsylvania in fact. This horde of immigrants has mainly come since the Irish potato famine of the middle of the last century. The rapid increase year by year is shown by the accompanying diagram. It has taken the form not of a steady growth but of an intermittent flow. First came the people of the British Isles after the downfall of Napoleon, from 2,000 in 1815 to 35,000 in 1819. Thereafter the numbers are about 75,000 yearly until the Irish famine, when 368,000 immigrants from the British Isles landed in 1852. To the English

succeeded the Germans, largely moved at first by the political events of 1848. By 1854 1,500,000 Teutons, mainly from northern Germany, had settled in America. So many were there that ambitious plans for the foundation of a German State in the new country were actually set on foot. The later German immigrants were recruited largely from the Rhine provinces and have settled farther to the northwest, in Wisconsin and Iowa; the earliest wave having come from northern Germany to Ohio, Indiana, Illinois, and Missouri. The Swedes began to come after the civil war. Their immigration culminated in 1882 with the influx of 50,000 in that year. More recent still are the Italians, beginning with a modest 20,000 in 1876,



[In the figures at the side five "0's" have been omitted; thus 1,3 = 1,300,000.]

IMMIGRATION TO THE UNITED STATES, 1820-1907.

rising to over 200,000 arrivals in 1888, and constituting an army of 300,000 in the single year of 1907; and accompanying the Italian has come the great horde of Slavs, Huns, and Jews. Wave has followed wave, each higher than the last; the ebb and flow being dependent upon economic conditions in large measure. It is the last great wave shown by our diagram which has most alarmed us in America. This gathered force on the revival of prosperity about 1897, but it did not assume full measure until 1900. Since that year over 6,000,000 people have landed on our shores, one-quarter of all the total immigration since the beginning. The newcomers of these eight years alone would repopulate all the five older New England States as they stand to-day; or if properly disseminated over the newer parts

of the country, they would serve to populate no less than nineteen States of the Union as they stand. The newcomers of the last eight years could, if suitably seated, elect 38 of the present 92 Senators of the United States. Do you wonder that thoughtful political students stand somewhat aghast? In the last of these eight years (1907) there were 1,250,000 arrivals, sufficient to entirely populate both New Hampshire and Maine, two of our oldest States with an aggregate territory approximately equal to Ireland and Wales. The arrivals of this one year would found a State with more inhabitants than any twenty-one of our existing Commonwealths. Fortunately, the commercial depression of 1908 has for the moment put a stop to this inflow. Some considerable emigration back to Europe has in fact ensued. But this can be nothing more than a breathing space. On the resumption of prosperity the tide will rise higher than before. Each immigrant, staying or returning, will influence his friends, his entire village; and so it will be until an economic equilibrium has been finally established between one continent where labor is dearer than land, and the other where land is worth more than labor.

It is not alone the rapid increase in our immigration which merits attention. It is also the radical change in its character, in the source from which it comes. Whereas until about twenty years ago our immigrants were drawn from the Anglo-Saxon or Teutonic populations of northwestern Europe, they have swarmed over here in rapidly-growing proportions since that time from Mediterranean, Slavic, and oriental sources. A quarter of a century ago two-thirds of our immigration was truly Teutonic or Anglo-Saxon in origin. At the present time less than one-sixth comes from this source. The British Isles, Germany, Scandinavia, and Canada unitedly sent us 90 per cent of our immigrants in the decade to 1870, 82.8 per cent in 1870–1880, 75.6 per cent in 1880–1890, and only 41.8 per cent in 1890–1900. Since then the proportion has been very much smaller still. Germany used to contribute one-third of our newcomers. In 1907 it sent barely one-seventh. On the other hand, Russia, Austria-Hungary, and Italy, which produced about 1 per cent of the total in 1860–1870, jointly contributed 50.1 per cent in 1890–1900. The growth of this contingent is graphically shown by the preceding diagram. I have been at some pains to reclassify the immigration for 1907 in conformity with the racial groupings of the "Races of Europe," disregarding, that is to say, mere linguistic affiliations and dividing on the basis of physical types. The total of about 1,250,000 arrivals was distributed as follows:

330,000 Mediterranean race	one-quarter.
194,000 Alpine race	one-sixth.
330,000 Slavic race	one-quarter.
194,000 Teutonic race	one-sixth.
146,000 Jewish (mainly Russian)	one-eighth.

In this year 330,000 South Italians take the place of the 250,000 Germans who came in 1882, when the Teutonic immigration was at its flood. One and one-half million Italians have come since 1900, over 1,000,000 Russians, and 1,500,000 natives of Austria-Hungary. We have even tapped the political sinks of Europe, and are now drawing large numbers of Greeks, Armenians, and Syrians. No people is too mean or lowly to seek an asylum on our shores.

The net result of this immigration has been to produce a congeries of human beings, unparalleled for ethnic diversity anywhere else on the face of the earth. The most complex populations of Europe, such as those of the British Isles, northern France, or even of the Balkan States, seem ethnically pure by contrast. In some of these places the soothing hand of time has softened the racial contrasts. Of course, there are certain water holes, like Gibraltar, Singapore, or Hongkong, to which every type of human animal is attracted; and a notably mongrel population is the result. But for ethnic diversity on a large scale the United States is certainly unique. Our people have been diverse in origin from the start to a greater degree than is ordinarily supposed. Virginia and New England, to be sure, were for a long time Anglo-Saxon undefiled; but in the other colonies there was much intermixture, such as the German in Pennsylvania, the Swedish along the Delaware, the Dutch in New York, and the Highland Scotch and Huguenot in the Carolinas. Little centers of foreign inoculation in the early days are discoverable everywhere. On a vacation trip recently in the extreme northeastern corner of Pennsylvania my wife and a friend remarked the frequency of French names of persons, and then of villages, of French physical types, and of a French cookery. On inquiry it turned out that many settlements had been made by French, who emigrated after the battle of Waterloo. Many such colonies could be named, were there time, such as the Dutch along the lake shore of western Michigan, the Germans in Texas, and the Swiss villages in Wisconsin, none of them recent but constituting long-established and permanent elements in the population. Concerning New York City, Father Jognes states that the director-general told him of eighteen languages spoken there in 1644. For the entire thirteen colonies at the time of the revolution, we have it on good authority that one-fifth of the population could not speak English, and that one-half at least was not Anglo-Saxon by descent. Upon such a stock it is little wonder that the grafting of these 25,000,000 immigrants should produce an extraordinary human product. For over half a century more than one-seventh of our aggregate population has been of actually foreign birth. This proportion of actual foreigners of all sorts varies greatly as between the different States. In Minnesota and New York, for example, at the present time, the foreign born, as we denote them

statistically, constitute about one-quarter of the whole; in Massachusetts the proportion is about one-third, and occasionally, as in North Dakota in 1890, it approaches one-half (42 per cent). It is in the cities, of course, where this proportion of actual foreigners rises highest. In New York City there are over 2,000,000 people born in Europe who have come there hoping to better their lots in life. Boston has an even higher proportion of actual foreigners; but the relatively larger number of English-speaking ones, such as the Irish, renders the phenomenon less striking. Nevertheless, within a few blocks, in the foreign colony, there are no less than twenty-five distinct nationalities. In this entire district, once the fashionable quarter of Boston, out of 28,000 inhabitants, only 1,500 in 1895 had parents born in the United States.

The full measure of our ethnic diversity is revealed only when one aggregates the actually foreign born with their children born in America—totalizing, as we call it, the foreign born and the native born of foreign parentage. This group thus includes only the first generation of American descent. Oftentimes even the second generation may remain ethnically as undefiled as the first, but our positive statistical data carries us no farther. This group of foreign born and their children constitutes to-day upward of one-third of our total population; and, by excluding the negroes, it equals almost one-half (46 per cent) of the white population. This is for the country as a whole. Considered by States or cities, the proportion is, of course, much higher. Baltimore, one of our purest American cities, had 40 per cent of foreigners, with their children, in 1900. In Boston the proportion leaps to 70 per cent, in New York to 80 per cent, and reaches a maximum in Milwaukee with 86 per cent thus constituted. Picture to yourselves, if you please, an English city of the size of Edinburgh with only about one person in eight English by descent, by only a modest two generations! To this condition must be added the probability that not over one-half of that remnant of a rear guard can trace its descent on American soil as far back as the third generation. Were we to eliminate these foreigners and their children from our city populations, it has been estimated that Chicago, with to-day a population of over 2,000,000, would dwindle to a city of not much over 100,000 inhabitants.

One may select great industries practically given over to foreigners. Over 90 per cent of the tailors of New York City are Jews, mainly Russian and Polish. In Massachusetts, the center of our staple cotton manufacture, out of 98,000 employees one finds that only 3,900, or about 4 per cent, are native-born Americans, and most of those are of Irish or Scotch-Irish descent two generations back. All of our day labor, once Irish, is now Italian; our fruit venders, once Italian, are now becoming Greek; and our coal mines, once manned by peoples

from the British Isles, are now worked by Hungarians, Poles, Slavaks, or Finns. A special study of the linguistic conditions in Chicago well illustrates our racial heterogeneity. Among the people of that great city—the third in size in the United States—fourteen languages are spoken by groups of not less than 10,000 persons each. Newspapers are regularly published in ten languages, and church services are conducted in twenty different tongues. Measured by the size of its foreign linguistic colonies, Chicago is the second Bohemian city in the world, the third Swedish, the fourth Polish, and the fifth German (New York being the fourth). I know of one large factory in Chicago employing 4,200 hands, representing twenty-four distinct nationalities. Rules of the establishment are regularly printed in eight languages. In one block in New York, where friends of mine are engaged in college settlement work, there are 1,400 people of twenty distinct nationalities. There are more than two-thirds as many native-born Irish in Boston as in the capital city, Dublin. With their children, mainly of pure Irish blood, they make Boston indubitably the leading Irish city in the world. New York is a larger Italian city to-day than Rome, having 500,000 Italian colonists. It contains no less than 800,000 Jews, mainly from Russia. Thus it is easily the foremost Jewish city in the world. Pittsburg, the center of our iron and steel industry, is another Tower of Babel. It is said to contain more of that out-of-the-way people, the Servians, than the capital of that country itself.

Such being the ethnic diversity of our population, the primary and fundamental physical question is as to whether these racial groups are to coalesce to form ultimately a more or less uniform American type, or whether they are to continue their separate existences within the confines of one political unit. Will the progress of time bring about intermixture of these diverse types; or will they remain separate, distinct, and perhaps discordant elements for an indefinite period, like the warring nationalities of Austria-Hungary and the Balkan States? We may perhaps best seek an answer by a serial discussion, first, of those factors which tend to favor intermixture, and thereafter of those forces which operate to prevent it.

The extreme mobility of our American population, ever on the increase, is evidently a solvent force from which powerful results may well be expected in the course of time. This is rendered peculiarly patent by the usual concomitant that this mobility is largely confined to the male sex. The census of 1900 showed that nearly one-quarter of our native-born whites were then living in other States than those of their birth. Kansas and Oklahoma are probably the most extreme examples of such colonization. Almost their entire population has been transplanted, often many times, moving by stages from State to State. The last census showed that only 53

per cent of the population of the former State were natives of Kansas. An analysis of the membership of its state legislature some years ago revealed that only 9 per cent were born within the confines of the State. Even in the staid commonwealth of Iowa, only about one-third of the American-born population was native to the State. This restlessness has always been characteristic of our original stock. Even our farmers, in other countries more or less yoked to the soil, are still on the move, traveling first westward, and now southward, seeking new outlets for their activities. And from this rural class is also drawn the steady inflow to the great cities and industrial centers, which is so much a feature of our time. Thus has rural New England been depopulated, leaving almost whole counties in which the inhabitants to-day number less than in 1800. In this process during the ten years prior to 1890 the little State of Vermont parted with more than one-half of her population by emigration. Maine sent forth one-third. And other States as far south as Virginia and Ohio parted with almost as many. It has been estimated even of the city of Boston, an industrial center of over half a million inhabitants, that the old, native-born Bostonians of twenty years ago number less than 64,000. At first our immigrants do not feel the full measure of this restlessness. The great inflowing streams of human beings at New York, Boston, and Philadelphia, like rivers reaching the ocean, tend to deposit their sediment at once on touching our shores. At the outset these immigrants are immobile elements, congesting the slums of the great cities. But with the men particularly, with the exception of the Jews perhaps, the end is not there. As among the Italians, Greeks, and Scandinavians, they are apt to return to the fatherland after awhile, and then to come back again, this time with a wider appreciation of their opportunities, so that when they return they scatter far more widely. Instead of bunching near the steamship landing stages they range afield. With their children this mobility may become even more marked. Cheap railroad fares, the demand for harvest labor in the West, the contract labor on railways and irrigation works, all tend to stimulate this movement. It was this mobility of our older Anglo-Saxon population which kept the nation unified over a vast and highly varied area; and it will be such mobility, engendered by the exigencies of our changing economic life, which will help to stir up and mix together the various ingredients of our population.

A second influence, making for racial intermixture, is the ever present inequality of the sexes among these foreigners. This is most apparent when they first arrive, about 70 per cent of them being males. Few nationalities nowadays bring whole families as did the Anglo-Saxon and German people a generation ago. The Bohemians, indeed, seem to do so, as well as many of those immi-

grants practically driven out from Europe by political persecution. Thus, in 1905, Russia sent 50,000 women folk—more than came from England, Sweden, and Germany combined, and Austria-Hungary sent 78,000, or thrice the number of women contributed by England, Ireland, and Germany. But of the main body the large majority are men. This vanguard of males tends, generally, to be followed by more women later, after an initial period of trial and exploration. Thus, among the Italians the proportion of men to women, once six to one, has now fallen to about three to one. Having established themselves in America, what are these men to do for wives? In all classes matrimony, early or late, is man's natural estate. They may write home or go home and find brides among their own people, or they may seek their wives in America. This probably the majority of them do, and, of course, most of these naturally prefer to marry within their own colony of fellow countrymen. But suppose, in the first place, this colony is predominantly men, or constitutes a small outpost, isolated among a population alien or semialien to them. An odd consequence of the ambition to rise of these foreign-born men, tending inevitably to break down racial barriers, is that they covet an American-born wife. The woman always is the conservative element in society, and tends to cling to the old ways long after they have been discarded by the men. The result is that in intermixture of various peoples it is more commonly the man who marries up in the social scale. Being the active agent, he inclines to choose from a social station higher than his own. There were about 15,000,000 people in 1900 born in the United States of foreign-born parents, wholly or in part. About 5,000,000 of these had one parent foreign born and one native born; that is to say, with one parent drawn from the second generation of the immigrant stream. And in two-thirds of these mixed marriages it was the father who was foreign born, the mother being native born. This law I have verified by many concrete examples and by some additional statistical data. It is the same law which, contrary to general belief, leads most of the infrequent marriages across the color line to take the form of a negro husband and a white wife. For certain States, as in Michigan, the registration statistics are reliable, and here again show that over two-thirds of the mixed marriages have foreign-born grooms and native-born brides. At the United Hebrew Charities in New York City many thousand cases of destitution among foreign-born women arise from the desertion of the wife, with her old-fashioned European ways, by the husband, who has outdistanced her in adaptation to the new life. This law is well borne out in the growing intermarriage between the Irish and the Italians. The Irish, from their longer residence in America, are obviously of a higher social grade. The ambitious young Italian fruit vender or the

Jewish merchant who has "made good," being denied a wife among his own people, there being too few to go around, then woos and wins an Hibernian bride. Religion in this instance is no bar, both being Catholics. In a similar fashion, in New England, where Germans are scarce and Irish abound, it is the German man who usually marries up into an Irish family. The same thing seems to be true even in New York, where the German colony is very large. When intermarriage between the two people occurs, six times out of seven it is the Irish woman who bears the children. In this connection the important rôle in ethnic intermixture by the Irish women deserves mention. One reason is surely her relative abundance. Thus, in our Boston foreign colony, with every other nationality largely represented by men, there is a surplus of 1,500 Irish females. But a second reason also is the superior adaptability and comradeship of the Irish woman, together with her democratic ways and lack of spirit of caste. Irish, or Irish-American, womanhood bids fair to be a potent physical mediator between the other peoples of the earth. One may picture this process going further, especially in those parts of the country where the more ambitious native-born males have emigrated to the West or to the large cities. The incoming foreigners, steadily working upward in the economic and social scale, and the stranded, downward trending American families, perhaps themselves of Irish or Scotch-Irish descent, may in time meet on an even plane.

The subtle effects of change of environment—religious, linguistic, political, and social—is another powerful influence in breaking down ethnic barriers. The spirit of the new surroundings, in fact, is so different as to prove too powerfully disintegrating an influence. In the moral and religious fields this is plainly noticeable and often pathetic in its results. The religious bonds are often entirely snapped. This is discernible among the Jews everywhere. As one observer put it to me, "Religion is supplanted by socialism and the yellow journal." Large numbers, notably of the young men, break loose entirely and become agnostics or freethinkers. The Bohemians are notorious in this regard. This is accompanied by a breakdown of patriarchal authority in the family, and with it, in the close contacts of city life, the barriers of religion against intermarriage visibly weaken. Differences of language are also less powerful dividing influences than one would think, especially in the great cities. One not infrequently hears of bride and groom not being on speaking terms with one another. And one of my friends tells me of a pathetic instance of a Czech-German marriage in which the man painfully acquired some knowledge of German, but in later life forgot it almost entirely, so that in the end the two old people were driven to the use of signs for daily intercourse.

Despite the best efforts of parents to keep alive an acquaintance with the mother tongue, it tends to disappear in the second generation. To be sure at the present time no less than about 1 in every 16 of our entire population, according to the census of 1900, can not even speak the English language. Such ignorance of English of course tends strongly to persist in isolated rural communities. The Pennsylvania Dutch, who still, after over two hundred years of residence in America, can say "Ich habe mein Haus ge-*painted* and ge-*whitewashed*," are a case in point. It is averred that in some of the Polish colonies in Texas even the negroes speak Polish, as Swedish is used in Minnesota and the Dakotas, German in the long-standing Swiss colonies in Wisconsin, and French among the French-Canadians in New England. On Cape Cod, in Massachusetts, many rural schools have a separate room for the non-English speaking pupils. But the desire, and even economic necessity, of learning English is overwhelming in its potency. In the transitional period of acquiring English the dependence of the parents upon the children entirely reverses the customary relationship. Even the young children, having learned English in the public schools, are indispensable go-betweens for all intercourse with the public. As a result they relegate the parents to a subordinate position before the world. Census enumerators and college-settlement workers agree in citing instances where the old people are commanded to "shut up" and not interfere in official conversations; or, in the familiar admonition, "not to speak until spoken to." The decadence of family authority and coherence due to this cause is indubitable. Thus it comes about that already in the second generation the barriers of language and religion against ethnic intermixture are everywhere breaking down. The English tongue readily comes into service, but, unfortunately, in respect to religion, the traditional props and safeguards are knocked from under, without as yet, in too many instances, suitable substitutes of any sort being provided. From this fact arises the insistence of the problem of criminality among the descendants of our foreign born. This is a topic of vital importance, but somewhat foreign to the particular subject in hand.

Among the influences tending to hinder ethnic intermixture, there remains to be mentioned the effect of concentration or segregation of the immigrants in compact colonies, which remain to all intents and purposes as truly outposts of the mother civilization as were Carthage or Treves. This phenomenon of concentration of our foreign born, not only in the large cities, but in the northeastern quarter of the United States, has become increasingly noticeable with the descending scale of nationality among the more recent immigrants. The Teutonic peoples have scattered widely, taking up land in the West and thus populating the wilderness. But the Mediterranean, Slavic,

and Oriental people heap up in the great cities; and with the exception of Chicago, seldom penetrate far inland. Literally four-fifths of all our foreign-born citizens now abide in the twelve principal cities of the country, and these are mainly in the East. We thought it a menace that in 1890, 40 per cent of our immigrants were to be found in the North Atlantic States; but in the decade to 1900 four-fifths of the newcomers settled there; the result being that in the latter year not 40 but actually 80 per cent of the foreign born of the United States resided in this already densely populated area. Four-fifths of the foreign born of New York State and two-thirds of those in Illinois are now packed into the large towns. To be sure this phenomenon of urban congestion is not confined to the foreigner. Within a 19-mile radius of the city hall in New York dwells 51 per cent of the population of the great State of New York, together with 58 per cent of the population of the adjoining State of New Jersey. But its results are more serious among the foreign born, heaped up as they are in the slums and purlieus. On the other hand, in the middle and far West, the proportion of actual foreign born has been declining since 1890. Cities like Cincinnati or Milwaukee, once largely German, have now become Americanized. In the second and third generations, not recruited as actively as before by constant arrivals, the parent stock has become visibly diluted. And in the rural northwest, as the older Scandinavians die off, their places are being supplied by their American-born descendants; but with admixture of raw recruits from the old countries to a lesser degree than before.

This phenomenon of concentration obviously tends to perpetuate the survival of racial stocks in purity. In a dense colony of 10,000 or 50,000 Italians or Russian Jews there need be a little contact with other nationalities. The English language may intrude and the old-fashioned religion may lose its potency, but as far as physical contacts are concerned, the colony may be self-sufficient. Professor Buck found in the Czech colony in Chicago that while 48,000 children had both parents Bohemian, there were only 799 who had only one parent of that nationality. Had there been only a small colony the number of mixed marriages would have greatly increased. Thus the Irish in New York, according to the census of 1885, almost overwhelmingly took Irish brides to wife; but in Baltimore at the same time, where the Irish colony was small, about one in eight married native-born wives. Such facts illustrate the force of the influences to be overcome in the process of racial intermixture. Call it what you please, "consciousness of kind," or "race instinct," there will always be, as among animals, a disposition of distinct types to keep separate and apart. Among men, however, this seldom assumes concrete form in respect of physical type; although in "The Races of Eu-

rope" I have sought to demonstrate its results among the Basques and the Jews. Marriage elsewhere appears to be rather a matter of social concern. There is no physical antipathy between different peoples. Oftentimes the attraction of a contrasted physical type is freely acknowledged. The barrier to intermarriage between ethnic groups is more often based upon differences in economic status. The Italian "Dago" is looked down upon by the Irish; as in turn the Irishman used to be characterized by the American as a "Mick," or a "Paddy." Any such social distinctions constitute serious handicaps in the matrimonial race; but on the other hand, as they are in consequence largely artificial, they tend to disappear with the demonstration of economic and social efficiency.

Heretofore our attention has been directed to a discussion of the influences making for or against a physical merger of these divers peoples. It may now be proper to inquire how much of this intermixture there really is. Does it afford evidence of tendencies at work, which may in time achieve momentus results? The first cursory view of the field would lead one to deny that the phenomenon was yet of importance. The potency of the forces tending to restrict intermarriage seems too great. But on the other hand, from such concrete statistical data as are obtainable, it appears as if a fair beginning had already been made, considering the recency of the phenomenon. The general data from the federal census are valueless in this connection. Although they indicate much intermarriage of the foreign born with the native born of foreign parentage, the overwhelming preponderance of this is, of course, confined to the same ethnic group. The immigrant Russian Jew, or young Italian, is merely mating with another of the same people, born in America of parents who were direct immigrants. The bride in such a case is as truly Jewish or Italian by blood as the groom, although her social status and economic condition may be appreciably higher. But evidence of true intermixture across ethnic lines is not entirely lacking. No less than 56,000 persons are enumerated in the federal census as being of mixed Irish and German parentage, for example; and of these, 13,400 were from New York State alone. German-English intermarriages are about as frequent, numbering 47,600. Irish and French-Canadian marriages numbered 12,300, according to the same authority. Three times out of five it is the French-Canadian man who aspires to an Irish bride. In the northwest the Irish and Swedes are said to be evincing a growing fondness for one another. For the newer nationalities the numbers are, of course, smaller.

Some idea of the prevalence of mixed marriages is afforded by the specialized census data of 1900. Take one nationality, the Italians, for example. There were 484,207 in all in the United States. Of these nearly one-half, or 218,810, had both parents

Italian. Marriages of Italian mothers and American-born fathers produced 2,747; while, conformably to the law already set forth, no less than 23,076 had Italian fathers and native-born mothers. There still remained 12,523 with Italian fathers, and mothers of some other non-American nationality; and 3,911 with Italian mothers, and fathers neither American nor Italian born. Thus of the 484,000 Italian contingent nearly one-tenth proved to be of mixed descent. For the city of Boston, special inquiry showed that 236 Italians in a colony of 7,900 were of mixed parentage, with predominantly Irish tendencies.

Mixed marriages are, of course, relatively infrequent; but at all events, as in these cases, constitute a beginning. Sometimes they occur oftener, especially in the great centers of population where all are herded together in close order. Thus in a census made in New York of the oldest part of the city south of Wall and Pine streets to the Battery by the Federation of Churches, out of 307 families completely canvassed it appeared that 49 were characterized by mixed marriages. This proportion of 1 in 6 is certainly too high for an average; but it is nearly equaled by the rather unreliable data afforded by the mortality statistics of old New York for 1906, showing the parentage of descendants. This gave a proportion of 1 to 8 as of mixed descent. How many of those called mixed were only offspring of unions of first and second generations of the same people is not, however, made clear. Some good authorities, such as Dr. Maurice Fischberg, do not hesitate to affirm that even for the Jews, as a people, there is far more intermarriage with the gentile population than is commonly supposed. In Boston the most frequent form of intermarriage, perhaps, is between the Jewish men and Irish or Irish-American women.

A few general observations upon the subject of racial intermixture may now be permitted. Is the result likely to be a superior or an inferior type? Will the future American two hundred years hence be better or worse, as a physical being, because of his mongrel origin? The greatest confusion of thinking is permitted upon this topic. Evidence to support both sides of the argument is to be had for the seeking. For the continent of Europe it is indubitable that the highly mixed populations of the British Isles, of northern France, of the valley of the Po, and of southern Germany are superior in many ways to those of outlying or inaccessible regions where greater purity of type prevails. But the mere statement of these facts carries proof of the partial weakness of the reasoning. Why should not the people of the British Isles, the Isle de France, and of the Po Valley be the best in Europe? Have they not enjoyed every advantage which a salubrity of climate and fertility of soil can afford? Was it not, indeed, the very existence of these advantages which ren-

dered these garden spots of the earth Meccas of pilgrimage? Viewed in a still larger way, is it not, indeed, the very beneficence of nature in these regards which has induced or permitted a higher evolution of the human species in Europe than in any of the other continents. The races certainly began even. Why are the results for Europe as a whole so superior to-day? Alfred Russel Wallace, I am sure, would have been ready with a cogent reason. What right have we to dissociate these concomitantly operative influences of race and environment and ascribe the superiority of physical type to the effect of intermixture alone? Yet, on the other hand, does not the whole evolutionary hypothesis compel us to accept some such favorable conclusion? What leads to the survival of the fittest, unless there be the opportunity for variation of type, from which effective choice may result? And yet most students of biology agree, I take it, in the belief that the crossing of types must not be too violently extreme. Nature proceeds in her work by short and easy stages. At this point the opportunity for the students of heredity, like Galton, Pearson, and their fellow-workers appears. What, for instance, is the order of transmission of physical traits as between the two parents in any union? We have seen how unevenly assorted much of the intermixture in the United States tends to be. If, as between the Irish and the Italians, who are palpably evincing a tendency to mate together, it is commonly the Italian male who seeks the Irish wife; and if, as Pearson avers, inheritance in a line through the same sex is prepotent over inheritance from the other sex, what interesting possibilities of hereditary physical differences may result?

An interesting query suggested by the results of scientific breeding and the study of inheritance among lower forms of animal life is this, what chance is there that out of this forcible dislocation and abnormal intermixture of all the peoples of the civilized word there may emerge a physical type tending to revert to an ancestral one, older than any of the present European varieties? The law seems to be well supported elsewhere that crossing between highly evolved varieties or types tends to cause reversion to the original stock, and the greater the divergence between the crossed varieties the more powerful does the reversionary tendency become. Most of us are familiar with the illustrations, such as the reversion among sheep to the primary dark type, and the emergence of the old wild blue-rock pigeon from blending of the fantail and pouter varieties. The same law is borne out in the vegetable world, the facts being well known to fruit growers and horticulturists. The more recently-acquired characteristics, especially those which are less fundamentally useful, are sloughed off, and the ancestral features, common to all varieties, emerge from dormancy into prominence. Issue need not be raised, as set forth by Dr. G. A. Reid, whether the result of

crossbreeding is always in favor of reversion and never of progression; but interesting possibilities linked up with this law may be suggested. All students of natural science have accepted the primary and proven tenets of the evolutionary hypothesis, or rather, let us say, of the law of evolution. And all alike acknowledge the subjection of the human species to the operation of the same great laws applicable to all other forms of life. It would have been profoundly suggestive to have heard from Huxley on a theme like this. We are familiar in certain isolated spots in Europe, the Dordogne in France for example, with the persistence of certain physical types without change from prehistoric times. The modern peasant is the proven descendant of the man of the stone age and the mammoth. But here is another mode of access to that primitive type, or even an older, running back to a time before the separation of European varieties of men began. Thus, to be more specific, there can be little doubt that the primitive type of European was brunette, probably with black eyes and hair and a swarthy skin. Teutonic blondness is certainly an acquired trait, not very recent, judged by historic standards, to be sure, but as certainly not old, measured by evolutionary time. What chance is there that in the unions of rufous Irish and dark Italian types a reversion in favor of brunetteness may result? Were it not for the inflammatory character of the controversy in a gathering of anthropologists over the relative primitiveness of the dolichocephalic and brachycephalic types in Europe, I might be tempted to go further and speculate as to the bearing of American racial intermixture upon this much-mooted question.

A relatively unimportant, yet theoretically very interesting, detail of the subject of racial intermixture is suggested in Westermarck's brilliant "History of Human Marriage." It is a well-known statistical law, almost the world over, that there are more boys than girls born into the world. The normal ratio of births is about 105 males to 100 females. Students have long sought the reasons for this irregularity, but nothing has yet been proven conclusively. Westermarck brings together much evidence to show that this proportion of sexes at birth is effected by the amount of inbreeding in any social group, crossing of different stocks tending to increase the percentage of female birth. Thus, among the French half-breeds and mulattos in America, among mixed Jewish marriages, and in South and Central America female births may at times even offset the difference and actually preponderate over the male birth. The interest of this topic lies in the fact that it is unique among social phenomena in being, so far as we know, independent of the human will. It is the expression of what may truly be denominated natural law. Westermarck's general biological reasoning is that inasmuch as the rate of increase of any animal community is dependent upon the

number of productive females, a sort of accommodation takes place in each case between the potential rate of increase of the group and its means of subsistence, or chance of survival. More females at birth is the response of nature to the increasingly favorable environment, or condition. In-and-in-breeding is undoubtedly injurious to the welfare of any species. As such, according to Westermarck, it is accompanied by a decline in the proportion of females born. This is the expression of nature's disapproval of the practice, while intermixture tends, contrariwise, to produce a relative increase of the female sex. Certain it is that an imposing array of evidence can be marshaled to give color to the hypothesis. My suggestion at this point is that here in the radical intermixture just now beginning in the United States, and sure to assume tremendous proportions in the course of time, will be afforded an opportunity to study man in his relation to a great natural law in a way never before rendered possible. Statistical material is at present too meager and vague, but one may confidently look forward to such an improvement in this regard that an inviting field of research will be exposed to view.

The significance of the rapidly increasing immigration from Europe in recent years is vastly enhanced by other influences in the United States. A powerful process of social selection is apparently at work among us. Racial heterogeneity, due to the direct influx of foreigners in large numbers, is aggravated by their relatively high rate of reproduction after arrival; and in many instances by their surprisingly sustained tenacity of life, greatly exceeding that of the native-born American. Relative submergence of the domestic Anglo-Saxon stock is strongly indicated for the future. "Race suicide," marked by a low and declining birth rate, as is well known, is a world-wide social phenomenon of the present day. Nor is it by any means confined solely to the so-called "upper classes." It is so notably a characteristic of democratic communities that it may be regarded as almost a direct concomitant of equality of opportunity among men. To this tendency the United States is no exception; in fact, together with the Australian commonwealths, it affords one of the most striking illustrations of present-day social forces. Owing to the absence of reliable data it is impossible to state what the actual birth rate of the United States as a whole may be; but for certain Commonwealths the statistical information is ample and accurate. From this evidence it appears that for those communities, at least, to which the European immigrant resorts in largest numbers the birth rate is almost the lowest in the world. France and Ireland alone among the great nations of the earth stand lower in the scale. This relativity is shown by the following table, giving the number of births in each case per thousand of population:

Birth rate (approximate).

Hungary	40	Australia, Sweden	27
Austria	37	Massachusetts, Michigan	25
Germany	36	Connecticut, Rhode Island	24
Italy	35	Ireland	23
Holland	33	France	22
England, Scotland, Norway, Denmark	30	New Hampshire (?)	20

This crude birth rate, of course, is subject to several technical corrections, and should not be taken at its full face value. Moreover, it may be unfair to generalize for the entire rural West and South from the data for densely populated communities. And yet, as has been observed, it is in our thickly-settled Eastern States that the newer type of immigrant tends to settle. Consequently, it is the birth rate in these States, as compared with that of the newcomer, upon which racial survival will ultimately depend.

The birth rate in the United States in the days of its Anglo-Saxon youth was one of the highest in the world. The best of authority traces the beginning of its decline to the first appearance, about 1850, of immigration on a large scale. Our great philosopher, Benjamin Franklin, estimated six children to a normal American family in his day. The average at the present time is slightly above two. For 1900, it is calculated that there are only three-fourths as many children to potential mothers in America as there were forty years ago. For Massachusetts, were the old rate of the middle of the century sustained, there would be 15,000 more births yearly than now occur. In the course of a century the proportion of our entire population, consisting of children under the age of 10, has fallen from one-third to one-quarter. This, for the whole United States, is equivalent to the loss of about 7,000,000 children. So alarming has this phenomenon of the falling birth rate become in the Australian colonies that in New South Wales a special governmental commission has voluminously reported upon the subject. It is estimated that there has been a decline of about one-third in the fruitfulness of the people in fifteen years. New Zealand even complains of the lack of children to fill her schools. The facts concerning the stagnation, nay even the retrogression, of the population of France are too well known to need description. But in these other countries the problem is relatively simple, as compared with our own. Their populations are homogeneous, and, ethnically at least, are all subject to these social tendencies to the same degree. With us the danger lies in the fact that this low and declining birth rate is primarily confined to the Anglo-Saxon contingent. The immigrant European horde, until recently at least, has continued to reproduce upon our soil with well-sustained energy.

Baldly stated, the birth rate among the foreign born in Massachusetts is about three times that of the native born. Childless marriages are one-third less frequent. This somewhat exaggerates the contrast, because of differing conditions as to age and sex in the two classes. The difference, nevertheless, is very great. Kuczynski has made detailed investigations as to the relative fecundity of different racial groups. The fruitfulness of English-Canadian women in Massachusetts is twice that of the Massachusetts born; of the Germans and Scandinavians it is two and a half times as great; of the French-Canadians it is thrice; and of the Portuguese four times. Even among the Irish, who are characterized nowadays everywhere by a low birth rate, the fruitfulness of the women is 50 per cent greater than for the Massachusetts native born. The reasons for this relatively low fecundity of the domestic stock are, of course, much the same as in Australia and in France. But with us it is as well the "poor white" among the New England hills or in the Southern States as the town dweller, who appears content with few children or none. The foreign immigrant marries early and children continue to come until much later in life than among the native born. It may make all the difference between an increasing or declining population whether the average age of marriage is 20 years or 29 years. The contrast between the Anglo-Saxon stock and its rivals for supremacy may be stated in another way. Whereas only about one-ninth of the married women among the French-Canadians, Irish, and Germans are childless, the proportion among the American born and the English-Canadians is as high as 1 in 5. A century ago about 2 per cent of barren marriages was the rule. Is it any wonder that serious students contemplate the racial future of Anglo-Saxon America with some concern? They have witnessed the passing of the American Indian and the buffalo. And now they query as to how long the Anglo-Saxon may be able to survive.

On the other hand, evidence is not lacking to show that in the second generation of these immigrant peoples a sharp and considerable, nay, in some cases, a truly alarming, decrease of fruitfulness occurs. The crucial time among all our newcomers from Europe has always been this second generation. The old customary ties and usages have been abruptly sundered and new associations, restraints, and responsibilities have not yet been formed. Particularly is this true of the forces of family discipline and religion, as has already been observed. Until the coming of the Hun, the Italian, and the Slav, at least, it has been among the second generation of foreigners in America, rather than among the raw immigrants, that criminality has been most prevalent. And it is now becoming evident that it is this second generation in which the influence of democracy and of

novel opportunity makes itself apparent in the sharp decline of fecundity. In some communities the Irish-Americans have a lower birth rate even than the native born. Doctor Engelmann, on the basis of a large practice, has shown that among the St. Louis Germans the proportion of barren marriages is almost unprecedentedly high. Corroborative, although technically inconclusive, evidence from the registration reports of the State of Michigan appears in the following suggestive table, showing the nativity of parents and the number of children per marriage annually in each class:

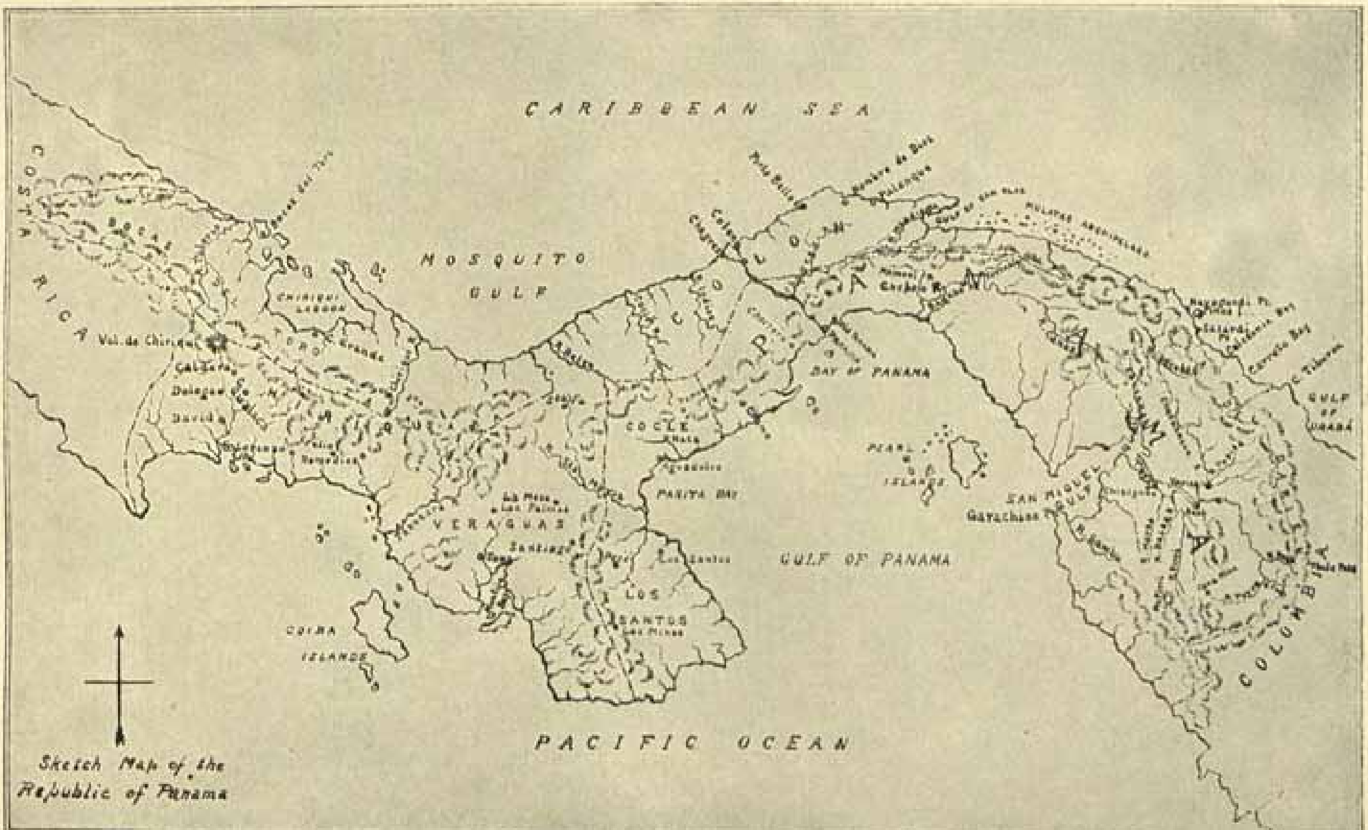
	Children.
German father, American-born mother	2.5
American-born father, German mother	2.3
German father, German mother	6
American-born father, American-born mother	1.8

I have been at some pains to secure personal information concerning the foreign colonies in some of our large cities, notably New York. Dr. Maurice Fishberg for the Jews and Dr. Antonio Stella for the Italians, both notable authorities, confirm the foregoing statements. Among the Italians particularly the conditions are positively alarming. Peculiar social conditions influencing the birth rate and the terrific mortality induced by overcrowding, insanitation, and the unaccustomed rigors of the climate make it doubtful whether the Italian colony in New York will even be physically self-sustaining. Thus it appears that forces are at work which may check the relatively higher rate of reproduction of the immigrants and perhaps reduce it more nearly to the Anglo-Saxon level.

The vitality of these immigrants is surprisingly high in some instances, particularly where they attain an open-air rural life. The birth rate stands high and the mortality remains low. Such are the ideal conditions for rapid reproduction of the species. On the other hand, where overcrowded in the slums of great cities, ignorant and poverty stricken, the infant mortality is very high, largely offsetting, it may be, the high birth rate. The mortality rate among the Italians in New York, for instance, is said to be twice as high as in Italy. Yet some of these immigrants, such as the Scandinavians, are particularly hardy and enduring. Perhaps the most striking instance is that of the Jews, both Russian and Polish. According to the census of 1890 their death rate was only one-half that of the native-born American. For three of the most crowded wards in New York City the death rate of the Irish was 36 per 1,000; for the Germans, 22; for natives of the United States, 45; while for the Jews it was only 17 per 1,000. By actual computation, at these relative rates, starting at birth with two groups of 1,000 Jews and Americans, respectively, the chances would be that the first half of the Americans would die within forty-seven years, while for the Jews this would

not occur until the lapse of seventy-one years. Social selection at that rate would be bound to produce very positive results in a century or two.

At the outset, confession was made that it was too early as yet to draw positive conclusions as to the probable outcome of this great ethnic struggle for dominance and survival. The great heat and sweat of it is yet to come. Wherever the Anglo-Saxon has fared forth into new lands, his supremacy in his chosen field, whatever that may be, has been manfully upheld. India was never contemplated as a center for settlement, but Anglo-Saxon law, order, and civilization have prevailed. In Australia, where nature has offered inducements for actual colonization, the Anglo-Saxon line is apparently assured of physical ascendency. But the great domain of Canada—greater than one can conceive who has not traversed its northwestern empire—is subject to the same physical danger which confronts us in the United States, actual physical submergence of the English stock by a flood of continental European peoples. And yet, after all, is the word "danger" well considered for use in this connection? What are the English people, after all, but a highly evolved product of racial breeding? To be sure, all the later crosses, the Saxons, Danes and Normans, have been of allied Teutonic origin at least. Yet encompassing these racial phenomena with the wide, sweeping vision of him in whose honor this address is rendered, dare we deny an ultimate unity of origin to all the people of Europe? Our feeble attempts at ethnic analysis can not at the best reach further back than to secondary origin. And the primary physical brotherhood of all branches of the white race, nay, I will go even further and say of all the races of men, must be admitted on faith—not on the faith of dogma but on the faith of scientific probability. It is only in their degree of physical and mental evolution that the races of men are different. You have your "white man's burden" to bear in India; we have ours to bear with the American negro and the Filipinos. But an even greater responsibility with us and with our Canadian fellow-citizens is that of the "Anglo-Saxon's burden"—to so nourish, uplift, and inspire all these immigrant peoples of Europe that in due course of time, even if the physical stock be inundated by the engulfing flood, the torch of Anglo-Saxon civilization and ideals, borne by our fathers from England to America, shall yet burn as bright and clear in the New World, as your fires have continued to illuminate the Old.



MAP OF PANAMA.

THE REPUBLIC OF PANAMA AND ITS PEOPLE, WITH SPECIAL REFERENCE TO THE INDIANS.

[With 14 plates.]

By Eleanor Yorke Bell.

INTRODUCTION.

The object of this paper has been chiefly to collect and record the somewhat scanty and widely scattered data concerning the Panama Isthmus, much of which is not available to the average reader, being written in either the Spanish or the French language, especially the most valuable information in regard to the aborigines. An attempt has also been made to describe the scenery and the natives (in many instances from personal observation), and to reconcile widely divergent statements, as given by various authorities, when occasioned only by minor mistakes, such as the confusing of geographical names, etc.

The notes throughout are numbered and refer to the list of books consulted.

Of the 31,571 square miles comprising the Republic of Panama only a small section is known to the foreigner, and even the educated Panamanians themselves possess a very slight knowledge of their country as a whole, vast areas of beautiful hills and valleys being practically unexplored. The great extent of coast line and proportionate small area, through which 463 so-called rivers flow, has worked against the development of the interior by means of extensive road building, as the small amount of native produce is easily transported down some navigable stream to a coast town. The climatic conditions, the scarcity of labor, the poverty of the country, and frequent political disturbances have also played an important part in this lack of progress in Panama. But Panama is undoubtedly a land well enriched by nature, and before long conditions must change which will result in the acquirement of many fortunes through the exploitation of its mineral and agricultural resources.

The Republic extends from the border of Costa Rica to the Department of the Cauca, in Colombia, about 470 miles, making, therefore, the greatest length from west to east. Panama City is east of Colon, a fact very confusing at first to the stranger who sees the sun rise in the Pacific and set in the Atlantic. At this point the Isthmus is about 47 miles in width, which is not, however, the narrowest part, as the distance from the mouth of the Rio Bayano to Mandingo Bay is only 30 miles. The country is scarcely half inhabited and in no sections at all thickly populated, except the above-mentioned cities and towns stretching along the Panama Railroad and the banks of the Chagres. The valleys of the Bayano or Chepo, the Tuyra, and lower Chucunaque have scattered villages, but west from Panama City, extending through the Department of Chiriqui are several large towns or cities with their surrounding districts well populated, the whole containing a larger per cent of the "sangre azul," white blood, than is to be met with outside of the capital city. The high Cordilleras are believed to be, to a great extent, uninhabited at the present day, though in several sections there are known to be numbers of Indians, as in the intervening valleys and coasts.

Geographically, the Isthmus appears to belong to the Northern Continent rather than the Southern, of which it has always been a part, politically speaking, yet its mountains are detached from those of Costa Rica, except a spur crossing the border between Chiriqui and Bocas del Toro, and at Darien there is also a decided break before reaching the Andes.[a]

The mountain elevations vary from 1,500 to 7,000 feet, with the three volcanic peaks—Rico Blanco, 11,740; Volcan de Chiriqui or Barú, 11,265; and Rovalo, 7,020 (44). In many cases the figures given of these mountain elevations must be largely conjectural owing to the fact that much of the interior is almost unknown, but those obtained by marine surveys are considered more reliable. Panama lies 8 degrees from the equator, and has a temperature averaging 26° C. It has two seasons, wet and dry, the latter lasting only from December to April, when it does not rain at all. During this period the climate is very agreeable—the days clear and the nights brilliant. While modern knowledge of sanitation and hygienic living in tropical countries has done much to improve the largely undeserved bad name of the Isthmus, still there are many sections of

[a] "La République de Panama appartient au point de vue géographique à l'Amérique Centrale. Elle se trouve au bout de la longue bande de terres isthmiques qui forment les anneaux de la chaîne de montagnes reliant depuis des temps tertiaires les continents septentrionaux et méridionaux de l'Amérique. La nature du sol, l'histoire de sa découverte, l'origine des habitants * * * fait classer la République de Panama parmi les contrées de l'Amérique Centrale" (19).

low-lying coast and shut-in valley districts where, especially during the rainy season, when the climate is far from healthy for the unacclimated and where the enervation occasioned by the excessive humidity with a comparatively high temperature produces much discomfort and endangers health. The whole north coast, with the exception of Bocas and Colon, has never proved a suitable place of habitation for the white man, though it was first settled by them, and many successive attempts at colonization along the shore have been made.

Much of the scenery in Panama, aside from the "beaten track," is extremely and unexpectedly beautiful. In the bush, as it is called, far from human dwellings, where complete solitude reigns, the wonderful charm can best be appreciated. Lovely effects of light and shade are produced as the everpresent rain squall sweeps over the scene, changing, in a moment, a brilliant green savanna or fringe of jungle covered with waving vines and many colored parasites into a soft yellow gray. Toward evening, when the sky glows with violet and golden lights, just before the curtain of night falls, the air is filled with the thrilling songs of birds as they seek shelter, and the hum of millions of insects, till suddenly, as the last sun's ray disappears, all is hushed and still and utter darkness envelops everything. There is, indeed, a mysterious beauty and nearness to nature, the intensity of which can nowhere be appreciated as in the Tropics. Through dark overgrown stretches of the trails, where the instinct of the native horses alone must be trusted, and the sky is obscured by masses of low-hanging branches, new wonders appear at every step. By little pools and brooks swarm numbers of those gorgeous blue-green butterflies (*Morpho*), resting in the cool shade, and the marvelous tropical ants, marching, each with a bit of flower or leaf, in ordered file, like soldiers on parade, give the appearance at a distance that the ground itself is actually moving. The jungle and marshes are the home of the armadillo, sloth, monkey,[a] anolis, iguana, and snakes; among the latter are many of the pitviper family and also the boa constrictor. The coral snake is feared, as is the fer de lance of Martinique, and is a beautiful though rather small snake with alternating red and black bands. Among the larger game on the Isthmus are the tiger, puma, jaguar, cougar, ant-eating bear, tapir, fox, peccary, hedge hog, wild-cat, and deer. Living on the banks of the rivers and in the streams of many sections are innumerable caimans and water fowl, brilliant flamingos and the valuable egret being frequently found. Of the birds common to the Isthmus there are the eagle, toucan, maccaw, parrot, parrakeet, etc.

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[a] The Chrysothrix monkey is found only in the Department of Chiriqui in Panama (44).

Panama is especially rich in rare cabinet and dyewoods,[a] which with spices, vanilla, medicinal plants, rubber, fruits, ivory nuts, cocoanuts, coffee, hides, and tortoise shell form the principal articles of export. The native trees are mahogany, cottonwood, logwood, laurel, lignum-vitæ, ebony, cork, cedars (the yellow cedar is considered indestructible), manzanillo, pepper, almond, and orange. The chief medicinal plants are ipecac, guaiacum, croton, sarsaparilla, and "maria balm." There are many varieties of fruits, though the cultivation of them is still a small industry; chief among them are the banana, lime, plantain, pineapple, alligator-pear, mango, mamai, guava, granada, papayo, granadillo, melon, pomarosa, sapote, and bread fruit.

The mineral wealth of the Isthmus has been justly famed from the earliest days, though the statement in a recent consular report, "Le Panama possède d'immense richesses minérales," is probably rather overstated. However, the gold which the Conquistadores found everywhere in extensive use by the Indians for ornament and even articles of utility, proves that there is a good proportion of this valuable metal in the small area of the Isthmus. The mines already known are probably not yet exhausted, as their exploitation has been very spasmodic, and one may conclude also that in a country so little explored there are other and possibly richer mines than those already discovered. In fact, since the eighteenth century the gold mines have not been in operation to any extent, except the Cana mine (called "Potosi" by Bancroft) in the Santo-Espiritu Mountains of Darien,[b] which is now being worked by an English company at a good profit. The expense incident to the operation of these mines and the lack of reliable labor have brought many attempts to ultimate failure, except in the case of the Cana mine, already mentioned, and the new enterprises just starting in western Panama. The gold of the Isthmus is of an unusually fine quality with a natural alloy of copper. Besides gold and copper, some silver, iron, coal, salt, manganese, cinnabar, and oil comprise the mineral resources. The famous pearl beds of the "Archipielago des Las Perlas" no longer produce any quantity of marketable pearls, though the industry is not entirely dead, and the trade in mother-of-pearl is extensive. Much tortoise shell is exported; from the port of Colon to that of

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[a] The dyewoods and plants are "ribes glandulosum, weinmannia glabra, pterocarpus draco, opuntea tuna, ruellia tuberosa, morus nigra, persea gralissima, bixa orrellano, indigo-fero tintorio, and the muquera, which produces a beautiful red without preparation (4).

[b] This mine was very productive, but was closed for many years by royal decree in 1685, owing to raids of the Indians and buccaneers. Its greatest output was 100,000 castellanos a year (5). The gold is brought on muleback to Real and thence taken in small ships to Panama.

New York alone, $12,742 worth of shell was sent during the first year of the Republic (26).

A brief general historical review of the Panama Isthmus is necessary before taking up the description of the seven departments in detail, as each must be treated separately, owing to the fact that the different races, dates of colonization, etc., make it impossible to treat the subject homogeneously.

The Atlantic coast of the Isthmus was first discovered by Rodrigo de Bastides and Alonzo de Ojedo about 1501 (some historians give the date as early as 1499), but no attempt at landing was made till Columbus on his last voyage founded a small colony on the Belen River, which was soon destroyed, however, by the war-like chief, Quiban. Columbus then sailed down the coast, discovering the harbor of Porto Bello and the Mulatas Archipelago, which he called "Islas Berbas." Ojedo was given a grant of land including the fertile valley of the Atrato and lower coast of Darien; his friend Nicuesa likewise obtained a grant which extended eastward along the coast to Cape Gracias à Dios. Two settlements were made, San Sebastian de Urabá and Santa Maria del Antigua. The former (not strictly in what is Panama to-day) was abandoned as early as 1514 (1, p. 31). St. Mary's was governed by Encesio and Balboa, and from here the latter, with Alonzo Martin, about 1513, crossed the Isthmus and discovered the Pacific Ocean from the peak of Mount Perri, as legend has it, near the Cana mine. At this time, also, the Gulf of San Miguel, the Chepo and Pearl islands were discovered.

After Balboa had seen the beautiful pearl encrusted canoe belonging to the Indian chief, Tumaco, he was determined to find the islands, and was aided in his quest by this friendly chief himself. Before the colony of Santa Maria removed to the site of Old Panama, various parties had explored as far as Veraguas, and a settlement was made at Natá by Espinosa as early as 1517 (5), or, according to the statement in "Colombia" (7, p. 308), by Alonzo Perez de la Rua, in 1515. Either of these figures make this settlement antedate Old Panama, founded in 1519, which is generally but erroneously considered to be the first colony on the Pacific side of the Isthmus. The story of Old Panama, the wealth and splendor of the inhabitants leading to its destruction by Morgan, the buccaneer, in 1671, is known by all. Old Panama's chief claim to interest is perhaps that it was here where Balboa was beheaded by Pedro Arias D'Avilla, at that time the governor, and that here also Pizarro fitted out his fleet for the conquest of Peru at the sacrifice of 2,000 poor Indians unaccustomed to such labor, who had been pressed into service. Old Panama was the seat of a bishopric and had a mint as early as 1535, and was in every respect a powerful and opulent city for that day. A need was soon felt by the colonists for cities on the north coast

which would be storehouses, so to speak, for the treasure on its way to Spain before being taken on board the ships. This resulted in the founding of Porto Bello and Nombre de Dios and the building of the Paved Road and the Royal Road to Cruces. Both cities, however, were soon destroyed by the buccaneers.

Spain's power in this part of the New World was of short duration, for, after a glorious few years of wealth and luxury, her cities were despoiled and left neglected. Spanish pride and lust of gold paved the way for the work of the pirates just as Spanish cruelty to the Indians reaped its own reward. Before 1570 the natives had rebelled and negro slaves from the Guinea coast were imported to take their places, proving in many ways disastrous to the country, for they soon became the predominant factor, outnumbering the descendants of the Europeans. That the original colonists were a wonderful people in various respects can not be doubted, and they certainly seem to have possessed great physical endurance and vigor. It is truly marvelous that, without the aid of modern science, they could have withstood successfully the dangers of the tropical jungle and to have so early subdued many hostile tribes of the aborigines who resented the invasions of their land, and, above all, that they could have built such beautiful and well fortified cities within a short century and a half under such difficulties.

After the period of piratical raids the Isthmus fell into a state of decay for more than a century, and has practically no recorded history. In 1719 it was divided into the departments of Panama and Veraguas, forming a part of New Granada. At one time the Isthmus was placed under the captain-general of Cuba as a punishment for some unruly act. Panama took small part in the war of independence and was the last province to be free of Spanish rule. The relation of this province to New Granada and later to Colombia was always a peculiar one. She submitted apparently at times to the authority of Bogota in military matters only, but retained control in the main, though not always, of her internal administration, monetary affairs, customs, revenues, stamps, etc. Indeed, at one period she positively refused the paper money issued by Colombia, though a heavy penalty was imposed on those who declined to receive it. The Isthmus was undoubtedly much neglected by the central government until the canal schemes began to develop, when her potential importance was realized. Overtaxation kept the country pitifully poor, and numerous attempts to free itself from Colombia were the result, though independence was not finally accomplished until 1903.

DEPARTMENT OF PANAMA.

Of the seven divisions of the Republic the largest and in some respects the most interesting is that of Panama, including the famous

"Isthmus of Darien." On the Atlantic coast the confines are the Rio Miel (forming the boundary of Colombia, though Panama still claims the Tanela River some distance to the southeast) and the Mulatas Archipelago. Here it joins the department of Colon, which with Panama almost evenly divides the Isthmus lengthwise till it reaches its western limit at Cocle. The entire southern Pacific coast is included in Panama from Cocle to Colombia. This department contains the largest city (Panama City), with towns like Chorrera, a small resort in the hills, and Chame, both in the western section. From the Bay of Panama to that of San Miguel the country is uninhabited, except the valley of the Chepo[a] or Bayano[b]. The Chepo is navigable as far as the hamlet of La Capitana, near the point where the Mamoni flows into the main stream. On this tributary is the town of Chepo (population 6,875 in 1898, according to Valdés, which must include, however, a large surrounding area). It is a poor place, though until comparatively recently it had some well-to-do inhabitants, who left it for Panama City, with which it is connected by trail. In 1565 Chepo was colonized by Cordova, governor of Old Panama, though it was known as early as 1515 as an Indian town. This section was so harassed by the buccaneers, Watling, Wafer, Sharp, Bullman, Dampier, Guzman, Coxon, Baskerville, and others that two forts were built, one on the tributary river, the Terrable, and the other, not more than a stockade, near Chepo, in the construction of which it is said the Indians actually assisted, as at the time the marauders were preying upon them more than were the Spaniards themselves. The Terrable River was surveyed by Reclus, who, however, failed to find his way by means of it to the coast, as was also the Mamoni, a beautiful river full of cascades and waterfalls, explored by the American surveyors from 1870–1875. The main waters of the Chepo flow in an approximately southeasterly (or westerly) direction, with no habitations along its banks, except the small hamlet of Jesus Maria. Its most southeasterly tributary, the Canaza, rises in a country absolutely unknown at the present time.

In fact, the only other parts of the interior of Darien that are known are the districts along the Tuyra and lower Chucunaque with their tributaries, along which small towns are scattered through this forgotten country, over which, in the old days, the buccaneers passed by many routes. The above-mentioned villages are the homes of negro and Indian half-breeds who, when they work at all, are rubber hunters or traders in hard woods. They are miserable towns and contain no permanent white residents, the largest of them

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[a] The name Chepo is derived from the chief Cheapes, encountered by Balboa.

[b] Bayano is from a famous fugitive slave, who, uniting with others of his kind, committed atrocities on the Spanish in these parts, and was killed after a laborious campaign by Pedro de Ursua in 1555 (4).

being Yavisa, Chepigana, Pinogana, Real, and Molineca. Beside the Cana mine, there is gold found at the present time in the waters of two tributaries of the Tuyra, the Balsas, and the Marea (19), and an old mine was recently located by an American on a supposed Colombia trail between the sources of the Tuquesa and the Ucurganti, tributaries rising eastward of the Chucunaque. There is no record that the upper Chucunaque has been explored farther than this since Admiral Selfridge's party reached the Sucubti in 1870, going in from the coast at Caledonia Bay. Reclus surveyed (1878) the lower tributaries of the Chucunaque, the Tupisa, etc., and with the other French engineers, Wyse and Sosa, ascended many of the navigable streams tributary to the Tuyra; such as the Paya and Cue, and from where descent into the valley of the Atrato can be made. Much work was also done in this section by La Charme, De Puydt, and Hellert. The Atlantic coast line of the department of Panama is the home of scattered Indians, who would, undoubtedly, still actively resent any invasions of their territory as they have always done in the past. From Careta and Caledonia bays several attempts have been made to cross Darien, but the parties never penetrated very far into the interior, as the Indians absolutely refused to properly guide them over trails and passes, though usually making a show of friendship to the white men when they were in any numbers. During the early part of the eighteenth century the Scotch attempted to found a colony at Port Escoces, the tragic misfortunes of which are quaintly related by the Rev. Francis Borland (21). As early as 1719 Jesuit missionaries had penetrated into the heart of Darien only to be massacred by the Indians. This hostility continued until 1740, when a peace was made, and priests were again sent out; those to the region about the north coast, by order of the viceroy, Don Sebastian de Eslava, and those to the south coast were sent from Panama. This resulted in the founding of the towns already mentioned in the Tuyra Valley. In 1784 there was a complete chain of forts across Darien that were well garrisoned, but by 1790 they were abandoned and Darien remains to a great extent the undisturbed domain of the Indian. But one of these forts is standing, that at Yavisa, which is in a ruined condition. Another was formerly to be seen at Viejo Real (a strategic point on an island in the Tuyra), but within the last fifty years or so all trace has been lost in the dense growth of vegetation covering it. In 1852 an abortive attempt was made by an English engineer, Gisborne, to penetrate Darien, who relied much on information obtained from Doctor Cullen, which he, and later also Admiral Selfridge, however, found to be untrustworthy.

DEPARTMENT OF COLON.

Colon lies between the Departments of Panama and that of Veraguas on the Atlantic coast, and is bounded on the south by the Departments of Cocle and Panama. Through it, and Panama as well, runs the Canal Zone, belonging permanently to the United States. These towns are too well known to warrant a description here. The San Blas coast and territory surrounding Mandinga Bay comprised the domain of the San Blas (Manzanillo) and Mandinga Indians, their country ending, approximately, where the Rio Mandinga rises. Back from low-lying coast hills, in the higher sierras, the region is supposed to be uninhabited as far as the source of the Chagres except for wandering tribes toward the south. The route from the coast to the northern tributary of the Chagres, the Rio Pequeni, has been traversed by Americans and no Indian villages were encountered.

Following the coast northwestward is seen the town of Palenque, settled by fugitive slaves many years ago, who lived in underground caves and passages and whose descendants to-day are held to be quite different from the usual Isthmian negro. They are extremely industrious, strong, and good woodsmen. Not far from here, on a small stream of the same name, was Nombre de Dios, of which no trace remains, and near it, on a beautiful but landlocked and unhealthy harbor, stands the ruins of Porto Bello, sacked by Drake, Vernon, Spring, and Morgan. The ruins of the two forts still exist, St. Felix on one side of the harbor, and Sts. Jéronimo y Christobal on the other, and fragments of the large government house "Santiago de la gloria," still remain. Porto Bello now has a small colored population, and is considered one of the most unhealthy places on the Isthmus. In the upper Chagres Valley are two little settlements, St. Barbara and San Juan, but the surrounding country is little known, and the sources of several of the rivers tributary to the main river are still to be surveyed as bearing on the canal-dam problem. A short distance up the coast from the city of Colon is the mouth of the Chagres, just beyond the zone border, where there is a tiny native village above which stands the fine old castle of San Lorenzo, famous in the history of the New World. It was built by Juan Antonelli, an engineer of Filip II, and was considered one of Spain's greatest strongholds. In fact, it did for some time defy the furious attacks of many buccaneers, but was almost destroyed at the time of its surrender to Morgan's forces. The account of its capture as told by the Dutchman, Esquemaling, one of Morgan's men, is very interesting. In 1740 the already ruined fortifications were completely laid low by the English under Admiral Vernon, but it was rebuilt in 1752 by Ignacio de Sala (5)

and now, once again stands a desolate, moss-covered crumbling ruin, a reminder only of the glory that was once Spain's.

The rivers, Cocle, Los Indios, and Belen, flowing into the Atlantic in the western part of Colon, have been known for centuries to wash down gold. Their sources in the high sierras are practically unknown. The old mine of San Antonio, on the Cocle, at one time had an output of about $40,000 a year, though it has been closed for a long period. With modern mining machinery, this, as other mines on the Isthmus, could undoubtedly be made to yield a much larger sum. On the banks of the Cocle, also, an attempt has been recently made by a Belgian company to raise bananas on a large scale, and, though not fully exploited as yet, it is expected to make good returns eventually. A great difficulty is encountered in the fact that the river is not easy to navigate, though other conditions, such as soil, etc., are extremely favorable to such enterprises.

THE DEPARTMENT OF COCLE.

In point of antiquity the Department of Cocle has a foremost place, for here on the Rio Chico was the second settlement on the Isthmus proper. The original town of Nata was destroyed in 1529 by the Indians, who were especially warlike in this region, and was rebuilt in 1531, when it was christened "Santiago de las Caballeros de Nata." The city attained much wealth and splendor in the colonial period. The church, still in existence, is in good condition and of excellent architecture, having a fine tower, in which are spiral steps, cut in the stone. To-day Nata is a small place with a poor population and practically no trade, quite different from the little town of Aguadulce, its neighbor, which is near the Estrella mine. This section is a good stock-raising country, and a quantity of hides are exported by way of Aguadulce to the coast. Near this place is the hacienda of Panama's last revolutionary spirit, Gen. Estaban Huertas, who retired here to take up stock raising, and who received also a generous pension from the last administration.

The most important place in this department is Penonome, with a population of 15,833 (46), making it the largest city on the Isthmus outside of Colon and Panama. Penonome has two churches, schools, barracks, public buildings, and enjoys a large trade, especially in grain, rubber, coffee. and straw hats.

LOS SANTOS.

Los Santos, the department south of Cocle and east of Veraguas, borders Parita Bay and is a fertile agricultural country, with a good climate. The principal towns are Los Santos, Pese, Las Minas, Las Tablas, and Parita. A good deal of salt is exported from the mines of the province, and gold is also found in the western section.

DEPARTMENT OF VERAGUAS.

Veraguas, lying between Chiriqui on the west and Colon, Cocle, and Los Santos on the east, stretches from sea to sea, though at present it has only a small coast line on the Atlantic, into which flow the boundary rivers, the Belen and the Concepcion, and between them the Viejo Veraguas. Veraguas was explored by Nicuesa and called "Castella del Oro." An immense amount of gold was taken from the mines in the years following its discovery at Montijo, El Mineral de Veraguas, and Sona (the last is operated at present time). Valdes says that as early as 1570 200,000 negroes were working in the mines of Veraguas, which, at that date, however, included those of Chiriqui and neighboring provinces as well.[a]

The chief place in Veraguas is Santiago, somewhat smaller than Penonome, situated on a plain 105 meters above the sea, having in consequence a fine climate. Here are preserved many old customs, modes of speech, and a strict moral code, such as have not been observed elsewhere on the Isthmus, derived undoubtedly from the aristocratic Spanish ancestors of the inhabitants who settled in this section. While Santiago is on the main line of travel from Panama to David, it remains a secluded, old-fashioned little city. The chief industries of Veraguas are mining, stock raising, and some cotton manufacture.

DEPARTMENT OF CHIRIQUI.

Chiriqui extends from Veraguas on the east to the Costa Rican border, and is bounded by the Atlantic Ocean and the Department of Bocas del Toro on the north. Chiriqui was not created a separate department till 1849, and came into special prominence a number of years ago (1859) after the discovery of great quantities of gold and archeological treasures in the old Indian tombs or huaccas. From one cemetery alone was taken $50,000 worth of gold (35). Chiriqui exports gold, copper, salt, ebony, dyes, spices, medicinal herbs, tobacco, coffee, cane, and cocoa. Coal is also found in some quantities on the island of Muerto, but the chief supply of this mineral is from the neighboring Department of Bocas. David, the capital, having a little smaller population also than Penonome, is, next to Panama itself, the most important place on the Isthmus—built on the site of an ancient hermitage which was connected by trail with San Lorenzo, a very early settlement. The climate and location of

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[a] "Dans le district de Cañazas (ouest) il y des mines, en exploitation et d'autres qui sont a l'état de projet. Ce district a une superficie d'environ 160 milles carrés, au nord, il est borné par les districts de Santa Fé et de S. Francisco, au sud, par el Rio San Pablo, a l'ouest, par Rios Piebras et Cañaza, et a l'est, par la rivièrre Santa Maria et le district de la Mesa" (19).

David are excellent, and the city itself presents an attractive picture with whitewashed houses and overhanging red-tiled roofs, surrounded by a fertile plain, the high mountains in the distance. There are many signs of progress in David, and the inhabitants would cordially welcome Americans among them, a few of whom have already settled there, where conditions of life are found to be not at all unpleasant. The people of the surrounding districts are Indian half-breeds, very industrious and cleanly, much above the average standard. In 1732 this section suffered terribly from an invasion of Indians inhabiting the Mosquito Gulf district, who completely overran it and committed all sorts of depredations. The towns of Chiriqui are Dolega, Remedios, Gualaca (gold mine), St. Felix (copper mine), Bugaba, Bugabita, Alanje, and Caldara. Near the last-named town, a mere hamlet, was discovered the "Piedra Pintal," the inscription on it still remaining a mystery, and is considered by some the supposed work of a race completely lost sight of. The carved gold, copper, and stone ornaments, weapons, and utensils, etc., of the Chiriqui tombs have made their way to Paris and London, many having been collected by M. Zeltner, who was at one time the French consul at Panama, and were sent by him to France. The National Museum, Washington, D. C., also has many small specimens, but most of the pottery is in the British Museum. Many of the rings and chains in the possession of Panamanians have been copied and make exquisite pieces of jewelry, bringing high prices when sold. The portrayal of animals forms a large part of the work, especially were frogs, lizards, and snakes depicted. A very complete description of them is given by Bollaert (37).

DEPARTMENT OF BOCAS DEL TORO.

The remaining department of the Republic is that of Bocas del Toro, with a large town of the same name on an island off the coast above Chiriqui Lagoon and is a well known port to merchant vessels. Bocas has largely a foreign population, its trade being almost entirely in the hands of Americans or Europeans. About the vicinity are ranches with small single-track railroads on which the fruit, chiefly bananas, is transported from the interior. This district is still only developed to a small extent, and the whole Chiriqui Lagoon region is destined in the future to become one of the greatest fruit-raising centers of the Caribbean. Chiriqui Grande, a small place, is connected by a good trail to David, the construction of which, though only a trail, cost considerable. This is the only route which crosses the Isthmus except the Panama Railroad. The shores of the lagoon are low and marshy, but they are, nevertheless, inhabited by Indians and half-breeds, living in small scattered settlements. Many of them speak a Spanish that can not be understood by educated

Isthmians at all. The Panamanians will tell you that this dialect contains a mixture of English, badly pronounced, and spoken with a peculiar accent, and that it is probably derived from the crews of the British merchantmen that in the old days frequently sought refuge from storms in the lagoon.

RACES AND RACE ADMIXTURE.

The population of the Isthmus is so variously stated that it is difficult to approximate the figures, ranging as it does from 300,000, as given in the Monthly Bulletin of the American Republics (February, 1904), to 400,000, as given by Menihold two years later, a discrepancy which is considerable, considering the smallness of the country. These figures exclude, of course, the Americans within the Canal Zone, and also the Indians living in their natural state.

Racial complexities are nowhere more in evidence in so small an area than on the Panama Isthmus. An accurate classification of the inhabitants would be practically impossible, as there are innumerable "permutations" in varying degrees among this heterogeneous people, who hardly recognize the bars of racial distinction.

The foundation of the population is found in the aborigines, the Conquistadores, and in their negro slaves. At the present time the pure white blood is in an exceedingly small minority, the vast majority of Isthmians being colored people with either Indian or white blood, or both. The combination of Indian and white without any negro blood is comparatively rarely seen. The distinctions are, however, as follows: Mestizo, white and Indian; mulatto, white and negro; zambo, negro and Indian.

It was not until the time of the building of the railroad and later, the canal enterprise, that the flood of Asiatics, Europeans, and West Indian colored people, from the Dutch, French, and English colonial possessions came to the Isthmus, many of whom never returned to their native lands and left in their adopted country a numerous and nameless progeny. Their children mingling in turn with those of various races has resulted in a most conglomerate people.[a] These descendants of foreign laborers are chiefly confined to the districts adjacent to the "great highway" and its terminal cities. The Orientals, chiefly Chinese or Japanese, though there are some Hindoos, at the present time do not mingle with the other races of the Isthmus to any appreciable extent, though in the towns along the railroad such as Matachin[b] there are many evidences of a former interbreed-

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[a] Valdes observes that in the Spanish spoken in rural communities of the Isthmus generally, idioms are used never observed elsewhere in either Central or South America.

[b] Matar=Spanish to kill, and Chino=Chinaman.

ing of the yellow with the black and the white races. The negro of Panama proper is the descendant of the original African slave and in some remote places high up in the hills are to be found a rather wild type, whose ancestors were the cimarrons (a term equivalent to that of "Maroon" as used in Jamaica). The lives of these negroes are very picturesque, existing as they do in a most primitive fashion in their palm thatch huts surrounded by a riot of gorgeous flowering vines and plants. In a small nearby clearing a little yucca, maize, frijoles, bananas, and tobacco are cultivated, and about the huts are a few chickens and a pig usually fraternizing with the black babies on the dirt floor. Often the shacks have no walls at all, simply consisting of a shelter from sun and rain supported by four bamboo poles. The bushman seldom has any need for money, as he obtains by barter the only articles necessary to his needs with which nature does not supply him. A few, very few, clothes and a machete, used to cut his trail and build his house and employed also as his weapon, are the only things he must obtain from the villages. The utensils and retainers are gourds or calabashes; seldom, if ever, is any pottery seen in these homes. If the head of the family works at all, he gathers a little rubber or burns charcoal, occasionally descending to dispose of it into the far-off settlement.

The natives of the Isthmus in general, even in the larger towns, live together without any marriage ceremony, separating at will and dividing the children. As there is little or no personal property, this is accomplished amicably as a rule, though should disputes arise the alcalde of the district is appealed to, who settles the matter. This informal system is always stoutly defended by the women, even more than by the men, for, as among all people low in the scale of civilization, it is generally held that the women receive better treatment when not bound and therefore free to depart at any time. Recently an effort has been made to bring more of the inhabitants under the marriage laws, with rather amusing results in many instances. The majority of the population is nominally Catholic, but the teachings of the church are only vaguely understood, and its practices consist in the adoration of a few battered images of saints whose particular degree of sancitity is not even guessed at and who, when their owners are displeased with them, receive rather harsh treatment, as these people have usually no real idea of Christianity beyond a few distorted and superstitious beliefs. After the widespread surveys of the French engineers, a sincere effort was made to re-Christianize the inhabitants of the towns in Darien as well as elsewhere, for, until this time, nothing had been done toward their spiritual welfare since the days of the early Jesuits. In the last thirty years spasmodic efforts have been made to reach the people with little result, and, excepting at Penonome, David, and Santiago, there are few

FIG. 1.—A SAVANNÁH.

FIG. 2.—NATIVES OF GOOD CLASS, SHOWING ONLY SPANISH AND NEGRO.

churches where services are held outside of Panama and the towns along the railroad.

The chief amusement of the Isthmian is gambling, cock-fighting, and dancing, the latter assisted by the music of the tom-tom and by dried beans rattled in a calabash. After feasts or burials, when much bad rum and whisky is consumed, the hilarity keeps up all night and can be heard for miles, increased by the incessant howls of the cur dogs lying under every shack. Seldom does an opportunity come to the stranger to witness the really characteristic dances, as the natives do not care to perform before them, though a little money will sometimes work wonders. Occasionally, their dancing is really remarkably interesting, when a large amount of pantomime enters into it and they develop the story of some primitive action, as, for instance, the drawing of the water, cutting the wood, making the fire, cooking the food, etc., ending in a burst of song symbolizing the joys of the now prepared feast. In an extremely crude form, it reminds one of the old opera ballets and seems to be a composite of the original African and the ancient Spanish, which is very probably the case.

The Orientals of the Isthmus deserve a word in passing. They are chiefly Chinese coolies and form a large part of the small-merchant class. Others, in the hill districts, cultivate large truck gardens, bringing their produce swinging over the shoulders on poles to the city markets. Their houses and grounds are very attractive, built of reed or bamboo in the eastern fashion and marked everywhere by extreme neatness, contrasting so strikingly with the homes and surroundings of their negro neighbors. Many cultivate fields of cane or rice as well, and amidst the silvery greens, stretching for some distance, the quaint blue figures of the workmen in their huge hats make a charming picture. Through the rubber sections Chinese "middlemen" are of late frequently found buying that valuable commodity for their fellow countrymen in Panama city, who are now doing quite a large business in rubber. These people live much as in their native land, seldom learning more than a few words of Spanish (except those living in the towns), and they form a very substantial and good element of the population.

THE INDIANS.

The estimated number of full-blooded aborigines in the Republic of Panama is stated from 10,000 (5) to double that figure. Some years ago Acosta thought there was an even greater number than 20,000, and, as the race is rapidly dying out, he may not have been as far wrong as it would seem—still, it is doubtful if the figure would have reached 30,000. These estimates are of little value, however, because at the present day no one can really know the number of aborigines.

The territory of the Indians lies chiefly in the mountains of Bocas del Toro, Veraguas, and Chiriqui, and on the Caribbean coast of Darien extending into the interior; also along the Pacific coast from the Gulf of San Miguel to Colombia, and on certain branches of the Chucunaque and Tuyra. Very little about the Indians has been recorded since the accounts of the early colonists given by the old historians, Herara, Andagoya, Gomara, Las Casas, Oviedo, Peter Martyr, etc., who confused the names greatly, and who usually spoke of a tribe by the name of its chief, which frequently happened to be that of the largest settlement of the vicinity as well. Much information has been obtained from the buccaneers, chief among them Wafer, whose book, with the above-mentioned historians, forms the basis of the material given by Bancroft and other authorities. In the middle of the nineteenth century an interest was awakened in Colombia by men like Acosta, who gives, from personal observation, some data of the Darien Indians, though his chief work was on the Chibchas of the plains of Bogota and Tunja. Acosta affirms that the most valuable knowledge concerning the Indians is hidden away in the libraries of Sevilla and in the Academia de Historia de Madrid, which, of necessity, though, must treat chiefly of the natives as the Spaniards first found them. When Acosta visited the coast of Darien he found no remaining words preserved from the time of the conquest except the proper noun "Careta." Another Colombian, Restrepo. some years later was sent on an expedition into Darien and made some very interesting notes on the customs of the Indians. It is to M. Pinart, however, a Frenchman and trained student, that most of the valuable contributions to the subject are due, as he traveled extensively through the country about the year 1880, collecting data, and the result of this work is the foundation of practically all the recent knowledge we have of the aborigines, though the French and American engineers have added much also by way of stray notes, etc., to the store of information. The preface of Pinart's "Colleccion de Linguistica y Ethnografía Americanas," written in 1882, is interesting as showing his reasons for taking up the work.

Considering the Indians in the western half of the Isthmus, we find two distinct stocks, the Doracho-Changuina and the Guaymies. The former, now almost extinct, as pure bloods, spread over parts of Chiriqui and Bocas, inhabiting chiefly the Cordillera which cross the Costa Rican border and the valleys of the Rio Tilorio and the Changuina-Aula. To them is attributed the megalithic monument at Mesa (35). They were noted potters and their elaborately painted vessels indicate some artistic ability. The Dorachos were held to be bold warriors and were usually at war with their neighbors. They were described as being much lighter in color than the other tribes.

FIG. 1.—NEGRO-INDIAN FAMILY OF YAVISO; CANE HOUSE WITH TILED ROOF.

FIG. 2.—A HUT IN THE PANAMA JUNGLE.

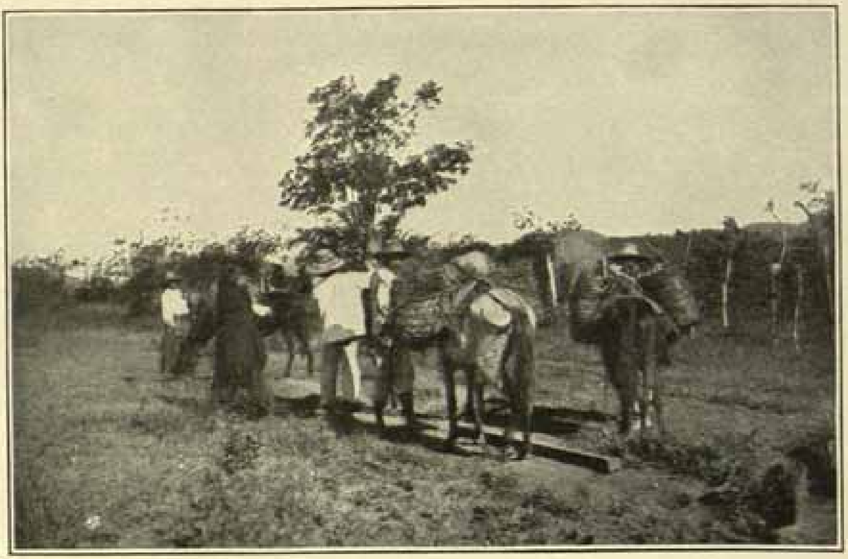

FIG. 1.—PANAMA NATIVES WITH PACK HORSES GOING TO MARKET.

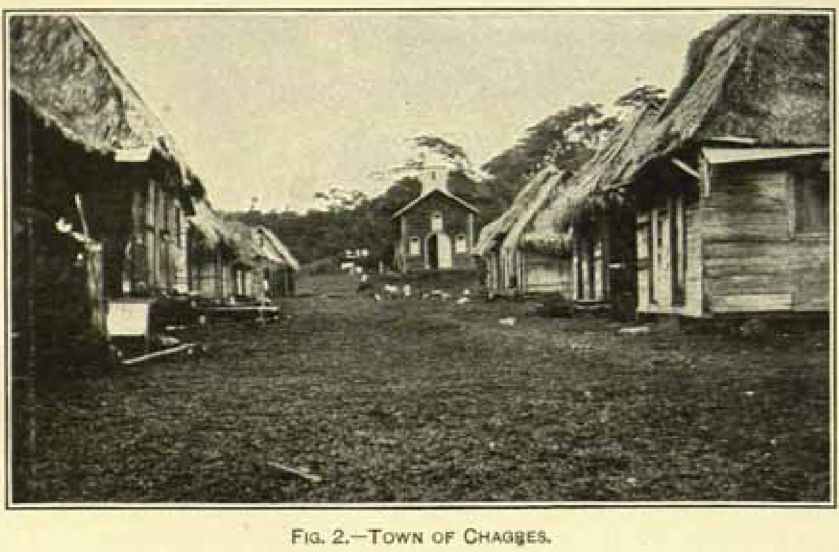

FIG. 2.—TOWN OF CHAGRES.

Little of their origin is known, but Brinton (35) and others suggest they are probably descended from the Mayas of Yucatan. According to Pinart, who made a collection of their idioms, the Dorachos did not believe in a God that abode in the skies, as the Guaymies have always done, but believed that the "great spirit" lived in the Volcan de Chiriqui, and when they were angered at the god they would avenge themselves by shooting their arrows toward the crater as a sign of their displeasure. They constructed tombs of "flat stones laid together with much care in which they placed costly jars and urns filled with food and wine." This was done for their great men, and for the lesser ones they dug trenches filled in with stones and in which gourds of maize or wine were substituted for the pottery (24, v. 4). The Dorachos were brave, honest, and intelligent and, in common with all isthmian tribes, fearless of death. From 1674–1681 war was made on these Indians by the governor of Costa Rica as they had descended, robbed, and killed travelers on the road then much frequented from Panama to Guatemala. The Indians who survived the years of exterminative war were gathered into the missions of Bugaba, Boqueron, San Francisco de Dolega, and Gualace.

We now come to the Guaymies, who still inhabit the mountains of the Serrania de Tabasana range with their interlying valleys and the plains of the Atlantic coast. These Indians live practically in a savage state, occasionally descending into the towns of Veraguas and Chiriqui, and are especially seen about Remedios. With the Talamancans of Costa Rica, of whom Gabb (36) has written so interestingly, the Guaymies are thought to be a remote branch of the Chibchas nation by both Deniker and Brinton.[a] Many Chibchas words are found in their dialect and especially is their affinity shown by their burial customs, their metal work, and the lack of anything like permanent temples or homes among them. To the ancestors of the Guaymies (or Guaimies) are attributed the treasures of the Chiriqui and Veraguas tombs, which bear a close resemblance to the art of the main stock of the Chibchas. Pinart has given the number of the Guaymies as 3,000, but Valdés puts it at "no less than 6,000," (5) though in his description of their customs (to be given here later) Valdes evidently draws much from Pinart's information, judged by the fact that in Deniker practically the same material is given in part, and there is accredited to Pinart. Reference is here made to Pinart's "Chiriqui" which the writer could not obtain. Pinart says in a note in his "Vocabulario Castellano-Guaymie"

[a] A number of tribes in the state of Panama were either filially connected or deeply influenced by outposts of the Chibchas nations. These are the Guaymies in Veraguas, who possessed the soil from ocean to ocean, and the Talamancans of Costa Rica (35).

that at the time of the conquest the Guaymies were the most important nation of the Isthmus, and defines the territories of their principal tribes, which are the Move-Valiente, Murire-Bukueta, and the Muoi. The Valientes are to-day the chief tribe of all, though the Muoi was the mother tongue of all Guaymie dialects.

A free translation of Valdes' (5) description of the Guaymies who, he says, remain, at the present time, completely pure in language and customs, is as follows:

The Guaymies live in groups for the most part in the high Valle de Miranda in the Cordillera de Veraguas, cut off from communication with the plains by defiles, difficult of access. They have retained their independence, having warded off invasions of both blacks and whites, who can not penetrate their land without the favor of the powerful chief. They are called (one tribe) Valientes on account of the great cruelties with which they punish the least offenses. Formerly, it was rare to see a Valiente whose body was not covered with scars. Some families * * * seem to be descended from those who, before the arrival of the Spaniards, carved symbolic figures on the rocks of the mountains and placed gold ornaments in their graves. In former times they were without doubt more civilized, but modern progress has destroyed their industries, as they now provide themselves with arms, tools, utensils, cloth, etc., from their neighbors, which formerly they made themselves.

Valdes further says:

The political rule of the Guaymies is varied, but they all obey a powerful cacique who has centralized the power. The Guaymi is small, muscular, and robust, with a large head and flat features, and is an indefatigable walker and carrier. As is common with all Central American tribes, the Guaymies have the "totem" or animal god. When the youths come to adolescence they submit themselves to rude tests and go to the forests in company with their comrades, far from their parents, for a period of novitiate. Old men, with bodies painted, masks on their faces, and crowns of leaves on their heads, teach them the traditions and songs of their tribe, composed in a strange and sacred dialect. Afterwards, when the youths have endured sufficient hardships—all that they can without complaining—they are admitted to the tribe and called "los hombres" (men) and each is given a distinct name—for the first time. For the girls, also, at this period [a] are held ceremonies, and soon after, they are either married or rather sold. The principal fiesta of the Guaymies, called "balceria" by the Spanish, usually takes place in summer. The day is indicated by knots tied in reeds along the wayside or sent to the different families. After a general bath, the women employ some hours in painting the men's bodies red and blue, adorning their faces with arabesques and extravagant figures much resembling those on the old vessels (pottery), and then the men array themselves in some historical attire, wearing a loin cloth of bark and the pelt of an animal. At a signal the dancing commences for the game of balsa, which consists in the breaking up of light wood and flinging it at the legs, knocking each other down and falling amidst the heaps of broken sticks. It is said these Indians feel the injuries thus inflicted very little.

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[a] Pinart (16) says, "that during the time of puberty a girl's tooth is broken, which is regarded as proof of the fact that she is nubile." In this paper Pinart gives also a complete illustrated description of the "Petroglyphes dans l'Isthme Americain," etc.

When the Guaymies believe that death is pursuing a sick person, they carry him to the woods and there abandon the dying man without leaving him anything but some plantains and a calabash of water. After death the body is straightened out and placed on a shed, and after one year the remains are gathered up, the bones cleaned, made into a bundle, and placed in the family burying place.

We now come to the Indians in the eastern part of Panama, between whom and those just described there is little in common, though they have lived for centuries within a few hundred miles of each other. Speaking generally, the Indians of the section inhabiting the coast and mountains of Darien belong to the great Cuna family, though there are evidences of a second nation to be discussed later.

As early as 1519 Fernandez de Martin says that "all along the (Atlantic) coast a man was called 'uma' by the Indians and a woman 'ira,' which are words in the Cuna language." Valdes holds that all the Darien Indians of the coast are Cunas, though he observes that as no one to-day knows the Cuna dialect it is difficult to state it positively. The comparison of speech (presupposing a thorough knowledge of various dialects) is, of course, the only means by which proof can be established. It is a well known fact that the Cuna family is of Carib origin,[a] but the word "Carib," however, as used by the colonists in speaking of the aborigines that they encountered, was equivalent only to the word "Indian" itself and was applied to natives all along the entire coast of the Caribbean. The Caribs, in Chibchas mythology, were supposed to be descended from tigers, yet there can be no doubt that the natives of Darien were, as a rule, peaceable, kindly disposed, and rather indolent at the time of the conquest and until stirred by resentment of the unfair treatment they received at the hands of the Spaniards. Borland says, in his quaint fashion, concerning them: "In general, they seem to be a pretty modest sort of people, considering them as wild pagans." A great mark of distinction among the Cunas is their comparative lack of arts and industries, in contrast to their neighbors, and in their manner of disposing of their dead. Of the many tribes of the Darien Indians mentioned by writers since the discovery of the country, some must have been merely subtribes, taking their names from their particular localities; though it is true the confined area of the Isthmus is remarkable for its number of

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[a] Ojeda found Indians about the settlement of San Sebastian de Uraba who were the warlike, flesh-eating Caribs (1).

Bancroft (24) observed "it is said that the Caribs ate human flesh whenever they had an opportunity. 'Herera says that some of the Isthmians purchased slaves whom they sold to the Caribs for food.'"

Restrepo (2) says that Dr. Aristides Rojos defends the Caribs and affirms that they did *not* eat human flesh, though Columbus, Ovieda, Herara thought the contrary.

tribes, and in comparing statements made by various authorities a great deal of discrepancy appears, as already mentioned. The following is a list of the important tribes of Darien, most of whom are believed to exist, as a whole or in part, at the present time, and those marked (*) are held to be non-Cuna from data referred to later.[a]

The tribes are:

Chucunas: Old name Tumanama (?). Inhabit mountains lying in interior from Atlantic coast. Held to be very warlike and much feared by coast tribes.

Sucubti: Living on river of same name; comparatively few in number, about 1,000, and were found to be timid when visited by Admiral Selfridge in 1870, never having seen white men.

Navagandi: Inhabiting region between Navagandi Point and the high mountains. Considered warlike, formerly. Probably absorbed by the Sasardi.

Sasardi: Held to be cowardly, but treacherous. Their chief is considered by some writers to be the head one of all coast tribes—others, that the caique of San Blas, on Rio Diablo, is chief of all. Live about Caledonia Bay.

Anachunas: North-coast Indians, thought to have been largely absorbed by other tribes.

Caiman: Inhabiting lower coast or west shore of Gulf of Darien. Held by Acosta to be certainly Cuna from words he collected among them. (Not in Panama proper.) No trace of any villages seen by naval officers in those waters in 1903–4.

Manzanillo or San Blas: Old name Comogres. Semicivilized.

Mandingas: Region of Mandinga Bay, probably subtribe of San Blas.

Payas: On tributary of Tuyra, much reduced in numbers since visited by Reclus and later by Restrepo. Have been brought into closer contact with whites, owing to their location on main route to Columbia, and are much reduced in number and degenerate, having practically lost their independence. Very cruel when drunk.

(*) *Paparos:* Whose territory was between the Yape and Puero near the Payas. Extinct as a tribe.

(*) *Chocamus:* Valley of Tuyra and lower Chunaque, also southeast shores of Gulf of San Miguel and Rio Sambu. Nearly extinct.

That all the Cunas of Darien could speak the Cueva dialect is held by practically all authorities. The Cuevas were a powerful tribe living on the Pacific coast near the site of Old Panama. Other tribes mentioned but ill defined by various writers were the Pacoris (or Pacri), Chiapes, Cheapes, Panamas, Chimans, Escorias, Cutaris, Chunachunas, Irmiacos, Tucutis, etc. Valdes gives the number of Cunas as 14,000 (1905), Pinart as 8,000 (1890), and Admiral Selfridge estimated the number at about 7,000 (1870). The following is a description of the Cunas taken from Valdes (5):

Generally speaking, the Cunas are small and very muscular. The women are extremely ugly and wither at an early age, and those of

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[a] Some old writers held Tule, Darien, Paparos, as all meaning Cunas of Darien. "Braves" is a term used to-day by Isthmians designating all mountain Indians of the section.

some tribes adorn themselves by hanging heavy gold rings through their noses, while those of other tribes wear collars of colored beads, also bracelets and anklets which oppress and disfigure the arms and legs. They wear only a short skirt reaching to the calf. Many of the men, Valdes says, have not preserved their old picturesque costumes adorned with the headpieces of brilliant birds' plumage. Especially is this so among the San Blas Indians. The Cunas wear their hair long, and it is very black, coarse, and abundant and does not turn gray or fall out even in old age. The men have no beards. All have very prominent cheek bones and small, sunken, bright eyes. Formerly they anointed their bodies with the juice of the "gerripa Americana," which keeps the flesh fresh and cool. For the great fêtes they paint their faces with the "bixa orellana." Their speech is strange, resembling a monotonous chant, and each phrase is spoken with great volubility, accentuating the last word and punctuating the phrases with pauses that the interlocutors take advantage of to express their assent or comprehension. General terms, moral or abstract sentiments can not be expressed. The Cunas measure time by the moon and count by tens, referring to the number of figures. Their villages are collections of scattered houses spread over great distances, and each has its "ina" (cacique) and its "piaces" or "lélé," who is the medicine man, priest, and magician, the third person of the community being the "camotura," master of ceremonies and chief musician; then comes the "urunia," or head warrior, usually the strongest man of the tribe. The favorite dance of the Cunas is the Guayacán, in which the men and women form a ring around the camotura, who occupies the center, playing his instrument, a kind of flute called "camó." Presently, all strike the ground twice with their feet, take two steps forward, breaking the circle; then the couples unite, turning around and around together rapidly to the rhythm of the music. The women give birth to their babies in isolated huts under the care of an old woman, who, after bathing the mother and child in the river, conducts them to the lélé, to be purified with clouds of tobacco smoke and to drive off bad fortune. As with the Guaimies, the age of puberty for a girl is the occasion of a fiesta; then, after the year following she can marry the man of her choice. Wafer (20) says that it was the custom for all the neighbors and friends to make a clearing, build a house, and plant the ground for a young couple during the time before the wedding ceremonies were completed. A husband among the Cunas acquires rights over all the women with whom he becomes related by marriage. Children are buried alive or drowned if illegitimate; also those born deformed, according to some writers. Formerly, if any man was present when a woman gave birth to a child he was punished by death. At the time of death the sign of mourning among some tribes is a toucan's

head placed over the house, and if more deaths occur there the place is burned to the ground. Among some tribes, also, the dead are put in hammocks[a] with provisions for the journey, kept fresh by the friends of the dead till the cords of the hammock rot, when the spirit is held to have reached the other land. When the Cunas travel, they take no provisions, but live on the crops of their neighbors, a perfectly correct proceeding in their code. All more or less take part in trade and at certain times voyage in small numbers to Colon and Panama or to nearer places with coffee, cocoa, cocoanuts, rubber, and ivory nuts, getting in return cloth, arms, and implements. The effect of the traffic has been to modify their primitive customs. (Valdes refers here evidently especially to the Cunas of San Blas.)

Other customs, from different sources, have been noted regarding the Cunas and are important to a better knowledge of these Indians. Soothsaying and sorcery played a large part in their lives, according to Wafer, Reclus, and others. Sometimes for days these sorcerers would shut themselves up in a small hut, shrieking and screaming above the noise of the drums, often imitating the cries of animals, as when a king beast disturbs the quiet of the jungle. After they emerged in a half-hypnotized condition, they could, with marvelous certainty, predict future events and the like. Drinking has always been indulged in to a great extent by these Indians, whose native beverage is chica, made by the old women of the tribe, who sit about in a circle chewing yam roots or cassava and expectorating it into a large bowl. It is fermented by the saliva, and set away to be taken through a further process later. In all festivities the chica forms a principal part, but the men never allow the women to drink, or even to eat, with them. When helpless from liquor the men stretch out in hammocks and are fanned and sprinkled with cold water by their wives. Tobacco is used by the Darien Indians in a peculiar way, and extensively so by men and women alike. The leaves are rolled up in long hollow twists, and the lighted end placed inside the mouth. They usually smoke in parties of four or five, sitting about in a circle, and blowing the smoke into each other's faces. An oath that is most binding among the Cunas is "sworn by the tooth," and their custom of saluting each other with backs turned is likewise a remarkable one.

SAN BLAS INDIANS.

The San Blas or Manzanillo Indians, appearing occasionally as they do at Colon, afford an opportunity to study the Cuna at close

[a] In Comagre and other provinces the bodies of the caciques were embalmed by placing them in a cane hurdle, hanging them up by cords or placing them on a stone or log, and around or below the body they made a slow fire of fine herbs at such a distance as to dry it gradually, till only skin and bone remained (24).

range and are the means by which much of the information of the race in general has been obtained. These queer yellow-brown people, resembling the Eskimo, should be classed as semicivilized, who, though retaining all their exclusive prejudices against the white man, have had their customs somewhat modified by their occasional contact with civilization. This is seen chiefly in the dress of the men, which no longer consists of garments made from home-grown cotton-wool and dyed blue with a vegetable stain, as the San Blas natives now wear, but, on their voyages at least, of felt hats and cotton cloth of English manufacture. They are wonderful sailors, and it is a remarkable sight indeed to see them in the early morning, before the rest of the world is awake, dashing into the harbor of Colon, managing their heavily-laden canoes or dugouts[a] through the surf with marvelous skill. A few hours after sunrise finds the San Blas men usually starting for home many miles down the coast to their little villages lining the shores of the Gulf of San Blas or dotting its coral islands. Here they live in entire independence and seclusion, fearing only the "braves" of the interior, who occasionally descend upon them. A few white men have from time to time sailed down their coasts. While the stranger is received in a friendly way when he first seeks permission of the chief to land, the white man is never allowed to remain ashore at night in any of their villages. At the time of the building of the railroad, American engineers sailed to San Blas and sought permission of the cacique to survey his country, but, being met with a blank refusal, were compelled to return to Colon. An inborn dread of strangers possesses these people, inherited, doubtless, from their ancestors, who suffered so cruelly from the Conquistadores, and, while nominally a part of the Republic, they are as independent, in fact, as on the day their country was first discovered. The San Blas people live largely on sea food and iguanas, caiman's eggs, and monkeys, when obtainable, though they plant a little cassava, yucca, etc. They excel in the art of snaring the tortoise, taking the shell to the market of Colon. Their fishing nets are made from silk grass and mahoe bark, from which they used to make all their ropes and cords after stripping and beating it till soft enough to twist. The canoes are solid trunks of mahogany or cedar trees, and tiny ones are given the little children as soon as they can walk, which results in making these Indians literally as much at home on the water as on the land. At the approach of a stranger among them the women are hidden away immediately and never seen except when coming upon them unawares, and to actually obtain a photograph of any of them is a rare feat indeed. The San Blas men swear an oath over their father's body to kill their women should their land be taken

[a] The native word is "ulo."

by the white man. The women alone at the present day paint their faces, and they always blacken their teeth on being married. All the women, more or less, wear nose rings, and their garments consist of a short skirt and sort of chemise of colored cotton, composed of various layers of appliqué work neatly sewed together, forming very curious designs. (See illustrations.) These garments seem to be peculiar to the San Blas women and are identical to-day with the description of them that Wafer gave over two hundred years ago. (Notice conventionalized figure of a man in the illustration.) The Indians of this coast have developed few arts, and make no pottery whatever, carved cocoanuts and gourds taking its place. They formerly used torches of palm wood dipped in oil and beeswax for light and made also from the palm a sort of braided box, covered with an animal's skin, which is very pretty. They make a rough basket of vine roots, very strong and serviceable, and some are cleverly shaped to fit the shoulder for the carrying of burdens, though their chief industry has been the making of their hammocks, many finely woven, from cotton-wool. These hammocks serve also as their coffins after death, as already stated. Then the bodies are hidden away in some remote and dense palm grove. They do not appear to have cemeteries. The houses are constructed with skill, built high above the ground, with overhanging, thatch-covered roofs, serving to keep out rain and dampness entirely, and are well suited to the climate. The supporting posts of the roof are large bamboos or palm trees. Three or four are driven into the ground at equal distances, according to the size that the house is to be, and across these is placed the ridge pole. On each side a few shorter posts are sunk, from which the long rafters are laid; then the outside is covered with palm or plantain. The high entrance is reached by means of notched poles, often large, split bamboo, and usually drawn up at night. The appearance of some of the San Blas villages seen from the sea is very attractive, especially those built on the islands in the midst of bright sand and waving cocoa palms, surrounded by the beautiful blue waters of the gulf, whose white-crested waves dash in over the reefs. Those hamlets of the mainland, showing a tawny yellow against the green hills, topped with low-lying clouds, present also a charming picture. The "poisoned arrow," formerly much in use by these and all coast Indians, it has been found, was only one dipped in the juice of the "Manzanillo del playa," which, as its name implies, grows by the sea, and, curiously enough, an antidote for the sharp inflammation its poison caused was discovered to be sea water. Only one tribe of the coast did not use bows and arrows originally, but wooden swords and spears tipped with bone instead. Polygamy is allowed among the San Blas Indians, but not widely practiced, only the caciques

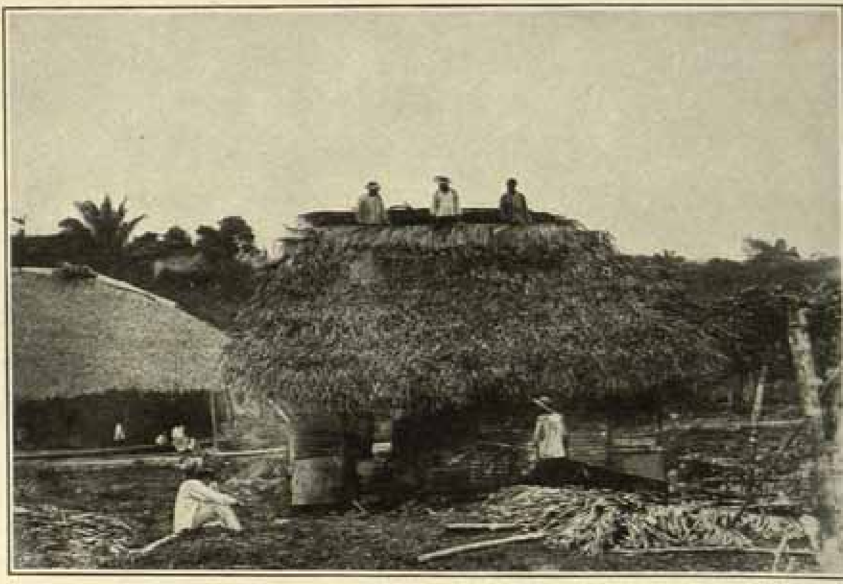


FIG. 1.—HALF-BREEDS—NEGRO AND INDIAN.

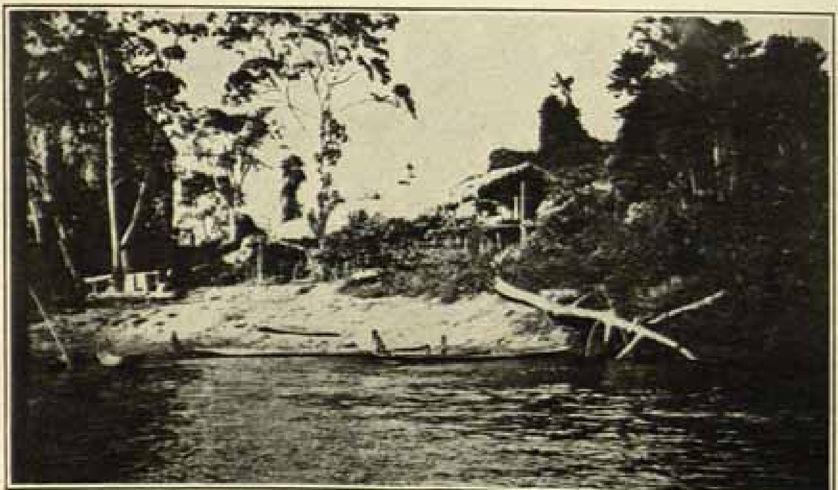
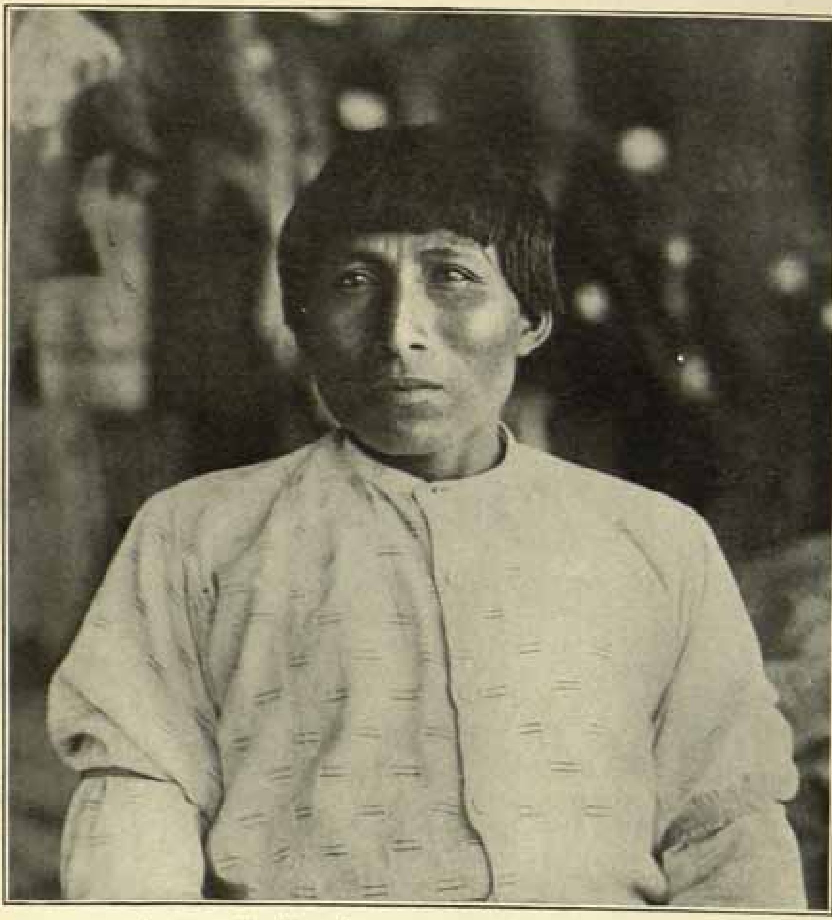


FIG. 2.—SAN BLAS COAST, PANAMA.

MACHE, A SAN BLAS INDIAN OF THE RIO DIABLO, PANAMA.

(Photograph by the Bureau of American Ethnology.)



KAY-AK, A SAN BLAS INDIAN FROM THE RIO DIABLO, PANAMA.

(Photograph by the Bureau of American Ethnology.)

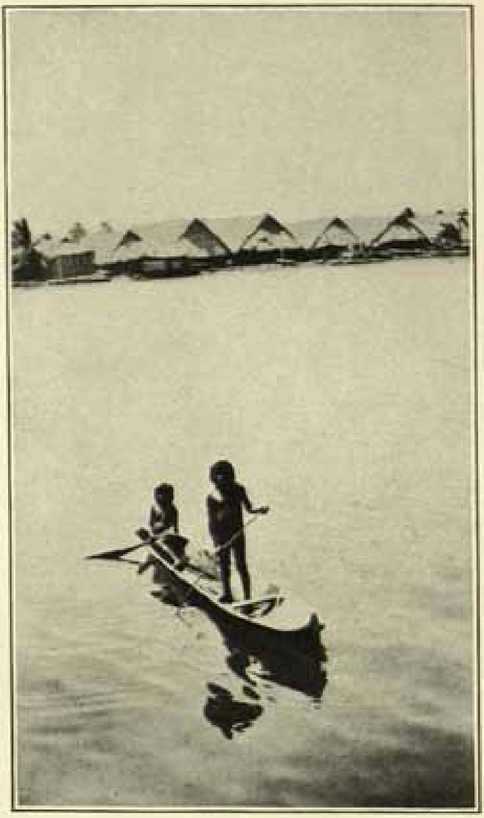


FIG. 1.—SAN BLAS INDIAN CHILDREN IN SMALL CANOE.

FIG. 2.—SAN BLAS INDIAN WOMEN HURRYING OFF FOR FEAR OF THE EVIL EYE.

FABRIC OF CUT AND INSET WORK.

Ground yellow, backing under cut work red, and on this smaller sections of dark blue, leaving a border of red. Lined with coarse linen. San Blas Indians, Panama. Original 17 by 21 inches. Design, human figure.

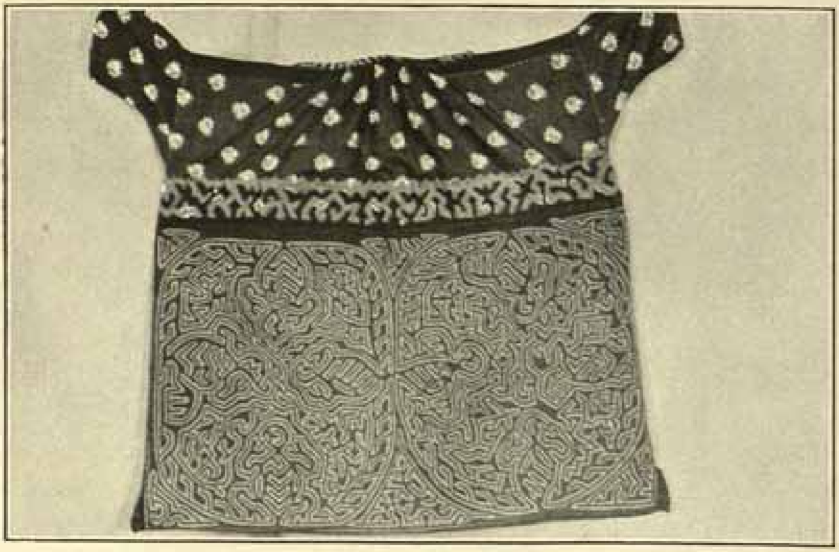


FIG. 1.—SAN BLAS WORK.

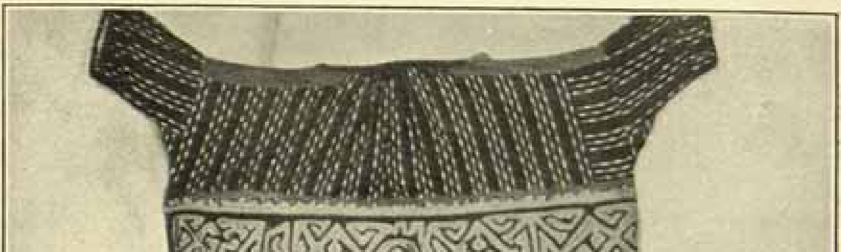


FIG. 2.—SAN BLAS CUT AND FILL WORK JACKET. PANAMA.

FIG. 1.—SAN BLAS INDIAN HOUSES.

FIG. 2.—SAN BLAS HOUSE AND UTENSILS. PANAMA.

FIG. 1.—VILLAGE ON CORAL ISLAND, SAN BLAS COAST.

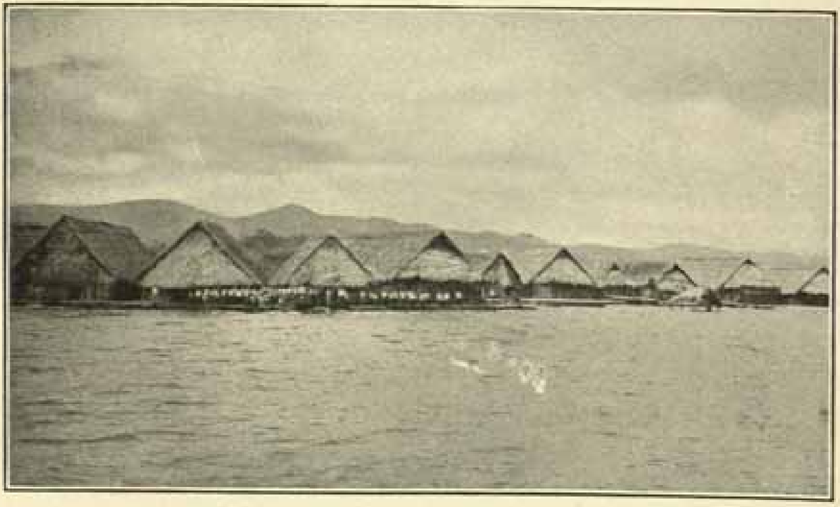


FIG. 2.—SAN BLAS VILLAGE ON MAINLAND.

maintaining more than one wife, as a rule. There seems to be little evidence of religion among these Indians, though they appear to believe in a God and in a devil. They also possess some idols, which they will part with readily in exchange for articles that they desire, holding them in scant reverence. How much longer these people will be allowed to remain in their seclusion it is difficult to conjecture, and, owing to the almost impassable jungle back of their country it would require an invading army of considerable size to subdue them. As a political move, an enterprising spirit at the time of the inauguration of the late president fitted out some of the leading men of the San Blas tribe in old, but exceedingly gaudy uniforms and took them to Panama to attend the ceremonies. They were much pleased, especially after liberal libations had been consumed, and felt keenly their importance.

THE SASARDI TRIBE.

In the winter of 1903-4 an American naval officer visited the district surrounding the beautiful Caledonia Bay, where the natives only occasionally meet with a stray trader in his small sloop, and who they have nothing more to do with than necessary for purposes of barter. The Sasardis were found to number about 200 or 300, living in three small villages[a] on the shores of the bay, presided over by a chief of great authority it seemed. This cacique ordered the American vessel to leave immediately, and, finding his order was not obeyed, he held an interview with the American officer a few days later, in which he said (through an interpreter) that the Indians wished to have nothing to do with the white people, that this county was their own, not belonging to the Colombians or the Panamanians, adding that under no circumstances could the crew remain ashore anywhere in the vicinity at night. Later the chief sent a letter to the ship which was addressed to Queen Victoria, whom he regarded as supreme over all white people, asking that she put a stop to strangers coming in vessels to his coasts. The Sasardis were dressed much in the fashion of the San Blas men, though they undoubtedly come much less into contact with civilized people. The women were only seen at a distance, but glimpses revealed the fact, often stated of Cuna women generally, that they are remarkably hideous. (In 1870 Admiral Selfridge's party did not meet with a single woman of this tribe when in Caledonia Bay.) These Indians had burying grounds in the vicinity of their towns, and the graves were surrounded with bits of broken glass bottles of

[a] The houses of these Indians differ from those of the San Blas people in that they are usually two stories high, the upper floor having no side walls except in perhaps one corner, and in the remaining open spaces are hung mats or curtains.

all colors, evidently held as great treasure, and also innumerable small trinkets filled the cemeteries. There was no evidence that they embalmed any of their dead. The chief insisted that if the Americans tried to penetrate into the interior they would encounter a savage tribe who would kill them with their poisoned arrows.

So far, only the Cuna family of Darien has been considered, yet there have been many references to other Indians in the southern part with whom the Cunas had frequent quarrels. Reclus (15) noticed that the Indians in some sections spoke of themselves as the "Ti" and others as the "Do" Indians, which is interesting, as "Ti" means water in the Cuna dialect, and "Do" means the same thing in the Choco dialect, according to the vocabularies of the two languages compiled by Pinart.[a] In one place Reclus (15) speaks of "les autochtones de la region (Darien) les Indiens Cunas et Chocas * * * refoulés dans l'intérieur ou ils habitent les hautes valles de la Tuyra et du Chucunaque." Reclus (p. 210) further says "that the 'Ti' Indians are small and thick set and early become obese; the 'Do' on the contrary are large and well made, keeping the purity of their forms to an advanced age." Pinart in "Les Indiens de l'etat Panama" says, "there is certain proof of a second nation" in Darien, but in his "Notes sur les limites de civilization de l'Isthme American," he says that the Chocos in Darien were only in small colonies, being a branch of the main Choco stock, which extended through Colombia, and which was a very brave and proud race. Without doubt the "Do" Indians encountered by Reclus, when in the vicinity of the Paya tribe, were the remnant of their neighbors, the Paparos, with whom they were usually at war. The original trouble between the Paparos and the Payas was caused by the former resenting the theft of their boys and girls, whom the Payas sold as slaves to the Spanish. Pinart's note on these Indians, in his little book entitled "Vocabulario, Castellano-Dorasque," is very interesting.

Brinton (35) says that the Chocos settled about the Rio Sambu, which flows into the Gulf of San Miguel near Point Garachine. These Chocos were of the Chocamus tribe, and were numerous till a few years ago. On comparing the photographs obtained of the Indians in the lower Chucunaque Valley, with the Cunas of San Blas, it will readily be seen that the former are larger and appear darker in color, exhibiting quite a different type altogether.[b]

[a] Belman (12), speaking of the main stock of the Chocos, gives the word water as "Da" instead of "Do."

[b] It is obvious from the photographs that the women of this region do not object to being seen by white men, and have apparently "posed" before the camera, which is another indication that there is a fundamental difference between them and the Cunas, as they are on the north coast.

CHOCO INDIAN WOMAN ABOUT YAVISA, CHUCUNAQUA RIVER DISTRICT, PANAMA.

CHOCO INDIANS ABOUT YAVISA, CHUCUNAQUA RIVER DISTRICT, PANAMA.

These Indians called themselves "Cholos," and I think may safely be considered Chocos. Cholo is a name applied to half breeds in many Latin-American countries, but these are obviously pure-blooded Indians, and it can easily be imagined that "Cholo" is a corrupted form of Choco. This explanation is further borne out by the following references from Bancroft, where the terms are used synonymously referring to the Indians of the section where the Chocos settled. Referring to "Seeman's Voy," Bancroft (24) says (in an appendix), "The Cholos extending from the Gulf of San Miguel to the Bay of Choco, and thence with a few interruptions to the northern parts of the Republic of Ecuador." Quoting from Latham in Journal of Geographical Society, London, Volume XX, page 189, is a statement, "Cholos inhabiting part of the Isthmus of Darien, east of the river Chucunaque."

A very interesting palm-wood stool and a cacique stick, measuring about 2½ feet, with a grotesque idol surmounting it and underneath bands of silver, was obtained in the deserted huts of these "Cholos" by the American to whom the writer is indebted for the two photographs of these Indians, appearing in this article. The cacique sticks are used by the medicine men among the Darien Indians generally, its magic effect is supposed to immediately follow when touched to the afflicted part.

CONCLUSION.

Panama is a land of wonderful possibilities, the home of an unambitious tropical people who have sat for generations at the gate of a world-traveled highway, watching the trend of progress as expressed in the passers-by. The small merchant of the towns in the main path of travel has developed a certain shrewdness, common to his class everywhere, in overcharging the wayfarer for his temporary needs, but the rest of the Isthmus remains much as it has been for centuries, half-awakened, sparsely settled, and in many parts semisavage or actually so. The necessities of life have come too easily, making progress very slow, but the day must come when a radical change will be brought about. Mr. Nicholas, in a magazine article in the Review of Reviews for March, 1904, says: "Panama is not without development in the present or promise for the future, even away from the zone of great expectations along the canal. * * * Minerals are in good evidence, government lands to be had for the taking around Chiriqui, Lagoon," etc. But the immediate interest in Panama should be its rediscovery leading to fields of research for the zoologist, biologist, ethnologist, etc., and it would, indeed, be regrettable if America, whose future interests in this country will be predominant, should not be first to send her scientists into this interesting and unexplored territory of Central America.

APPENDIX.

In chronological order, the following brief notes concerning the aborigines are extracted from the accounts of the principal men who have made expeditions into Darien (the dates of their published work being given only):

WAFER, 1669.

Wafer, who lived two years as hostage to the Cacique Lacenta, describes the Indians among whom he was as having a certain degree of civilization. They extracted gold from the mine in the Santo Espiritu Mountains, the chiefs wore long white robes with diadems on their heads and lived in comfortable houses surrounded by a railed-in area, and whose tables were well supplied with fruits, the results of the chase, and fish from the streams. Wafer was well treated by the Indians whose territory is thought to be in the vicinity of the source of the Rio Sabanna.

BORLAND, 1779.

Borland was a member of the Scotch colony which attempted to settle on the shores of Caledonia Bay and to share in the reported wealth of the New World. He described the Indians of the vicinity as small, great swimmers, living always by the rivers or on the sea, and very clean of body and in the preparation of their food, which consisted of dried fish, plaintain, and cassava, with a drink made from plantains. At first the Indians were very timid, then in a friendly way visited the colony, bringing fruits and fish to trade. It was not till the Spaniards attacked the settlement, inciting the natives to enmity, that the colonists had any serious difficulty with them. They used bows and arrows, and lived in houses without side walls, always sleeping in hammocks, with fires at night to ward off wild beasts and to keep from feeling the effects of the dampness. The men labored little, but hunted and fished. Men and women alike wore gold nose rings.

ACOSTA, 1848.

Acosta says that the Gulf of Darien Indians (and those of La Goajira), after 340 years have preserved much of their independence, primitive character and language, etc., as described by the early historians, still having their priest, medicine men, and seers, and painting their bodies. English firelock guns had already replaced in part, however, the bows and arrows, which they obtained in trade for tortoise shell and cocoa. During his stay among them he collected their words by which they counted up to eight; five were, "pogua," "pagua," "quencheco," "auvege," and "eugule."

GISBORNE, 1853.

Lionel Gisborne was an engineer sent out by an English syndicate to investigate conditions of Darien. He made an attempt to cross the Isthmus from Caledonia Bay to the Gulf of San Miguel, a region which he observes had been abandoned entirely to Indians since 1800. He speaks of a large settlement that was formerly composed of Spaniards and Indians on the Rio Sabanna (probably meaning the well-known one on the Chepo, as the marshy soil surrounding the greater part of the Savanna made it unlikely that a large number of Spaniards settled here and no other writers give any record of any such place). He observed that the San Blas and Mandinga Indians never allow any inspection

of their country and described coast tribes as follows: High cheek bones, short necks, set on high broad shoulders, though chest not deep; limbs small and well shaped and very muscular, with perfectly formed hands and feet. Their hair was long and black and neatly combed. Women wore necklaces of beads and nose rings. Noticed albinos among the Sasardis. Offenses against chastity punished severely. Indians of the interior much less civilized and he thought the number of them was large. Gisborne states that in 1852 the towns of Yavisa, Moleneca, and Chepigano were of considerable size, but were peopled, even then, by half-breeds entirely. He found it impossible to penetrate any great distance over the Rio Sabanna route where there was the densest vegetation and where animal life abounded.

Selfridge, 1874.

Admiral Selfridge, Lull and Collins, also other American naval officers, made extensive surveys in parts of Darien and in the Chepo district. Admiral Selfridge's report contains many notes on the Indians, chiefly the Sasardi, Sucubti, and Paya tribes. His force of men, well armed, was of sufficient size to minimize danger from the Indians, though the impression prevailed that a small force would have encountered active hostility.

Reclus, 1888.

Reclus, a French engineer, who worked with the French naval officer, Lieutenant Wyse, gives some account of the flora and fauna of Darien in his book, with also much information of the Indian tribes, especially the Payas, whom he described as having a certain state of civilization with much cultivated area, tilled by the women. The men were great hunters, and in the forests and streams were abundant game and fish, but even at that date they were drunken and improvident in many ways.

Restrepo, 1892.

In a prologue to Restrepo's book, written by his father, he states that his son was sent into the interior of Darien by "La Compania Minera del Darien," and calls it a rich and forgotten country. Restrepo was well received by the chiefs he encountered, but did not visit the Atlantic coast areas himself, apparently. He relates many curious customs of the natives, one, especially, for which he could find no explanation; he observed among the Payas, who gave their children, when in fits of crying rage, chica, in which a shaving from the door sill had been placed. Restrepo says that the warriors of the Isthmus adorn their heads with leopards' and tigers' paws, also that they wore yellow and black plumed head pieces. He speaks of the cruelty of the "Guamos" tribe, possibly meaning Guaymies, who were far famed for this attribute, and in another place he says "Guanes" are considered a section of the Chibchas. He also observed that Isthmian Indians were distinguished from those of Colombia in the old days by the enormous size of their bows and arrows. The full account of Restrepo's expedition is to be found in "Repertorio Colombiano, Bogotá, Nos. 11 and 12," under the title of "Un Viaje al Darien."

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CERAMIC DECORATION—ITS EVOLUTION AND ITS APPLICATIONS.[a]

By Louis Franchet.

Some author has said "The ceramic art is one of the most ancient of the world's arts. Its birth is lost in the shadows of time." It is into these deep shadows that we must first penetrate, but there is little fear that we shall lose our way, for glowing trails have been blazed for us by such men as Boucher de Perthes, Lartet, de Mortillet, Piette and others still, who have made prehistoric civilization known to us.

Among all the industrial arts, ceramics is of the most controlling interest when we wish to study the evolution of that artistic sense that has developed little by little among men.

To express the conception of his genius the potter must be at once a modeller, a sculptor, and a painter. He must also possess special faculties of invention and intuition so as to avoid the pitfalls scattered along his path, hazards which he meets at every turn in the preparation of his clays, in the working of them and above all in their baking.

The study of ceramic decoration is also of considerable importance in connection with the history of peoples, since it often affords a means of following the progression of great migrations and even discloses, as we shall see later, the very customs of the ancients. It is the ceramic art, even more than metallurgy, which enables us to more fully appreciate the degree of civilization of races which have gone before us.

We must look back, to be sure, several hundred centuries to find the first appearance of ceramic objects and we are struck with admiration as we examine the remarkable conceptions that emanated from the still primitive brain of man.

There are not yet in our possession any positive proofs that pottery was known in the paleolithic epoch, in the hewn stone age, but

[a] Translated by permission from Revue Scientifique, Paris, 47th year, No. 23, June 5, 1909.

in the era of polished stone which followed this, art was first manifested solely in the form of ceramic objects. The forms of prehistoric pottery evidence an extraordinary artistic sense in their designers. In spite of our schools of fine arts we do not equal them to-day. Our designs, so complicated and generally so ungraceful, as a general rule are only poor derivations and consequently mere alterations of these prehistoric designs. But we need not believe that it was the lack of all decorative material that suppressed ornamentation among primitive peoples. The plasticity of the clay itself pointed out the road to the first artists. The imprint of the potters' fingers gave birth to the intaglio decoration, and in the copper age succeeding that of polished stone, we find designs engraved by means of a cord, or a bit of wood or bone, or with imprints of the leaves of ferns or other plants.

After these engraved vases came the incrusted vases, with the intaglio design filled up with a white or a colored clay, a process in common use during the middle ages. The most beautiful of these specimens are the splendid faiences ascribed to Henry the Second, made at Saint-Porchaire (Charente-Inferieure) in the sixteenth century.

However, besides this, we find in the neolithic age an ornamentation made by gluing the bark of trees or small pieces of tin to the pot with a sort of pitch. During this long period, though civilization was more advanced than is generally realized, yet man was still in a half-savage state, and struggles between tribes were no doubt frequent. It is for this reason that the custom arose of building villages in the center of lakes to give better defense in case of attack. We have to-day proof that engraved ceramic ware was used for the decoration of the rude dwellings of these lacustrine villages. In the lake of Bourget (Savoy) have been found lining panels of graven clay still carrying the imprint of the wood partition to which they had been applied. At the same time were discovered the clay matrices which had been used to make certain of the intaglio imprints observed on the panels. These precious objects are deposited in the Museum of Chambéry.

Along with the graven and incrusted neolithic pottery we find also painted pottery, not painted with artificially prepared metallic colors, however, but with colored earths. This application of one earth to another to obtain an artistic effect was the beginning of the "engobe" which itself gave birth, many centuries later, to decoration with hard enamel, which we will now consider.

What is known as "engobe" is a layer of one sort of clay applied over another clay to conceal its color and to furnish a surface capable of receiving certain decorations. In "engobing" a piece of pottery it is plunged quickly into a paste made of the engobe clay or it may

be sprinkled with the clay. Over the engobe may be applied the colored pigments. Decoration by engobage was practiced in the most ancient times, but no race took such a remarkable part in its development as the Greeks and Etruscans, who produced the greatest artists ever known in the art of fired pottery.

From a technical point of view the only feature that demands attention here is the fact that they had the skill to introduce into these engobes materials sufficiently fusible to give a true glaze to the work, and that with only three colors—red, brown, both iron colors, and manganese black—they have inscribed on their vases the entire history of ancient Greece.

The Greeks have always been our teachers in the practical utilization of ceramic decoration. Their most ancient pottery, it is true, bear only elementary designs painted with colored clays, but little by little there appeared representations of fabulous animals, then the great scenes that enable us to construct ideas of their life, customs, and religion, both from the nature of the forms and from the inscriptions and the scenes which they portray. In a word, here we find the utilization of ceramic decoration carried to the limit of perfection.

Etruscan pottery offers examples quite as remarkable. Then there are the celebrated Roman potteries, about which certain archeologists have advanced the most unlikely hypotheses to explain the famous red luster which covers them. It is to chemistry that they should have turned to find the solution of the problem, for it is chemistry that has revealed to us the fact that this luster is a true enamel which the Roman potters made by mixing a strongly ferruginous clay of rock with a glass composed of sand and carbonate of soda with small quantities of alumina and lime.

This red enamel of the Romans is therefore derived directly from the "engobe." It was applied to the unbaked piece and was consequently baked at the same time as the clay base itself, the temperature being comparatively low, about 900°.

It is pretended that we do not know how to duplicate this beautiful red; nothing, however, could be more incorrect. We have a rock, the sandstone of Thiviers (Dordogne), which, when mixed with a glass, or, more correctly speaking, a frit rich in silica, gives us exactly the same enamel that we admire on the Roman pottery.

In this field we are even more advanced than were our predecessors, for we can vary at will this red tone from an orange shade all the way to brown. All that need be done is to add to the glass (or frit) certain elements such as alumina, boric acid, borax, or zinc oxide, the proportions of which can be infinitely varied.

The Romans, however, abandoned ceramic painting to devote themselves entirely to sculpture. Their vases ornamented in relief,

their statuettes, even without other monuments, would show them to us as masters of sculpture. But where the Roman plastic art manifests itself most strikingly is in the use of fired clay in the decoration of their temples and palaces. Their historical antefixes and bas-relief are chefs-d'oeuvre, after which our famous art nouveau appears quite ridiculous.

The Greeks and Romans had learned the technique of glazes in Egypt, which, after the defeat of Darius the Third by Alexander the Great, fell under Greek domination, only to pass, three centuries later, into the hands of the Romans. But they no doubt wished to make the clay alone responsible for the disappearance of ceramic art.

As I have shown in a former paper, it was the Egyptians and not the Phœnecians who in their discovery of glass in the eighteenth dynasty also discovered the art of glazing. As a matter of fact, what is a glaze but a transparent glass formed of silica and potash or soda and the more lately discovered oxide of lead?

Enamel is glaze rendered opaque by oxides of tin, antimony, chromium, and sometimes of iron, an example of which we have seen in the Roman pottery; covered glazes are those which are only applicable to vitrified clay, such as stoneware and porcelain, in making clay articles.

The discovery of glazing did not completely supersede the use of engobe. This was overlaid in many cases by a glaze, as is proved by a great many antique oriental ceramic objects.

In the beginning, the first Egyptian glazes were composed entirely of quartzeous sand and carbonate of soda. Later, however, in the Saite epoch, perhaps because of their contact with the Persians, the Egyptians came to know all the numerous enamels that we are cognizant of to-day.

It is in the Orient, however, that we should look for the most beautiful manifestations of ceramic decoration and for the complete comprehension of the science of colors. Not only are we very inferior to the ancients in these respects, but it would appear that as our scientific progress becomes more accentuated art seems to become more and more feeble. The enameled ceramic ware of the Orient is the most beautiful that human genius has conceived, and I would even say the most grandiose if we considered the monumental ceramic pieces. It embodies the successful solution of all those difficult problems which confront the potter in his struggle for perfection—the form, design and coloring, the working of the clay, the application of the enamel, and the firing. Our famous faïences of Palissy, of Nevers, of Rouen, of Moustiers, and of Marseille, not to mention those of Italy and Holland, are but child's play by the side of these works of genius carried out by the Egyptian, Persian, and Arabian ceramists.

There was a reflection of this art in Spain from the thirteenth to the fifteenth century because the Spaniards had brought back with them the skill in ceramics which they had acquired in Asia. There the Arabs first carried out the process of applying enamel over an "engobe," a practice which persisted up to a time when the use of white opaque enamel had passed into the current technique.

Again, it was the Mohammedans who brought from Persia the process of decoration by metallic luster, which consists in applying deposits of copper and silver on the enamel giving the effect of fleeting iridescence. This was carried from France to Spain in the fourteenth century and into Italy in the fifteenth. With respect to the latter country it would be more correct to say that the Italians went in search of these processes among the Moors in Spain.

After being in disfavor for three centuries, decoration by metallic luster reappeared in France, at Blois first, in 1876, then on the Gulf of Juan-Vallauns in 1882, where it was introduced by the Italians.

As for the pretense that the process of decoration by metallic luster was a secret one, I have elsewhere shown that this is not a fact because this process has never been completely abandoned. Sometimes more and sometimes less of this luster pottery has been made, but in the last ten centuries the manufacture of it has never ceased.

During the middle ages, when the manufacture of enameled pottery was at its dawn in France, the making of lining tiles occupied the most important place in the art. In the twelfth century they were content to apply a white engobe to tiles made of red clay, and then to cover the engobe with a glaze consisting solely of galena, a natural sulphide of lead, or even merely to coat them with finely divided lead, which oxidizing under the double influence of the heat and the oxygen of the air is transformed on the tile into a fusible oxide of lead, making a true glass of a yellow color.

In the thirteenth century, inlaid ceramic ware appeared to have been in great favor. The tile of red clay was molded in such a way that the design appeared in intaglio; this was filled with a white clay and then enameled either with the yellow lead glaze or with a green glaze of copper. In either case the ornamentation in white clay stood out clearly in tone under the glaze after firing, while the base formed of the red clay retained its very deep tones.

This manufacture was kept up until the seventeenth century, making use principally of three colors, yellow, green, and brown, blue being sometimes used.

The utilization of lining tiles for architectural decoration had developed to an even greater extent in Spain, where the oriental influence had dominated to the end of the fifteenth century—that is, until the Moors were driven from the Peninsula by Ferdinand the Fifth.

In the sixteenth century, when opaque white enamel first made its appearance in current practice, it was substituted for the engobe, so that instead of decorating with crude engobe they decorated over crude enamel. This was first applied to the piece, the decoration was painted on it, and it was fired at 900° C. The enamel, in vitrifying, incorporated with it the color, giving tones of great softness. As examples of painting on crude enamel, may be mentioned the beautiful majolicas of the Italian Renaissance, the faïences of Nevers, of Rouen, of Moustiers, which are Italian products, and finally of Delft.

In the fifteenth century the Italians were familiar with most of the colors and enamels which we use to-day, as well as with the metallic lusters. The processes had become widely known among them and it is their formulæ which have furnished a basis for all our modern discoveries in polychromatic decoration. For this reason, when Bernard Palissy began the manufacture of his celebrated ceramic ware, he had only to make use of the enamels which were employed in the Latin countries. One can not take him seriously, therefore, when he puts himself forward as the inventor in France of enameled faïence. He wished us to believe from his incredible statements that there had been no ceramists before him (which, by the way, is still the fashion in our day). In any case, he made a great mistake in burning his furniture and reducing his family to beggary in order to discover that which the humblest potters of his time already knew.

The Italians during their great artistic Renaissance had imitated the ancients in giving to their beautiful decorations a utilitarian purpose. Each form not only corresponded to its determined purpose, but the decoration was appropriate to the use to which the piece was designed. They had, for example, small round dishes which were filled with preserved fruit and sent to young maidens on festival occasions. The painting on these generally represented love scenes. Certain curious vases were offered exclusively to women soon after confinement. These singular pieces could be separated into six or seven parts—spoon, bouillon cup, egg plate, etc.—which after having been used were placed in the original order, so as to reconstruct the vase. These were decorated with allegorical subjects representing all the gods and goddesses of love. The same idea was carried out in all their other utensils. Thus, on their washstands we find tritons, nymphs, and marine scenes. The fruit dishes were decorated with agricultural scenes. It is well known that their architecture was largely derived from the ceramic art.

There existed in France at the period when Bernard Palissy was alive a form of decoration quite as remarkable as his, as remarkable because it denotes in its originators a really novel conception in the

way of inlaid ceramic ware. This is the decoration of the Saint Porchaire faïences.

Instead of making large inlaid ornamentations of archaic design such as were made in France during the twelfth century, the artists of Saint Porchaire ingeniously conceived the idea of filiform inlays, offering extraordinary difficulty in the way of execution, entirely different in this respect from the faïences of Palissy.

The faïences of Saint Porchaire are of yellowish color with incrustations generally colored brown by oxides of iron and manganese, and are enameled with a colorless glaze.

Painting on rough enamel such as was practiced in Italy and later in France has one feature of great inconvenience in that since the crude enamel is very fragile, the artist can do no retouching. At the beginning of the eighteenth century a new sort of technique was adopted. The enameled piece was baked at 900° and after this baking the design was painted with colors rendered fusible by the addition of a flux, which is a glass melting between 600° and 800°.

The colors prepared by mixing a color producing oxide and a flux are applied over the previously baked covering and are then submitted to a special firing at a low temperature, say 650°. These colors when they become vitrified adhere to the enamel and attain a brilliant hue. This form of coloring is called decoration with vitrifiable colors. The best-known ancient faïences decorated by this process are those of Strasbourg, Lunéville, Saint Armand, and Marseille. These vitrifiable colors were first applied to the decoration of soft porcelain, and afterwards to hard porcelain, on which it was almost exclusively used during the nineteenth century at Sevres, Berlin, and Meissen. They were abandoned in the art when decoration under the glaze appeared nearly a century ago. This latter form of decoration consists in applying infusible colors reduced to an impalpable powder to the unenameled piece, or in other words to the paste after it has been baked. This is then covered with a transparent glaze. All the earthenware which is manufactured to-day for table use is decorated by this process. The temperature at which the faïences are baked never exceeds 1,070°, so that all the known metallic oxides can be used in this decoration. This is not the case in porcelain decoration, which must be subjected to a temperature of 1,400°. The number of colors that can resist this high temperature is extremely limited; they are the cobalt blues, the chrome greens, the roses and reds obtained from the grés (sandstone) of Thiviers, the yellow from nickel, the brown from iron and manganese, the gray of platinum, and the rose of gold. At this temperature a very beautiful yellow may be obtained with uranium oxide, which requires a highly oxidizing flame. The straw yellow obtained by the use of titanic acid is somewhat pale in tone.

It was the Royal Manufactory at Copenhagen which, in 1885, first demonstrated the advantage obtained by the decoration of porcelain at a high temperature (1,400°).

The factory at Sevres followed it in this process and with very great success, for it had possessed for a long time the knowledge of the decoration with colors at high temperatures, which had been investigated there long before it had been carried out at Copenhagen. Sèvres possessed a range of tones much more vigorous than those in use at Copenhagen, as may be observed by comparing the products of the two establishments.

I must now take up the subject of stoneware (grés), to which Brogniart has added the name of cérame to distinguish it from the natural grés (sandstone) which is that abundant rock, certain hard varieties of which are utilized in making mill stones and paving blocks.

I may first mention the fact that there are four classes of ceramic products, earthenware, faïence, stoneware, and porcelain. The first two are made of unvitrified paste and are consequently porous. The other two are of vitrified paste (after baking of course) and are impermeable.

Porcelain is the most beautiful of all these ceramic products, but its very high price largely limits its use. However, as vitrified clay articles are much superior to the unvitrified, in the last twenty years stoneware has been accorded a most important position.

At the same time that stoneware was adopted into the art a special decoration was applied to it, consisting of covered colors obtained by the mixture of a coloring agent with a colorless covering.

Stoneware is baked at 1,250° at most, at a temperature consequently much lower than porcelain. No faith should be given to the assertions of certain ceramists who pretend to bake their stoneware above the temperature I have just indicated, some of whom talk temperatures as high as 1,800° to 2,000°.

Others do not hesitate to claim that the manufacture and decoration of stoneware are much more difficult than with porcelain. I hear this absurdity continually repeated, but I am sure that experience would lead them to a change of mind in this regard.

In considering the question of stoneware, the idea came up of resuscitating an old color discovered in 1792 by the German chemist Klaproth. This is the color based on titanic acid. Titanic acid is met with abundantly in nature, associated to the extent of 2 or 3 per cent with oxide of iron. It appears in the form of a red crystalline mineral called rutile. One of the most remarkable properties of rutile is that it gives a mat finish to covering layers in which it is incorporated. These mat finishes have been declared the supreme perfection in ceramic decoration, though no one will

admit that, while they suit certain circumstances, they are deplorable in many others. A mat finish can be obtained with great facility with all shades without exception, but there are three which have been adjudged worthy of serious consideration. These are the brown mat finish obtained with rutile; the green obtained by combining rutile with cobalt oxide; the gray blue obtained in the same way as the green, but by the use of a less proportion of cobalt.[a]

The introduction of mat finishes in ceramic decoration filled a long-felt want. They are necessary because they make possible the use of certain motifs of sculpture that lose much of their character with brilliant glazes. The best things should not be abused, however. The mistake has been made of applying mat finishes to everything, notably in architecture. The Sèvres manufactory has set the example, as, indeed, it may well do, since it is our great national establishment for ceramic study. That factory was responsible for the construction of the immense portico of stoneware with a mat finish seen to-day in the square of Saint-Germain-des-Pres in Paris. This sample of modern ceramic architecture bears witness to our inferiority to the Orient, where they use brilliant enamels exclusively with a skill that might well inspire our architects and ceramists. Paris to-day numbers several edifices of mat stoneware. Let us hope that they will not be multiplied.

The tones communicated to glazes and covering layers by metallic oxides are, from the standpoint of coloration, closely dependent on the nature of the atmosphere of the kiln. The flames that come from the hearth of a kiln and penetrate into the firing chamber, inclosing the articles to be fired, are possessed of different properties according to their composition. They may be oxidizing, neutral, or reducing. A flame is oxidizing when it is saturated with oxygen derived from the air and contains not only an excess of carbon but an excess of oxygen. Under these conditions it is blue in color. A flame is neutral when it contains neither carbon nor oxygen in excess. It still has a blue tint, but this is less intense than in the preceding case. A flame is reducing when there is a lack of oxygen in it and it is saturated with carbon. It is then yellow in color. It is therefore easy to understand that these flames, having different compositions, will exert considerable influence on the colors which may be submitted to their action. The ceramic ware which we usually see is fired with an oxidizing flame.

Two kinds of decoration may be obtained with a reducing fire; one at a low temperature, the other at a high temperature. The decoration with a low temperature is represented by the faïences

[a] All the formulæ for mat finishes have been published many times, and are known to-day to all ceramists.

with metallic luster. To obtain these scintillating deposits, whose process of manufacture I have described several times, it is only necessary to apply to the glaze after it is fired a copper salt—oxide sulphide, oxalate, or the like. The piece is then heated to a dull red (about 550°) and afterwards submitted to the action of reducing gases. These iridescent tones may be varied by the addition of salts of silver and bismuth, but I have previously shown that the brown, yellow, golden, or red shades of metallic deposits are not due, as heretofore believed, to the nature of the mixture of oxides, but to the duration of the reduction.

The copper red, called rouge, flammé, or flambé, is fired in a reducing flame, not at a low but at a high temperature. At the present time, it is true, the public has been so misled by ceramic fairy tales that they are completely ignorant as to what these flamed pieces are. As a matter of fact, when a particular vase has little value, and is consequently difficult to sell, they embellish it with the description "flammé de grand feu" (flamed at a high temperature), demand quadruple the actual worth, and almost always then find a purchaser. Everyone seems to possess a peculiar mentality that leads him to see something wonderful in the simplest things. He is easily led astray by these ceramic fables, for the art to him is secret, of fearful temperatures, and of mysterious manipulations worthy of the most somber epochs of the middle ages. These fables are a relic of Bernard Palissy, who had better never have written his Art de terre.

Many imagine that these flame effects can not be obtained except on stoneware. This is again an error; they are even more beautiful on porcelain on account of the whiteness of the clay.

The term flammé applies exclusively to that beautiful red finish, with a copper base, which generally shows vertical striations due to the variable intensity of the coloring material. These variations of tone are a result of the action of the reducing gases, which contain zones in the interior of the kiln which are not all saturated in the same degree with carbon dioxide or hydrocarbons. This is clearly indicated by the fact that on a vase colored with this copper red are frequently found greenish or bluish parts, and sometimes even palpable greens or blues showing an oxidizing action, and brown and black parts produced by a more intense reduction than that causing the vivid reds. These peculiarities show that there evidently exist varied zones in the kiln, some oxidizing, some neutral, and some reducing, the latter of course being the preponderating element.

These rouge flammé coverings may be either brilliant or mat; the former, however, are incomparably more beautiful than the latter. To obtain a mat red a large proportion of alumina (in the form of kaolin) or lime (in the form of chalk) must be introduced into the

covering layer. By a large proportion I mean from 20 to 30 per cent. The covering should be applied to the piece in a very thin layer, however, 2 millimeters at most.

The reduction should be an energetic one, and in this connection I have observed that this can be controlled by the proper regulation of the draft damper. The constructors of kilns have gotten into the bad habit of placing this directly over the grates, and I have noticed that such a practice is injurious to the proper operation of the kiln, while if the regulator is placed at the base of the chimney, which surmounts the dome, the draft is perfectly even; it can then be regulated in such a way that the interior atmosphere may be rendered at will either strongly oxidizing or strongly reducing.

In an oxidizing fire a lead glaze with copper acquires that vivid green tone which has always been very popular among primitive peoples, and which is still in general usage in the north of Africa—for example, in Algeria and Morocco, in spite of constant contact with France—in Italy, and in Spain. An alkaline covering (rich in potash and soda) acquires a remarkable blue tone (Egyptian blue), to which may be given a greenish tinge by the addition of lead. This gives a turquoise tone.

In a reducing fire the green glaze, the blue glaze, or the turquoise become red, but the last is alkalino-plumbous and will always give a much more beautiful red than one containing only lead.

With this red I have associated the titanium blue. We have seen that rutile, natural titanic acid, gives a yellow or brown-yellow in an oxidizing fire. Under the influence of reducing gases, the titanic acid passing over into the blue sesquioxide of titanium is an important feature in the decoration of the flamed pottery. This titanium blue has the remarkable peculiarity of preserving its blue tone in artificial light, instead of appearing brown like the cobalt blues, or green like the copper blues.

When the copper red and the titanium blue are combined on the same piece, violet would ordinarily be expected, but each color keeps its own shade. Violet can nevertheless be produced as I have observed in extremely rare cases, an effect due, perhaps, to particular conditions of reduction that escaped my attention in the firing. Violet tones in the flamed ware can be easily obtained, however, by combining the copper red with the blue of cobalt if the latter is not added in too great excess.

Finally, I have obtained some curious modifications of tone by combining copper, sesquioxide of titanium and glucinum. (I say copper and not oxide of copper because, according to the theory of Ebell, the coverings are colored red, not by the oxide but by the metal itself.) I introduce the glucinum in the form of silicate, conse-

quently as emerald, using the emerald of Limousin, which is nearly white because it is free from the chromium oxide present in the green emerald used in jewelry; an oxide which is really an impurity.

To sum up, ceramic decoration in a reducing fire makes it possible to obtain effects which are totally unknown in decoration by an oxidizing firing. The colors obtained by reduction possess a considerable power; they are not due to chance, as certain ceramists declare, but they are determined by true chemical reactions between the metallic oxides and the products of combustion. We have not yet mastered them, it is true, for the study of them is only roughly sketched out, and if I have been able to determine the exact conditions under which copper red can be obtained at will it is only the result of a considerable number of observations.[a]

Decoration with a reducing flame offers a vast field for research which I believe will reveal some absolutely new facts.

In this brief study of the evolution of ceramic decoration I think I have demonstrated sufficiently the truth of the statement I made at the beginning; that is, that this art has been intimately connected with the history of races since the origin of humanity.

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[a] I can not enter into all the details of the production of copper red. I have recently written an article on this subject which appeared in the Transactions of the English Ceramic Society, vol. 8, p. 71 (on the development of copper red in a reducing atmosphere).

SOME NOTES ON ROMAN ARCHITECTURE.[a]

[With 4 plates.]

By F. T. Baggallay, F.R.I.B.A.

Roman buildings, after remaining for three centuries the sole inspiration of the architects of all Europe, have for a long time now received far less attention from English students than is their due, whether they are judged on their merits or by the fact that they are the direct ancestors of all such modern architecture as can claim ancient descent.

Our attention has lately been directed once more to Roman work—first, by the fact that when last English architects examined it they were content to look at a part only, and hardly went below the surface even there; secondly, I think, by our growing acquaintance with M. Choisy's illuminating work on Roman building methods; and, lastly, by a half hope that, as the Imperial Roman system of construction was largely a monolithic concrete system, it may contain some suggestions for dealing with ferro, or reenforced, concrete: all the more since Roman concrete was almost always itself in a sense reenforced with brickwork. It is true that to call the brickwork used with concrete by the Romans "reenforcement" is somewhat misleading; at best it has but little resemblance to what we call reenforcement now; and much is merely centering or facing. On the whole, however, the cause for paying special attention at the present time to Roman architecture is strong enough, I hope, to excuse me for bringing the subject before you, although I have no fresh information and little new to say about it. I should like to treat it historically; for, although the dry facts connected with an architectural style or system of building can be learned without reference to the historical point of view, they can only be really interesting or fruitful when seen in chronological sequence and in connection with the circumstances that molded them. Without the help of history we see only the effect and not the cause,

[a] Read before the Birmingham Architectural Association, February 19, 1909. Reprinted by permission, after revision by the author, from Journal of the Royal Institute of British Architects, London, third series, vol. 16, No. 20, October 16, 1909.

and without perceiving both we get at nothing that is of much real use to us.

A good history of Roman architecture has yet, however, to be written; and there are some difficulties in the way of writing it which are surprising if we consider only how many remains still exist and how much we know about Roman history and civilization in other directions. The difficulties are the paucity and architectural unimportance of existing remains that can even probably be assigned to periods before the establishment of the Empire, the frequent difficulty in dating with certainty the existing remains in Rome of later structures, and the entire absence, in most cases, of definite clues to the dates of provincial buildings. The first two difficulties are largely due to the building activity of the first two centuries of our era, which led, with considerable aid from fires, to the repeated partial or complete reconstruction of almost all important buildings in Rome.

The uncertainty of the chronology of Roman architecture was somewhat violently illustrated only a few years ago. In 1894 M. Chedanne, a young Frenchman, seizing a favorable opportunity, was able to show that the rotunda of the Pantheon is not the building erected by Agrippa in B. C. 27, as had generally been supposed, but almost certainly a structure of the time of the Emperor Hadrian; quite certainly not earlier, for all the bricks which he extracted at random from various parts bore stamps known to be of that reign.[a]

This discovery removed the principal witness to the extraordinary fact, hitherto always assumed, and often asserted in so many words, that the Imperial Roman system of brick and concrete construction sprang suddenly into existence fully developed in the reign of Augustus, and endured, virtually unchanged, for nearly three and a half centuries. M. Choisy himself, in a short chapter[b] labeled—perhaps in irony—"historical," spent much language in enlarging on the unprecedented and surprising nature of the thing; but he insisted nevertheless on the sudden rise of the system, its almost as sudden abandonment, and the absence of growth or development between.

M. Choisy, like others, evidently compared the Pantheon with the writings of Vitruvius, who must have published them at just about the time it was being built, yet was obviously entirely ignorant of any methods of building nearly so advanced; and instead of finding what now appears to be the obvious solution of the puzzle—namely that the date assigned to the Pantheon was a mistake—M. Choisy accepted the date as others had done and arrived at the only conclusion then possible—namely that the incredible had really happened, that the system on which the Pantheon is built had just sprung suddenly into existence, and that Vitruvius was a poor old fellow far

[a] R. I. B. A. Journal, 1895, 176–177. [b] L'art batir, Part 3, chap. 1.

behind his times and grossly ignorant of what was going on around him. Unless we believe this of Vitruvius it is impossible to suppose that walls faced with burnt brick were common, if they existed at all, in the earlier part of the reign of Augustus. It is true that in a passage[a] in which he is supposed to be quoting a law then just promulgated he mentions burnt brick as one of the materials allowed to be used for ground-floor walls in Rome. (It is a passage that reads rather like a later insertion, but that need not be insisted upon.) But he nowhere mentions the triangular bricks used in all known remains of Roman brick facing, and in the long chapter in which he describes minutely the various kinds of walls he not only does not mention brick facing at all, but says that opus reticulatum—a facing of small blocks of stone—was what everyone was then using—"quo nunc omnes utuntur."[b]

There is one piece of Roman brickwork, the basilica at Pompeii, which Overbeck in his great work on the town put down to 93 B. C.[c] and which others, on the strength of a date said to be scratched on the building, have attributed to the consulship of Lepidus and Catulus—that is, 76 B. C. But such dates are most improbable. The work is beautifully executed with molded bricks (pl. 1, fig. 2), in a style which one can not suppose to have been possible at such dates, but would be quite natural if the basilica had been rebuilt after the earthquake of A. D. 63, which, according to the contemporary evidence of Seneca, threw down a great part of the town.[d]

Without admitting that because one doubts whether the Romans used brick-faced concrete quite so early as has been supposed, one is therefore obliged to point out when they did begin to use it, it may be suggested that the upper part of the ruins of Caligula's palace, and the original part of the wall of the prætorian camp in Rome, which Doctor Middleton succeeded in distinguishing from later additions, are the earliest works of the kind of which considerable remains exist. From Middleton's description[e] the latter wall must have been a very fine piece of work—better even than that executed under the Flavian emperors, and he attributed it to the time of Tiberius, when the camp was first established by Sejanus in A. D. 23. Dean Merivale says the wall was not built until two centuries later, but he was probably thinking of the work of Aurelian, who, as Doctor Middleton shows, merely raised it. The latter's supposition that the wall was built at once upon the establishment of the camp is not, however,

[a] Vit., II, 8, 17. The text by Rose and Müller-Strübing, Leipsic, 1877, is used throughout.

[b] Vit., II, 8, 1.

[c] Overbeck, Pomp., 121.

[d] Sen. Quaest. Nat., VI, 1. See also Tac. Annales, XV, 22 and 34.

[e] Remains, II, 233 et seq.

necessarily correct. The mere establishment of the camp was sufficient for the purposes of the moment, and to fortify it permanently at once would have been to further alarm the people of Rome without adequate reason. The coin, too, of Claudius on which the camp is pictured appears to show a timber fence rather than a brick wall. On the whole, it seems quite likely that the wall was not built before the time of Claudius, or even Nero. With regard to the other example also, the works are immense, and if completed by Caligula must have been built in three and a half years at most. There is nothing improbable in supposing that part of the palace to have been completed by Claudius; and there is a distinct difference of system between the lower and upper parts of the work, the lower being of opus reticulatum with brick quoins and arches only. One part of the ruins of Nero's "Golden House" Doctor Middleton also describes as being faced with brick, and another with a mixture of opus reticulatum and brick [a]—that is no doubt with brick quoins. It would be rash to entertain a positive conviction opposed to the generally accepted opinion, but it seems possible we may eventually discover that though fired building bricks were gradually coming to the front from the middle of the first century B. C., and may have been given a certain impetus by the metropolitan building act of Augustus, their use in the place of stone for entire wall facings did not become general before the time of Nero. If that should be so, we may perhaps also find that the system of building concrete vaults with a lacing or framework of brick did not reach its final development before the middle of the second century of our era.

With respect to Roman concrete, I should like to enter a protest against the indiscriminate use of the term by Doctor Middleton and other writers, who apply it even to the walls called by Vitruvius incertum and reticulatum, in opposition, as it seems to me, to what Vitruvius himself tells us. It may be merely a question of a definition, but if a writer has one definition for a thing and his readers another, he becomes misleading. Doctor Middleton argues for the word concrete because "the result was a perfectly coherent mass, like a block of stone, particularly unlike what is now usually known as rubble work." [b] But to the professional reader the difference between concrete and rubble work is not one of result, but of the way in which the result is obtained—the results by either method may differ as chalk from cheese. The doctor himself acknowledges that in the examples he examined the larger stones were placed with so much regularity that they must have been thrown in separately. He arrived at the conclusion that thick layers of mortar, mixed with small stones, and layers of larger stones, were thrown in alternately.[b] When this

[a] Remains, II, 148, 149.

[b] Ibid., I, 47.

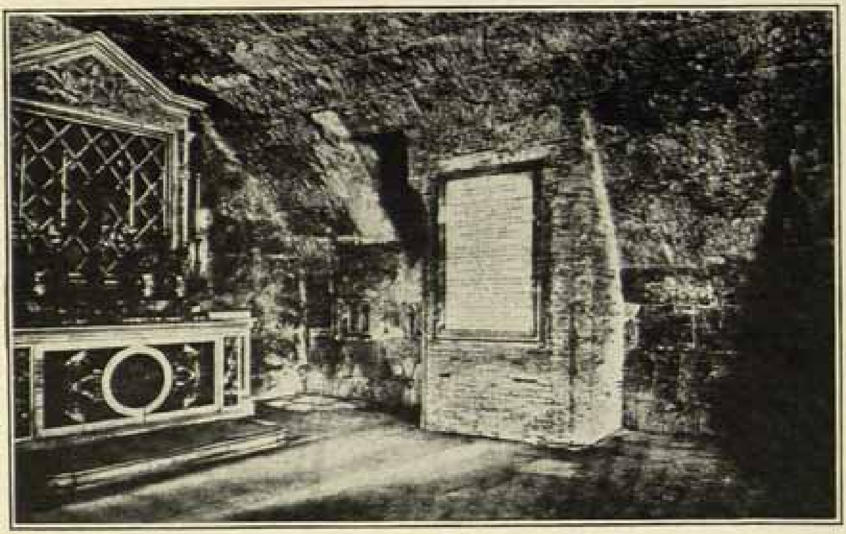


FIG. 1.—VAULT OF THE MAMERTINE PRISON.

FIG. 2.—BASILICA, POMPEII.

All the columns are of brick covered with hard stucco (Opus albarium).

was done in trenches in the ground, within wooden molds, of which he found distinct marks on certain walls, or between two built faces, as described by Vitruvius in speaking of wrought stonework,[a] one may very well admit the term concrete, even though the regularity of the larger stones suggests that they were laid in by hand rather than thrown in (pl. 3, fig. 1). But Vitruvius never by so much as a hint suggests the use of "false work" in his time. He tells us, and the appearance of the walls at Pompeii, for instance, bears out the description, that opus incertum consisted of rough quarry stones, "one over the other bonded together"[b]—in fact, a rubble wall, built, no doubt, with a larger quantity of mortar than we use, but built, not cast. Opus reticulatum he does not describe in detail, but evidently regards as a fashionable variety (which he does not altogether approve) of incertum.[c] As a matter of fact, it would not be possible to cast a wall faced with opus reticulatum, and would be very difficult even to build it behind boarding, especially the weather boarding, of which Middleton found traces. The facing was of small conical stones with square heads, which were required to fit neatly together on the face; to set them inside boarding a man must have worked overhand and without seeing what he was doing. Without the boarding, however, there would be no more difficulty in building such a wall than in building a flint wall with split facing; and there can be little doubt that that is how it was done. It must, however, have been slow work. One knows how necessary it is to go slow when building with flint or small rubble in lime mortar. After getting a foot or two one must wait for the mortar to set before putting more weight on, otherwise the work will bulge and twist. Now, mortar made with pozzolana, such as the Romans used, though it eventually gets extremely hard, does not in the first few days set appreciably faster than good lime mortar; and the Romans used it in large quantity. If one may venture to guess, it was this slowness that led after a time to the introduction of false work to support walls while in course of erection. It seems nearly certain it was unknown in the early years of the reign of Augustus, but it may have been introduced soon afterwards. The building activity of that reign was unprecedented, and would probably have demanded methods quicker than the old. On the other hand, most of the remains of the time are of squared stone or very neatly executed opus reticulatum, which can not have been built behind false work (pl. 2). Middleton's

[a] Vit., II, 8, 3.

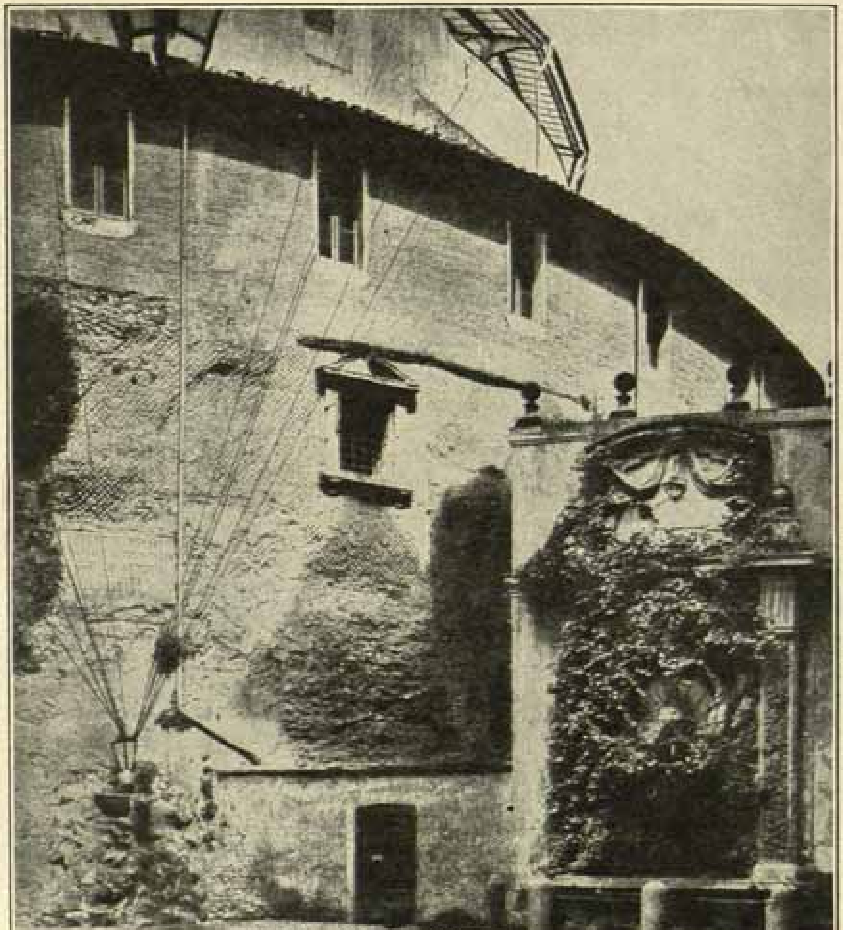
[b] Vit., II, 8, 1.

[c] The way in which a contrast is set up between the two, sufficiently excuses Doctor Middleton, as an amateur of building, for the mistake he makes in regarding incertum as applying, like reticulatum, to the facing of the wall only. There can be no doubt about the real meaning of the passage.

earliest dated example of the evidence of false work is part of the foundations of Caligula's palace,[a] and he mentions[b] also a facing of opus reticulatum and brick, which may very well be of the same period, as being very roughly executed, which would be natural if an attempt had been made to apply the new discovery to a purpose to which it was not suited.

In the matter of arches and vaults, the later Romans believed that they had learned the art of building them from their old neighbors and enemies, the Etruscans; and probably they did, though it is easy to see that the character of the materials they had at hand was such as to favor an arched system, while the nature of the site of Rome and the surrounding country suggested the construction of drains and aqueducts, in which arching, to say the least, came in very usefully. The history of Roman architecture in early and Republican times may, perhaps, never be recovered. The difficulties in the way of excavations are great, while, owing to the continuous occupation of sites, the results rarely throw much light on early work. There are some remains of early walls of that squared and bonded masonry which Vitruvius seems to have thought was one of the things Roman architects had borrowed from the Greeks,[c] and we may assume as certain that, like the Etruscans, the Romans early used the arch to span gateways. But we do not know how soon they began to put the arch to other uses, and the extent to which vaulting was developed, before it was taken up by the architects of the imperial period, is not altogether clear. The little dome over the ancient subterranean chamber, called the Tullianum in Rome, is built of cut stone in horizontal courses, and M. Chedanne declared[d] that the dome of the Pantheon is built entirely of brick in the same way—that is, in horizontal courses. If he was right, it would seem to indicate that even in the reign of Hadrian the Romans had not arrived at our conception of domes as developments of the arch and dependent for their stability on much the same forces, but they regarded them as systems of corbelling. The chamber above the Tullianum, called the Mamertine prison, is, however, roofed with a small barrel vault neatly built with stone voussoirs (pl. 1, fig. 1). Its date is uncertain except that is very early Republican. If Vitruvius knew how to build a vault at all, it is surprising that he did not give instructions in the art in a work which he evidently intended should cover the whole field of building and in which he deals with so many smaller matters. In the chapter on baths[e] he twice mentions Cameræ, that is,

[a] Remains, I, 196.
[b] Ibid., II, 149.
[c] Vit., II, 8, 7.
[d] Op. cit.
[e] Vit., V, 10.



OPUS RETICULATUM IN THE MAUSOLEUM OF AUGUSTUS, SAID TO HAVE BEEN BUILT IN 28 B. C.

arched ceiling, over the hot rooms and twice the hemisphere over the semicircular recess in which the labrum was placed. But he implies that the arched ceilings would not usually be structural ones. He says "they will be more serviceable if built," but not how that is to be done, and proceeds to describe[a] as an alternative a ceiling of "roofing tiles without margins" laid on iron rods or arches hung to a timber framing.

The still existing barrel and hemispherical vaults over some of the rooms in the public baths at Pompeii are often quoted as of the republican period, but their date is very uncertain. From illustrations it would appear that they are entirely of concrete or rubble without brick, but the walls of the rooms are shown as having brick piers and lacing courses, which, according even to Doctor Middleton, would make them not earlier than the last years of the reign of Augustus.[b] The oldest important Roman vaults to which a date can be assigned with tolerable certainty are those in the building called the Tabularium, erected against the face of the Capitoline Hill, on the Forum side, probably in B. C. 78. These are narrow barrel vaults of tufa concrete strengthened in one part at intervals with arches constructed with stone voussoirs, and partly, perhaps, resting on them. The next are those of the substructures of Caligula's palace, which, if not quite so old as Caligula's reign, must be older than those of the Colosseum. Middleton says they are cast concrete.[c] Then come the vaults behind the two lower ranges of arches of the Colosseum (pl. 4), which must have been erected between A. D. 70 and 80. These are barrel vaults constructed with brick arches at intervals, between which they are of concrete, on the lower surface of which the marks of boarding are still visible. All the more elaborately constructed vaults illustrated by M. Choisy are of the second century or later.

To turn from the history of construction to other matters: There is other evidence, besides that of Vitruvius, for the fact that the Romans acknowledged their indebtedness to the Etruscans for the form of their early temples, which appear to have had tree trunks for columns, widely spaced, and carrying wooden architraves. The cella walls were of rubble or unburnt brick, stuccoed over, and no doubt terminating opposite the columns of the prostyle portico in timber antæ. The roof was of timber, covered with terra-cotta tiles; a terra-cotta cornice and ornaments were fixed round the eaves and sometimes, at least, terra-cotta or bronze statues ornamented the tympanum and the ápex of the pediment. All was crudely painted in bright colors. Judging by a custom of later times, which must be

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[a] Vit., V, 10, 3. [b] Remains. I, 54. [c] Ibid., p. 196.

mainly due to tradition, the whole structure was probably raised on a high base or podium, perhaps to lift it above the marshy ground common in Roman and Etruscan territory, perhaps because the first Roman temple had for some reason to be built overhanging the edge of the Capitoline mount on a substructure built upon the hillside. Vitruvius mentions three temples[a] still standing in Rome in his day as specimens of what he calls the old Tuscan order, describing them as "clumsy, heavy roofed, low and wide," and in another place[b] he gives his usual set of pedantic rules for reproducing such temples. These run to some length, and are chiefly interesting because they appear in the main to describe the most important temple in Rome, that of Jupiter Capitolinus, as it existed in his day—that is, as it was rebuilt by Sulla after the fire of 83 B. C., and remained until again destroyed by fire in the faction fight that ushered in the reign of Vespasian in A. D. 70. We learn that the temple was not far from square on plan, the width being to the depth as 5 to 6; that it had only one pediment, the back of the roof being hipped; that the eaves were very wide; that half the depth of the temple was taken up by the portico; that the cella, which occupied the back half, was divided into three in width; that the columns were of pseudo-Doric character with bases; and other interesting particulars. Vitruvius specifies wooden architraves, but does not say anything about the material of the columns. We know, however, from Pliny[c] and the researches of Penrose,[d] that the shafts of the columns of this particular temple were colored marble monoliths, stolen by Sulla from the temple of Olympian Zeus at Athens. We know, too, that the pediment was crowned with a huge terra-cotta quadriga, reputed to have been brought in ancient days from Veii.

But the temple of Jupiter Capitolinus, of which we thus get a fairly complete and detailed view, was not typical of the buildings, nor even of the temples, of the later Republican period, but was obviously peculiar. Although it had been rebuilt only about half a century before Vitruvius wrote, a great conservatism had presided at the reconstruction of a fane reputed the oldest and most sacred in Rome, and the light thrown upon it is chiefly of use to illuminate what may be called the first period of Roman architecture, before it came under the direct influence of Greece, or was stimulated by the broader outlook, the new requirements, and the wealth arising from foreign conquests and ever-increasing commercial activity. Some of these influences began to be felt soon after 200 B. C., between the end of the second Punic war and the final destruction of Carthage. In that period at least three basilicas were erected in Rome to accom-

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[a] Vit., III, 3, 5.
[b] Vit., IV, 7.
[c] Pliny, XXXIV, 45.
[d] Athen. Arch., edit. 1888.

FIG. 1.—ONE OF THE PIERS OF THE AQUEDUCT OF CLAUDIUS, SHOWING THE COURSES IN ROMAN CONCRETE.

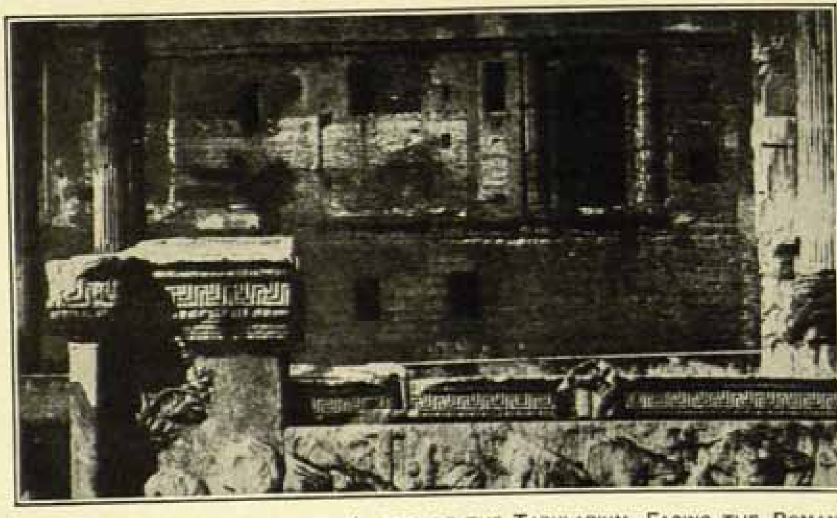

FIG. 2.—REMAINS OF THE LOWER ARCADE OF THE TABULARIUM, FACING THE ROMAN FORUM.

modate the increasing legal business arising from her position as mistress of all Italy and suzerain of most of the known world. They were probably the first of the long line of public civil buildings which distinguish Roman architecture. Before their erection the Forum and the temples seem to have sufficed for all public business except ordinary meetings of the Senate, which took place in the Curia, itself, however, merely an old temple enlarged for the purpose.[a] Nothing remains of two of these basilicas, and even their sites are matters of controversy. One, the Basilica Æmilia, is pictured on a coin, where it is represented as a small two-storied porticus of columns, roofed, but with open sides. Professor Lanciani believes he has discovered its remains.[b] The earliest triumphal arches—three or four at least—were also built in this period; but again all we know for certain of their appearance or construction is that they were adorned with statues of gilt bronze. Two more bridges over the Tiber (there was already one) were also built, one of which was reputed to be the first stone bridge. But for some time the piers only were of stone, the arches not being added until 142 B. C., whether from lack of skill, or because there were superstitious objections to the use of anything but wood for bridges, is not clear. Meanwhile many Greek works of art and educated slaves were finding their way to Rome, and after 146 B. C., when Greece became a Roman province, we are told that Roman art and literature fell entirely under Greek influence. One could wish there were more evidence of the extent and effect of that influence on architecture, for the last century of the Republic was one of considerable building activity, and it would help greatly toward a comprehension of the laws, if such there be, that govern architectural development if we had but a few well-authenticated remains of the many old temples rebuilt, and of the others and the public buildings erected in Rome and elsewhere in that century. But for temples we have to rely on a single small example, the so-called Temple of Fortuna Virilis at Rome, which, on the evidence of the building itself, is attributed to this time, probably correctly; and, for public buildings, on the so-called Tabularium, the main evidence for the date of which is a little shaky, but is borne out by that of the structure; and finally, the lower part of the theater of Marcellus, which was begun by Julius Cæsar. Of the Temple of Fortuna Virilis (or Fortuna simply) Doctor Middleton says:[c] "What the real date of this very interesting building may be it is impossible to guess, except that it is probably earlier than the middle of the first century B. C. Its early date is indicated by its pure Hellenic style, free from any Roman

[a] Livy, I, 30, and XXII, 55.

[b] "Architectural results of the latest excavations in the Forum at Rome," by Professor Lanciani. [Journal R. I. B. A., 24th Nov., 1900.]

[c] Remains, II, 190.

modifications (except perhaps the form of its elevated podium), by the absence of any marble, and by its being mainly built of tufa, travertine being used in a very sparing way, though much care and labor have evidently been spent on the construction and decoration of the building." The temple is a very small one, pseudo-peripteral with a prostyle portico, and of the Ionic order. It was stuccoed all over with marble-dust cement, in which all the moldings and ornaments were finished. The moldings were cut in the stone, but in the cornice, at any rate, the finished cement moldings differ in several respects from the stone ones. The proportions of the plan are Greek, the length being just twice the width. But the ornaments of the frieze, garlands hung from candelabra and ox skulls, are essentially Roman. The attached columns are only half columns. The strongest items of evidence for early date are the Greek simplicity of the moldings, the absence of marble, and the proportions of the building, with regard to which the Romans, a little later on, were not in the least particular. The sparing use of travertine proves nothing; as a matter of fact it was more sparingly used in many later buildings.

The principal evidence for the exact date when the Tabularium was erected is an inscription discovered in the building in 1450, now only known from a quotation and which Doctor Middleton describes as very vague and puzzling.[a] But its purport is that substructures and a tabularium were erected by Quintus Lutatius Catulus, who was Consul in 78 B. C., and Doctor Middleton's hesitation about it seems to rest mainly on the fact that, while many tabularia, or record offices, existed in Rome, this is not known to be one of them. It is not, however, known to have been anything else; it appears to be suited by position and arrangement to such a purpose; it has extensive and conspicuous substructures; the character of the masonry shows it to be of early date; and, finally, Doctor Middleton himself points out[b] a very interesting fact which appears to prove conclusively that the substructures, at any rate, were built between 121 B. C. and about 6 A. D.—that is, during the existence of the second Temple of Concord. He says that the only part of the facing of the tabularium wall not neatly dressed is that which was concealed by that temple, which can hardly mean anything but that the wall was built up against it. Altogether the evidence of date is nearly conclusive, and far better than in the case of the Temple of Fortuna or any other conspicuous building except tombs supposed to be of the Republican period. I have already described the vaulting. The walls and arches are all of very neatly wrought masonry, with fine joints, mostly of the native tufa (probably the rock that was cut away to make room for it), faced with the harder peperino, in which the arches are of travertine. The

[a] Remains, I, 366. [b] Ibid., I, 336.

VAULT IN COLOSSEUM.

blocks of peperino are all cut to the same size—4 feet by 2 feet. The upper part of the structure consisted on the front of an open arcade, said to have been once two stories high, though now only part of the lower story exists, mostly built up and surrounded by other buildings (pl. 3, fig. 2). The architectural interest of this arcade is that it is probably the earliest, or the earliest extant, example of the famous Roman façade, namely, a series of constructional arches and piers, like those of an aqueduct, ornamented with a framework of columns and entablatures planted against them. It may be the first attempt to endow a native arched structure with what was considered Greek architectural grace. The engaged columns in this case are Doric—the Roman variety—and parts of the architrave still exist, but all above that is gone. If there were really two stories and the second had Ionic columns the design must have been very like what we have left of the outside of the Theater of Marcellus, only built straight instead of circular, and raised on a lofty basement. Pompey's Theater, the first stone theater in Rome, built 55 to 52 B. C., seems to have been similar. The Theater of Marcellus was begun by Julius Cæsar, but, as it was not finished until 13 B. C., the works had probably not got very far at his death. It is too well known to need description. The whole of the outer wall is built of solid travertine masonry, as we are told was that of Pompey's Theater. It was all stuccoed over, but, as in the case of the Temple of Fortuna, the moldings are carefully cut in the stone beneath and, except the impost molds of the arches, are good. The voussoirs of the arches are of great size and no archivolt molding is worked on them. One may, of course, have been formed in the stucco covering, but probably was not, for had it been in scale with the heavy impost moldings it would have needed a core and would also have been very ugly. The substructures of the cavea or auditorium, much of which still remain, can hardly be coeval with the outside wall; they may be part of the restoration undertaken by Vespasian or of a later one.

A good deal might perhaps yet be learned concerning the history of architectural details and construction from a critical comparison of tombs, and even of sarcophagi. They are more often dated by inscriptions than buildings, and very little liable to extensive restoration. There are several large tombs near Rome known to be of the later Republican period; for instance, that of Cæcilia Metella, and the curious baker's tomb, close to the Porta Maggiore. Both of these are built of wrought masonry with a backing of concrete or rubble, and were once covered with the usual hard stucco. Neither brick nor marble entered into their construction. The drum of Cæcilia Metella's tomb has false V joints cut in the masonry, and a frieze of ox skulls and garlands which seems characteristic of the time.

The most interesting architectural development in the last century of the Republic was the birth of a domestic architecture properly so called, a domestic architecture nourished by the immense private fortunes which became common. The rapidity with which it grew up may be gathered from the difference between the state of affairs in 125 B. C. and sixty or seventy years later. In the former year Sulla, afterwards Dictator, was paying 3,000 sesterces—say £25—a year in rent,[a] which is said to mean that he was living in two rooms; and Lepidus, the augur, was called to order by the censor, for luxury, because he paid twice as much.[b] At the later time Cicero, besides his town house, for which he had paid a sum equivalent to about £30,000,[c] owned no fewer than seven country ones—that is, for his own use—and though we do not know the exact numbers of the houses kept up by other rich men, it is quite clear Cicero was not singular in that respect. These houses were of immense size. Sallust speaks of them as like cities,[d] and they were adorned with marble columns, paintings, statues, and works of art of all kinds. They covered large areas, the greater part being but one story high; moreover, even in Rome they were often surrounded by extensive gardens. One such house changed hands for fifteen millions of sesterces[e]—say £132,000—which probably did not include the movable works of art. It is recorded that as early as 92 B. C. Crassus erected in his atrium columns of the marble of Mount Hymettus 12 feet high, for which piece of luxury Brutus nicknamed him "the Palatine Venus."[f] By 78 B. C. Lepidus was using Numidian marbles not merely for columns, but for thresholds.[g] Marble slabs for lining walls seem to have been introduced rather later, in Cæsar's time. Before that, all walls, internally as well as externally, were covered with hard plaster and painted. No remains are known of the large country houses or villas of the time; and the impossibility of finding out much about them from the allusions in ancient literature may be judged by the various interpretations that have been put upon the fuller descriptions of his own villas by Pliny in the next century.

Passages in the sixth book of Vitruvius indicate, however, that country houses of the better class in his day did not differ materially as regards their domestic arrangements from town houses except that the peristyle was the first court entered, with the atrium beyond it, and that they had baths and various farm buildings attached to them. After several chapters devoted to describing private dwellings generally, the several apartments, and the modifications of size and arrangement required for different classes of owners, he says: "But the

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[a] Plut. Sall., c. 1.
[b] Vell. Pat., II, 10.
[c] Cic. ad Att., I, 13, 6.
[d] Cat. 12.
[e] Plin., H. N., XXVI, 115.
[f] Ibid., XXXVI, 7.
[g] Ibid., XXXVI, 48.

same things are true, not only of buildings in the town, but also in the country, except that in town the atriums are usually next the gates, but in the country and suburbs uniformly the peristyles, then at once paved atriums having porticos around and looking on the palaestras and walks."[a] The object of the country arrangement was obviously to get this view of the grounds from the common dwelling room of the house. It would seem not to have held at a later date in the larger villas of the Imperial period, when atrium had become less a dwelling room than an entrance hall, for Pliny says that in his Laurentine villa the atrium was the first apartment entered. In the suburban villa at Pompeii, called the villa of Diomed (fig. 1), the description of Vitruvius holds good; for the long apartment, called the gallery, which looked onto the terrace round the palaestra and to the country beyond, no doubt served most of the purposes of the atrium in a town house, though its form differs entirely both from those described by Vitruvius elsewhere and from others in Pompeii. Unfortunately there are no means of dating the building. For a wealthy man's house it is not large, and the decoration, though it is described as tasteful, was inferior to that of many

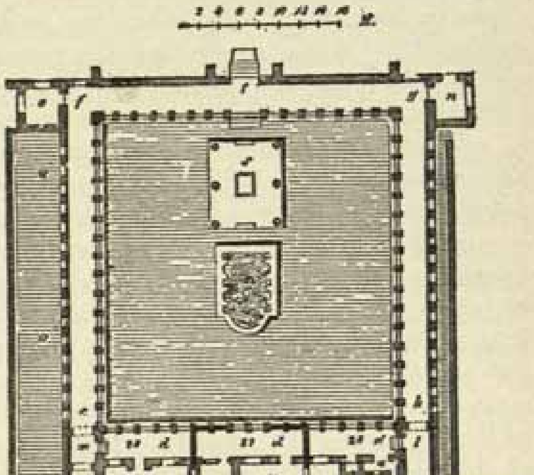

FIG. 1.—Plan of the villa of Diomed. (From August Mau's Pompeii.) 1. Steps. 3. Peristyle. 8. Tablinum. 10. Exedra. 12. Dining room. 14. Sleeping room, with anteroom (13). 15. Passage leading to a garden at the level of the street. 17. Small court with hearth (ε) and swimming bath (ζ). 18. Storeroom. 19–21. Bath. (19. Apodyterium. 20. Tepidarium. 21. Caldarium.) 22. Kitchen. 26. Gallery, facing a terrace (28) over the front rooms of the lower part. e, f, g, h. Colonnade inclosing a large garden. i, k, l, m. Rooms. r. Fish pond. s. Arbor.

[a] Vit., VI, 5, 3.

other Pompeiian dwellings. One can hardly accept it as a specimen of the spacious and sumptuous habitations we hear of even under the late Republic.

In his chapter especially devoted to country houses[a] Vitruvius is evidently describing only what we should call farmhouses. He speaks of the several aspects and the arrangement of farm buildings, stables, kitchens, wine presses and baths—which he says should be placed so that they can be used also by the farm hands. And then he adds: "If something of luxury is to be introduced into country houses they are to be built according to the proportions that are laid down above for those in towns, on the fixed condition they are to be so arranged as to be without impediment to country uses."[b] In Diomed's villa this part of the problem seems to have been solved by putting the farm buildings at the side of the house, separated from it by a narrow court, probably as a safeguard against fire or noise; and one may take it that in a gentleman's villa some such arrangement is so obvious that it would be the usual one. Of the better class of Roman house at the end of the Republic, that is, the separate house of the wealthy called a domus, as distinguished from the insula or block of flats inhabited by poorer folk, we can obtain a very clear idea from the descriptions of Vitruvius, which necessarily refer to this time, because they are illustrated by considerable remains of such houses at Pompeii. These agree very closely with the descriptions, and many date no doubt, at any rate as regards plan and the lower parts of the walls, from soon after 64 B. C., when the town was Romanized and became a fashionable resort of the wealthy. One of Cicero's seven villas was at or near Pompeii; he calls it his Pompeian villa. It would be wearisome to repeat the oft told names and uses of the various apartments of the Roman or Pompeian house, though a comparison of description with example is exceedingly interesting, both in itself and in the light it throws on the life of the period. But it may be worth while to repeat once more that the Pompeian houses are essentially Roman, and not Greek in their arrangements. They do not agree with the contemporary description of a Greek house by Vitruvius, and they do agree both with his description of a Roman house and with what has been discovered of the plans of houses in Rome; it is not very much, unfortunately, but adequate for the purpose of comparison. The decorations of the Pompeian houses certainly appear to owe something to Greek influence, but similar decoration has been found in Rome. The Greek names which Vitruvius gives to many of the principal apartments he applies to Roman houses generally and not to those in Pompeii alone. If the architecture of Pompeii owes anything to Greek influence it is the influence

[a] Vit., VI. 6.

[b] Vit., VI, 5.

which for a long time dominated all Roman art, and can not be due to the Greek origin of the city, as has been assumed. Pompeii had ceased to be a Greek colony for many centuries before it became a Roman one, and had passed successively, it is said, through the hands of Oscans, Etruscans, and Samnites. The Greek tongue had long been extinguished, and any Greek blood left in the inhabitants can have been neither sufficient nor sufficiently important to inspire its architecture.

If you compare Pompeian ruins with those of the immense structures in Rome, the walls seem to be but slightly built, but they are quite as thick or thicker than we should erect now under similar circumstances. They are mainly of the so-called Roman concrete, really rubble. Many quoins, most isolated piers, and some walls are of wrought masonry. A certain amount of burnt brick is used, especially for patching and in the upper parts of the ruins. It probably indicates work of the Imperial period, and generally, no doubt, the repairs and restorations after the earthquake of A. D. 63, before referred to. That upper stories over parts of the houses were common is shown by the considerable number of staircases and traces of staircases found, although most appear to have been of wood and many would leave no trace. The small remains of the upper stories recovered indicate that they were constructed with wooden framing and, sometimes at least, overhung the footways. The existence of upper stories at Pompeii is interesting because a remark of Vitruvius might have led one to suppose that in his day upper stories were peculiar to Rome. He says: "The immense population (of Rome) makes it necessary to have a vast number of dwellings, and as the area is not enough to contain them all (on the ground story), the nature of the case obliges us to raise them in the air."[a] It hardly seems likely that all the upper stories in Pompeii were additions subsequent to the time of Vitruvius, and one must suppose he was referring only to an exceptional number of stories in Rome. It is difficult to guess how many these were. On the one hand no Latin author ever mentions more than four, and Juvenal, a century after the time of Vitruvius, speaks of the dwellings of the poor "in the fourth story under the roofs."[b] Besides, Vitruvius tells us that walls next a public way might not be more than a foot and a half thick.[c] On the other hand Augustus thought it necessary to limit the height of buildings to 70 feet.[d]

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[a] Vit., II, 8, 17.

[b] Juv. Sat., III, 199 et seq.

[c] Vit., II, 8.

[d] Strab., V, 235. The houses in Carthage when it was destroyed are said to have been eight stories high.

The only existing remains of a house of Republican date in Rome are those of the so-called house of Livia, under Domitian's palace on the Palatine. It contained a small atrium with the alae formed by a long, narrow recess on each side of the tablinum, and not in the position of those in the Pompeian houses. The walls are of wrought masonry and the arches of stone voussoirs. From the plans of the three houses found on a fragment of the celebrated "Marble Plan" of Rome, it would seem that alae were not essential in the atriums of the Imperial period. In two cases they are altogether absent, and in the third they have been separated from the atrium and turned into a sort of gallery by a wall built across it. There are, too, several cases in Pompeii where there are no alae or only one.

A number of ancient writers distinguish between the insula, or group of small dwellings, and the domus or separate house, as we distinguish between a house and a block of flats. But in Pompeii, at any rate, the domus as often as not formed part of a group which included habitations of various sizes. The typical example is the insula called the house of Pansa, where around the domus are grouped, besides shops that must have been separately occupied, at least five small houses, three containing some five or six rooms, and two of one room each and a staircase leading to an upper one, now gone. There is, besides, a separate staircase from the street, which probably led to other dwellings on the upper floor. It is said that such an arrangement would have been impossible in Rome, where the insulæ were built four or more stories high, because the light would have been shut off from the main domus. But with internal courts as large as the atria and peristyles of Roman houses, and the little value evidently attached to light in the bedchambers and other small apartments, there can have been no such objection. It can only be raised to give the distinction between insula and domus too strict a meaning. No doubt many a domus in Rome and the suburbs, as elsewhere, was (in the language of the auctioneer) a "desirable detached residence," but probably many others formed parts of insulæ, as in Pompeii. Shops on the principal street front, both communicating with the house and separated for letting off, are characteristic of the Pompeian houses. Those belonging to the house were nominally for selling the produce of country estates, and illustrate a passage of Vitruvius in which he says: "For those, again, who have to deal with country produce; at their entrances shop inclosures, and among the buildings cellars, granaries, storehouses, and so on . . . are to be made."[a]

The construction of the houses in Rome must have made it a somewhat unpleasant place to live in. The streets must have been as nar-

[a] Vit., VI, 5, 2.

row and dark as those in the worst of mediæval cities. The stories overhung one another, and, in addition, balconies projected so far that in some cases at least it was possible to shake hands across the street. Even after Nero had enacted that all external walls were to be of fireproof materials the upper stories continued to be of wood, and were so badly built that they frequently fell. One writer declares that people were driven out of Rome by the fear of falling houses. Many speak of the danger of tiles slipping from the roofs or thrown by persons in the upper stories. Of course bad fires were frequent. A very old law directed that two and a half feet should be left clear between the buildings,[a] but it fell into abeyance and does not seem to have been observed even after it had been reenacted by Nero.[b] Probably "vested interests" were too strong by that time to be overcome.

I will only add an apology for referring so often to Vitruvius, a writer who seems to me to receive less attention and respect than he deserves; from scholars, because he wrote indifferent, or at any rate, rather obscure Latin, and from architects, because, unfortunately, few show any profound curiosity to know what he says, and consequently do not find out how interesting he really is.

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[a] A law of "The twelve tables." See Festus, pp. 5, 11, M.

[b] Tac. Ann., XV, 43.

THE RELATION OF SCIENCE TO HUMAN LIFE.[a]

By Prof. Adam Sedgwick, F. R. S.

In casting about for a suitable introduction for my address this afternoon, I came across some words written by a great Englishman, which, with your permission, I will read to you:

> Remember the wise, for they have labored and you are entering into their labors. Every lesson which you learned in school, all knowledge which raises you above the savage and the profligate—who is but a savage dressed in civilized garments—has been made possible to you by the wise. Every doctrine of theology, every maxim of morals, every rule of grammar, every process of mathematics, every law of physical science, every fact of history or of geography, which you are taught, is a voice from beyond the tomb. Either the knowledge itself, or other knowledge which led to it, is an heirloom to you from men whose bodies are now moldering in the dust, but whose spirits live forever and whose works follow them, going on, generation after generation, upon the path which they trod while they were upon earth, the path of usefulness, as lights to the steps of youth and ignorance.
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> They are the salt of the earth, which keeps the world of man from decaying back into barbarism. They are the children of light. They are the aristocracy of God, into which not many noble, not many rich, not many mighty are called. Most of them were poor; many all but unknown in their own time; many died and saw no fruit of their labors; some were persecuted, some were slain as heretics, innovators, and corruptors of youth. Of some the very names are forgotten. But though their names be dead their words live, and grow, and spread over every fresh generation of youth, showing them fresh steps towards that temple of wisdom which is the knowledge of things as they are; the knowledge of those eternal laws by which God governs the heavens and the earth, things temporal and eternal, physical and spiritual, seen and unseen, from the rise and fall of mighty nations to the growth and death of moss on yonder moors.

So spake Charles Kingsley, and his words I make use of as an introduction which strikes the keynote of what I have to say to you to-day.

The subject which I have chosen for my address—the relation of pure science, and especially of biological science, to human life, and inferentially the relation which ought to exist between pure and

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[a] Address delivered at the Imperial College of Science and Technology on December 16, 1909. Reprinted, after author's revision, from Nature, London, No. 2095, vol. 82, December 23, 1909.

applied science in a college of science—is naturally of great interest to us in the Imperial College, which is a college of science and technology, and the purposes of which are, in the words of the charter, "to give the highest specialized instruction and to provide the fullest equipment for the most advanced training and research in various branches of science, especially in relation to industry." Particularly do I desire to set forth as clearly as I can the justification for including in a college which deals, not only with science, but with science in relation to industry, those branches of science which deal with organisms.

As industry forms the principal occupation of human life, and as the phenomena of organisms constitute the science of life, it may seem absurd to set out solemnly to justify the inclusion of the biological sciences in a college which deals with science especially in its relation to human life. Nevertheless, having regard to the fact that I have heard some doubt expressed as to whether the cult of the biological sciences properly falls within the scope of the Imperial College, it may not be out of place to bear the matter in mind on this, the second, occasion of the prize giving of our new college.

What is the meaning of the word science? As in the case of so many words, its meaning has become confused by its partial application, i. e., by its application to a part only of its contents, and this has often led to a misapprehension of the relation of science and of the scientific man to life. Science simply means knowledge, and to speak of scientific knowledge, as opposed to ordinary knowledge, is to use a redundant phrase, always supposing that we are using the word knowledge in its strict sense. Huxley defined science as organized common sense, by which, I take it, he meant knowlege of things as they are—knowledge the reality of which can at any time be checked by observation and experiment—for common sense, if it is anything, is the faculty by which we are made aware of reality. Science is sometimes spoken of as exact knowledge, but I am bound to say that I do not like the phrase exact knowledge; it seems to imply an insult to the word knowledge. Its use reminds me of a friend of mine who, when he was offered one morning at breakfast a fresh egg, mildly asked, "In preference to what other kind of egg?" It recalls those regrettable phrases one so often hears, I honestly believe, or I honestly think; one wonders how the people who make use of them usually believe and think.

It must, I think, be admitted that science simply means knowledge, and that there is nothing peculiar about the knowledge of scientific men by which it differs from other knowledge.

Scientific men are not a class apart and distinct from ordinary mortals. We are all scientific men in our various degrees. If this is so, how comes it that the distinction is so often made between scientific

men and nonscientific men, between scientific knowledge and nonscientific knowledge? The truth appears to lie here: Though it is true that all men possess knowledge, i. e., science, yet there are some men who make it their main business to concern themselves with some kind of knowledge, and especially with its increase, and to these men the term scientific has been technically applied. Now, the distinctive feature of these men, in virtue of which the term scientific is applied to them, is that they not only possess knowledge, but that they make it their business to add to knowledge, and it is this part of their business, if any, which justifies their being placed in a class apart from other possessors of knowledge.

The men who make it their main business to add to knowledge may be divided into two classes, according to the motive which spurs them on: (1) There are those whose immediate object is to ameliorate the conditions of human life and to add to its pleasures; their motive is utility, and their immediate goal is within sight. Such are the great host of inventors, the pioneers in agriculture, in hygiene, preventive medicine, in social reform and in sound legislation which leads to social reform, and many other subjects. (2) There are those who pursue knowledge for its own sake without reference to its practical application. They are urged on by the desire to know by what has been called a divine curiosity. These men are the real pioneers of knowledge. It is their work which prepares the way for the practical man who watches and follows them. Without their apparently useless investigations, progress beyond the limits of the immediately useful would be impossible. We should have had no applied electricity, no spectrum analysis, no aseptic surgery, no preventive medicine, no anæsthetics, no navigation of the pathless ocean. Sometimes the results of the seeker after knowledge for its own sake are so unique and astounding that the whole of mankind stands spellbound before them, and renders them the same homage that the child does the tale of wonderful adventure; such is the case with the work on radium and radio-activity, which is at present fixing the attention of the whole civilized world. Sometimes the work is of a humbler kind, dealing apparently with trivial objects, and appealing in no way to the imagination or sense of the wonderful; such was the work which led to and formed the basis of that great generalization which has transformed man's outlook on nature—the theory of organic evolution; such was the work which produced aseptic surgery and the great doctrines of immunity and phagocytosis which have had such tremendous results in diminishing human pain. The temper of such men is a curious one; no material reward can be theirs, and, as a rule, but little fame. Yet mankind owes them a debt which can never be repaid. It is to these men that the word scientific has been specially applied, and with this justification—they have no other profession

save that of pursuing knowledge for its own sake, or, if they have a profession, it is that of the teacher, which, indeed, they can hardly avoid. Ought such men, working with such objects, to find a place in the Imperial College?

It is a curious thing, but it has only comparatively recently been realized, that a sound and exact knowledge of phenomena was necessary for man. The realization of this fact, in the modern world at any rate, occurred at the end of the middle ages; it was one of the intellectual products of the Renaissance, and in this country Francis Bacon was its first exponent. In his "Advancement of learning" he explained the methods by which the increase of knowledge was possible, and advocated the promotion of knowledge to a new and influential position in the organization of human society. In Italy the same idea was taught by the great philosopher, Giordano Bruno, who held that the whole universe was a vast mechanism of which man, and the earth on which man dwells, was a portion, and that the working of this mechanism, though not the full comprehension of it, was open to the investigation of man. For promulgating this impious view both he and his book were burned at Rome in 1600. You will find the same idea cropping up continually in the written records of that time; Copernicus gave it practical recognition when he demonstrated the real relation of the earth to the sun, and it was thoroughly grasped by our own Shakespeare, who gave it expression in the dialogue between Perdita and Polixenes in the Winter's Tale:

Perdita. The fairest flowers o' the season
Are our carnations, and streak'd gillyvors
Which some call nature's bastards: of that kind
Our rustic garden's barren; and I care not
To get slips of them.
Polixenes. Wherefore, gentle maiden, do you neglect them?
Perdita. For I have heard it said
There is an art which, in their piedness, shares
With great creating nature.
Polixenes. Say there be:
Yet nature is made better by no mean,
But nature makes that mean: so, o'er that art
Which you say adds to nature, is an art
That nature makes. You see, sweet maid, we marry
A gentler scion to the wildest stock and make conceive a bark of baser kind
By bud of nobler race: this is an art
Which does mend nature,—change it rather; but
The art itself is nature.[a]

[a] This is an intensely interesting passage, for it shows that Shakespeare had grasped the idea of evolution, the idea, that is to say, that nature contains within herself the power of altering or "mending" herself. The interest is

It is not difficult for us, though it may be difficult to our descendants, to understand how hard it was for man to attune himself to this new, this mighty conception, and the intellectual history of the last three hundred years is a record of the struggles to make it prevail.

Trained through long ages to believe that the heavens were the abode of the gods, who constantly interfered in the daily affairs of life and in the smallest operation of nature, it seemed to men impious to maintain that the earth was in the heavens, and to peer into the mysteries which surrounded them, and the endeavor to do so has been stoutly resisted; but the conflict, in so far as it has been a conflict with prejudice, is now over. It vanished in the triumphs of the modern views on the origin of man which will be forever associated with the names of Lamarck, Spencer, and Darwin.

The triumph of these views does not mean that they are correct or that we know anything more about the great mystery of life than we did before. He would be a bold and a prejudiced man who made that assertion. What it means is this, that man is grown up, that he has cast off the intellectual tutelage under which he has hitherto existed, that he has attained complete intellectual freedom, and that all things in heaven and earth are legitimate subjects of investigation. But it means even more than this; it means that he has at last come to realize the true significance of the injunction of the old Hebrew teacher: "Fear God and keep His commandments, for that is the whole duty of man;" and of the psalmist when he said: "Make me to go in the path of Thy commandments, for therein do I delight. In keeping of them there is great reward." But in order to keep them he must first ascertain what they are, and this he is determined to do, so far as his capacities permit, by the only method open to him—that of minute and arduous research.

Let us hear then the conclusion of the whole matter. We claim for science no less a scope than this, the discovery of what God's commandments are. Some of these we already know, for they have been handed down to us in our sacred books or have been discovered for us by our forefathers. To discover others is our whole duty; but the task is endless, and to the end of time man's prayer must ever be, in the words of that splendid old collect now being read in our churches, "Give us grace that we may cast away the works of darkness and put upon us the armor of light."

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increased by the opening lines of Perdita's next speech, in which is implied the modern doctrine that acquired characters are not inherited, for he makes Perdita reply:

I'll not put
The dibble in earth to set one slip of them;
No more than were I painted, I would wish
This youth should say, 't were well, and only therefore
Desire to breed by me.

We hear a great deal nowadays about the humanities and the humane studies—the study of "ancient elegance and historic wisdom"—and I should be the last to minimize in any degree the value and intense interest which is attached to the study of the writings and utterances of the mighty dead. They will always retain undimmed their attraction and inspiration for man, and man will always think with gratitude and affection of their authors; but surely the humanities consist of something more than the study of the writings and philosophy of the ancients. To limit them to that is to take the view of the schoolmen, the death blow to which was given by Bacon and Bruno.

We have got beyond that; we claim that the true study of the humanities is a far wider thing—it is the study of the stupendous mechanism of the universe of which man forms a part, and the understanding of which is necessary for his happiness. That is the true humanity of which the other forms only a small portion. The time is coming when the principal preoccupation of man shall be the gradual disclosure of this mechanism and his principal delight the contemplation of its beauty.

In spite of the work and writings of such men as Bacon and Bruno in the end of the sixteenth century, the progress of science was at first but slow and the workers few. We have, of course, the immortal achievements of Newton and Harvey, and the foundation of the Royal Society, and the tremendous outburst of scholarship as typified in this country by Bentley and his coworkers; but the eighteenth century was, on the whole, characterized by intellectual quiescence both in scientific output and in literary creation. The quiescence was apparent rather than real. To borrow a metaphor from the garden, though there was little growth above ground, active root formation was going on. Linnæus (1707–1778) was at work in Sweden creating the framework which rendered future work in botany and zoology possible; Buffon in France was cautiously feeling his way toward a theory of organic evolution; Henry Cavendish (1731–1810), Joseph Priestley (1733–1804), and Antoine Lavoisier (1743–1794) were laying the foundations of modern chemistry; Albrecht von Haller (1707–1777), Kaspar Friederick Wolff (1733–1794), and John Hunter (1728–1793), those of anatomy and physiology. The spade work of these men, together with the improvement of the microscope was necessary for the great outburst of scientific investigation which characterized the nineteenth century. Ushered in by the work of Cuvier (1769–1832), Lamarck (1744–1829), St. Hilaire (1772–1844), in biology, Thomas Young (1773–1829), Laplace (1749–1827), Volta (1745–1827), Carnot (1758–1823), in physics, it was adorned in its middle and latter period by the names of Davy,

Faraday, Dalton, Arago, Richard Owen, Darwin, Lyell, Joh. Müller, Agassiz, Helmholtz, Stokes, Kelvin, and Pasteur.

The advance of knowledge is yearly becoming more rapid; if its steps were slow and hesitating in the seventeenth and eighteenth centuries, and if it quickened to a rapid walk in the nineteenth, we now hear the sound of a trot, which at the end of the century will be a gallop, and as the centuries succeed one another its pace will become ever faster. Where will it lead us and what will be the upshot for man?

But it is no part of my purpose to-day to give you an historical summary of scientific progress. The point I wish to illustrate is the vast increase in the scientific army and in the results achieved by them.

My thesis is that pure research into the sequence of natural phenomena is in itself of the greatest importance to the progress and welfare of humanity, and that a great statesman can have no higher aim than to solve the problem of how it may best be fostered. To what extent can such a thesis be justified by experience?

I might begin by examining the origin and progress of our knowledge of what is called current electricity, to which modern life, from a material point of view, owes so much. In illustration of what we owe to workers in electrical science I need only mention land telegraphy, ocean telegraphy, wireless telegraphy, telephones, electric light, electric traction, and our knowledge of radio-activity. The history of this science forms perhaps the best example of the importance to man of pure, apparently useless, scientific research, for at every stage of it, from Galvani's original observation through the discoveries of the Swede Oersted and of the Frenchman Ampère to those of our own Faraday and to the theoretical adumbrations of Clerk Maxwell and to the researches of Crookes on the passage of electricity through vacuum tubes, we meet with the investigation of phenomena which were apparently perfectly useless, and which to most practical men must at the time they were made have appeared as little more than scientific toys provided by nature for the harmless amusement of the queer people who meet in the rooms of the Royal Society and such-like places where unpractical oddities resort. And yet I ask you to reflect upon the astounding results which have arisen from Galvani's observations made to discover the cause of the twitching of the frog's legs, and of Faraday's discovery of induction, and to indulge your imaginations in an endeavor to predict what may issue for man from Crookes's investigations of the glow without heat of the vacuum tubes.

But I have neither the knowledge nor the time to dwell upon the physical side of science. As in private duty bound, I must devote the short time at my disposal to examples culled from the biological sciences.

The great Frenchman, Pasteur, in making a thorough examination of the process by which alcohol was obtained from sugar, discovered the part played by the organism known as yeast, and established the idea of organized ferment bodies. He extended his observations to other micro-organisms, and, in conjunction with his coworkers, among whom must be included those who were looking into the question of the spontaneous generation of living matter, definitely gave us the idea that putrefaction was caused by micro-organisms acting upon organic matter, that these micro-organisms are capable of resisting drought, and when dried float freely in the air and are distributed everywhere. When they fall upon a suitable material, their vital activity is resumed, and they increase with incredible rapidly and set up putrefaction. It was reserved for our distinguished countryman, Lister, then a surgeon in Edinburgh, to recognize the importance of these discoveries for surgery. Knowing of the researches of Pasteur and his fellow-workers, he conceived the idea that suppuration was due to putrefaction in the organic matter of the wounds caused by micro-organisms. Acting on this, he introduced his method of antiseptic surgery, by which his name has been rendered immortal. I think we may say that no single application of the results of pure research has done more to preserve human life and to diminish human suffering than this linking up by Lister of the putrefaction of suppuration with the work of his predecessors on the effects of the actions of micro-organisms upon organic matter. It is well to notice, in passing, that this discovery of Lord Lister's is a good illustration of the difficulty which the human mind has of conceiving even the simplest new idea. To us, now, how simple seems the step which Lister made; yet there were thousands of surgeons in the world who failed to make it, though they were continually dealing with suppurating wounds and wondering why they suppurated, and when it was made it was stoutly discredited by many quite able men.

I must now turn to another subject which is closely connected with the preceding, and well illustrates my thesis that pure scientific research, without reference to practical utility, is of the highest importance to mankind.

It will doubtless have occurred to many of you to ask the question, How is it, if the air contains floating in it the dried spores of multitudinous micro-organisms which only need a suitable medium for their development and increase, how is it that they do not obtain a lodgment in the healthy animal body, which one would think offers all the conditions necessary to their growth? It can easily be shown that the air we breathe, the water we drink, the food we eat, everything that we touch, swarms with these microscopic creatures; that they enter our lungs, that they germinate in our skin, that they occur

in countless numbers in our alimentary canals, in short, that they are found everywhere on our body surfaces. How is it that they do not increase and turn our organs into a seething mass of putrefying corruption? One would expect that even if the skin and the membrane bounding the internal organs to which they obtain entrance incurred the slightest lesion, even a pin prick, that they would have been able to enter. We know that after death they at once obtain complete dominion, and we therefore infer that in life there must be some protective mechanism in the body capable of dealing with them.

The discovery that there is such a mechanism was made in the early eighties by the distinguished Russian zoologist Elias Metschnikoff, though the need of its existence was not recognized by biologists in general until later. The result of this was that his remarkable discoveries were at first pooh-poohed and discredited by many, but ultimately they gained acceptance, and their further development in his own hand and that of others has wrought a revolution in the art of preventive medicine.

The mechanism consists of the small amœboid cells found in the blood, lymph, and body fluids generally, and called leucocytes, or white blood corpuscles. Though long known to exist, very little had been ascertained as to their function until Metschnikoff, working at such remote subjects as the embryology of sponges, the structure and digestion of polyps, the blood of water fleas, realized that these small amœba-like cells, which exist in all organisms, actually swallow, digest, and so destroy small foreign bodies which have invaded the organisms. He called them the phagocytes, and all his subsequent work has been directed to the elucidation of their mode of action.

It is to Metschnikoff's work, prompted solely by the scientific spirit, that we owe our knowledge of phagocytosis and the great theory of immunity which has proceeded from it. It is impossible at the present moment to estimate fully the value to man of Metschnikoff's discoveries. Suffice it to say that they have already led to important practical results, and have revolutionized treatment.

I must now turn for a moment to another subject of the greatest importance to mankind, and one which has been brought into notice by the researches, perfectly useless so far as our material welfare is concerned, which were undertaken with the view of elucidating the great question of organic evolution. I refer to the study of genetics, which deals with the question mainly of the transmission of the properties of the organism; but it deals with even a larger subject than that. It looks into and tries to determine the laws which govern the origin of the characters of individuals, whether plants or animals, whether those characters have been acquired by inheritance or in some other way. The subject is of the utmost interest and practical importance to man from three points of view. It has

a bearing on philosophy of a most important and far-reaching kind through the theory of organic evolution. That theory largely depends for its proof upon the science of genetics. Secondly, it has a most important bearing upon practical questions affecting breeders of animals and raisers of plants, and also upon man himself in connection with practical legislation. This brings me to the third point, in which this subject specially appeals to us, and that is what I may call its bearing upon ethics. This is, of course, closely connected with the last.

We are constantly confronted with questions in which we have to think, not only of the advantage and happiness of those alive at the present moment, but also of those not yet born who will succeed us on the earth. The decision of these questions is one of the most important and burning subjects which can be put before us. They often crop up in legislation, and yet we are quite unable to answer them because of the very little knowledge we possess of the laws which govern the transmission of characters from generation to generation.

The interests of future generations often appear to be in conflict with the immediate pleasure and happiness of the living, and we are confronted with the question whether we ought to give way to our own humane and benevolent feelings or whether we ought to set our teeth and deal ruthlessly with a number of people who must appeal to our pity, lest by saving them from elimination we should bring about an increase in the number of people who are unable to hold their own, and so weaken the nation and increase for the next generation the difficulties which we set out to cure. I do not pronounce any judgment on these questions; I merely wish to emphasize the immense, the transcendent importance, from the human point of view, of the investigations which the study of the question of evolution has caused biologist to carry out into that most difficult of all subjects, heredity, and of obtaining clear ideas upon the subject. These, I admit, are elementary examples, and probably familiar to most of you—and they might be largely added to from other branches of zoology, such as entomology, marine fauna, and physiology—of the great practical achievements which have followed from the recognition of the fact, possibly appreciated in some ancient civilizations,[a] but in modern times first understood by Bacon and his compeers,

[a] There are, as is well known, indications that research into natural phenomena was practiced and esteemed in some ancient civilizations which have been destroyed by the inroad of barbarians or by other causes. One of the most striking of these indications is the record in one of the sacred books of the Hindus, which can not be less than 1,400 years old, and is probably much older, that malarial fevers are directly caused by the bite of mosquitoes. Attention was first directed to this record by Sir H. A. Blake, G. C. M. G., in 1905, while he was governor of Ceylon (vide Journal of the Ceylon Branch of the British Medical Association, vol. 2, Pt. 1, 1905).

that natural phenomena are in themselves, and without reference to immediate utility, proper subjects of man's inquiry, and that all progress must be based on their thorough and accurate investigation.

The genesis of a new idea is so difficult, and the amount of work necessary for its complete elucidation and development so vast and detailed, that many eminent men, taking only a short period of time and not realizing the minute steps by which the advance of knowledge takes place, have been led to doubt the value of scientific investigation in the higher realms of pure knowledge, even to the extent of speaking of the bankruptcy of science. Others, again, perceiving the apparent aimlessness of many investigations and undervaluing the motive which urges them on, have come to look with a certain contempt upon the man of pure science and his slow and plodding progress. What is the good of all this work at unimportant details? What do you get out of it, and what pleasure do you find in it? they ask, and when they are told that the humble worker usually gets nothing out of his work except the pleasure of doing it, and that his motive is nothing more elevated than the satisfaction of his curiosity, there does appear to be, it must be admitted, some justification for the contemptuous indifference with which the poor researcher is regarded by a considerable section of the population, as is shown by the almost entire absence of support of pure scientific research on the part of the Government. With the exception of an annual grant of £4,000 a year given to the Royal Society, I think I am correct in stating that the Government affords hardly any support to science save to such as is concerned with teaching or with some practical problem; and when one remembers the composition of governments and the manner in which, and the reasons for which, they are chosen, one can not unreservedly blame them for this attitude. The best method of fostering research is a difficult problem, and I can well understand that a modern democratic government, depending as it does upon popular support, with its attendant popular mandates, should shrink from dealing with it. To do so would bring them no popularity and no votes, and too often they are not really aware of its immense importance to human progress, and when they are they have great difficulties to face.

For it is impossible to organize research on a commercial basis. "All attempts," says Professor Nichols, of Cornell, "at a machine-made science are doomed to failure. No autocratic organization is favorable to the development of the scientific spirit. No institution after the commercial models of to-day is likely to be generously fertile. You can contract for a bridge according to specifications. No one, however, can draw up specifications for a scientific discovery. No one can contract to deliver it on a specific day for a specified price, and no employee can be hired to produce it for wages received."

This it is impossible to get the public to understand even when it has undergone the process which we call education. You may establish paid posts for scientific research, but you can not be sure that you will get research, for science is like the wind that bloweth where it listeth, and that is what our educated public do not like. They want something for their cash, and they will not wait.

Even those who are aware of the immense value of pure research forget the fact that the aptitude for scientific investigation is as rare as the gift of poetry, to which in many respects it is allied, for both are creative gifts, rare and precious. They forget that it is impossible to ascertain without trial whether a man possesses it or not, and that this trial can only be made when he has passed his student days and looks to support himself by his own exertions. To provide for this support money is needed, and studentships must be established in considerable numbers, from the holders of which those who show that they possess the gift of research can be selected and promoted to higher posts in which their gift can find full opportunity; but we want more than this—we want compensation for those whom we have encouraged to make the trial and who have failed to show that they possess the gift, and an outlet by which they can emerge and find work in practical life.

This has been and is a difficulty in all schools of science, for many are called but few are chosen. The situation is this: It is desirable that a large body of able young men should be encouraged to take up scientific research, but as experience has shown that only a small proportion of them will possess the qualities by which success in research can be attained, and as it is undesirable to encumber the progress and the literature of science by a host of workers who have no real capacity for research, it results that a time will arrive when a great proportion of those whom we have encouraged to give some of the best years of their life to this unremunerative work should be invited to find other occupations. What is to be done? We can not throw them into the street. Some compensation must be given. There are two ways in which this can be done. One is the system of prize fellowships, which has for long been in vogue at the old universities, and which it has of late been the custom of those who have not really studied the matter to decry. Nevertheless, it is a good system, for it provides an income by which those who have given some of the best years of their life to this trial of their capacity can support themselves while they qualify for taking part in a practical profession.

A prize fellowship system, or something like it, is a necessary accompaniment of a university which induces a large number of young men to follow for a time the intellectual life; it acts both as an inducement and a compensation, and it would be a mistake and an

injustice, in my opinion, to abolish it; but there is another way in which the difficulty can be met, and that is the way which has been adopted by the wise and farseeing founders of the Imperial College, namely, by the combination of a school of science with a school of technology. If you have incorporated in your school of science a school of applied science, and if you at the same time take care that none but able men are allowed to enter the research grade, and if you establish, as you must do if you honestly work your school, a connection with the great industrial interests of the country, you have all that is necessary for the disposal of those men who, for whatever reason, find themselves unable to follow a life of pure science. As is well known, the faculty for pure, apparently useless, research in science is often possessed by men without any aptitude for practical application of science or desire of practical success and the wealth which practical success brings, while, on the contrary, many minds of the highest order can not work at all without the stimulus of the thought of the practical outcome of their labor.

In our college there is room both for those with the highest gifts for pure scientific research and for those with the inventive faculty so important in the arts, or with the knowledge and ability for controlling and organizing great industrial enterprises; and, what is more, the combination of the two types of mind in the same school can not but be of the greatest advantage to both, not only on account of the atmosphere which will be created, so favorable to intellectual effort, but also because good must result from the contact in one school of minds whose ultimate aim is to probe the mysteries of nature and to acquire control over her forces.

As Professor Nichols has well said in pointing out the dependence of technology on science:

> The history of technology shows that the essential condition under which useful applications are likely to originate is scientific productiveness. A country that has many investigators will have many inventors also. * * * Where science is, there will its by-product technology be also. Communities having the most thorough fundamental knowledge of pure science will show the greatest output of really practical inventions. Peoples who get their knowledge at second hand must be content to follow. Where sound scientific conceptions are the common property of a nation, the wasteful efforts of the half-informed will be least prevalent.

These are sound conclusions, and experience has shown that if the terms are interchanged the same remarks may be made with equal truth of the good influence which results to a school of science from its association with a school of technology.

Before concluding, it may be well to say a word as to the origin of the great imperial institution in the interests of which we are met here to-day. It may justly be described as the natural and necessary outcome of the scheme for scientific instruction which was originated

by that great Prince whose memorial stands near the end of Exhibition road, and to whom science and art in England owe so much. He dreamed a dream which his untimely death alone prevented him from realizing. Had he lived, who can set a bound to what he would have achieved for science and education in England? It is a most happy circumstance that the final stages of the realization of that dream should have been entered upon in the reign, and have received the sympathy, patronage, and active support of his great son, our most gracious King, who is working in so many directions for the welfare and happiness of our race.

There is one further point I must touch upon. In the few remarks which I have had the honor to make to you, I have endeavored, however imperfectly, to embody in words certain thoughts which bear upon a great subject. I thank you for the patience with which you have heard me. Whether I have produced the effect I desire I know not, but I know this, that even if I had the tongue of men and angels, no words of mine could have been so apt, so expressive as the magnificent deed of Mr. Otto Beit recorded in to-day's newspapers.[a] It is impossible for me to pass this over in silence, so closely is it connected with the subject of my address. There are two ways of manifesting thought, by word and by action. Mr. Beit has chosen the latter and far more effective way. We can only express our respectful admiration and gratitude for his generosity, and our thankfulness that a man should exist among us with the power, the insight, and the true humanity to do such a splendid deed.

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[a] It was announced in the Times of December 16, 1909, that Mr. Otto Beit had given the sum of £215,000 to establish a number of fellowships of the annual value of £250, the holders of which would devote themselves to medical research in all its branches.

INTELLECTUAL WORK AMONG THE BLIND.[a]

By Pierre Villey.

Scarcely two months have passed since the little world of the blind was en fête. They celebrated the centennary of the birth of Louis Braille, who is, among the blind, the object of great veneration and deep gratitude. Blind himself from the age of 3 years, professor after 1828 at the Royal Institution for Blind Youth, where he was educated, he devoted his thoughts and his entire life to the amelioration of the lot of his unfortunate companions, and it is to him that they owe the method of reading and writing which is employed to-day throughout the whole world. His memory is not less cherished than that of Valentin Haüy. Although Haüy conceived the idea of instructing the blind, Louis Braille discovered the means by which this could be made to bear fruit.[b]

Their united efforts have transformed the life of the blind. Before their time only a few blind persons who were in favorable circumstances succeeded in developing their faculties. To-day all are invited to take advantage of intellectual culture; all may lead a useful life in society. In spite of this transformation, the prejudice against blindness exists everywhere. It gives place but slowly. In nearly all minds the word "blind" always evokes the same pitiable and false image. The first inclination is to suppose that behind these sightless eyes, this lifeless countenance, everything is quiet—intelligence, will, sensations—that all the faculties are torpid and, as it were, benumbed. Furthermore, habituated as are those who can see to do nothing without the use of their eyes, it is quite natural that it should appear to them that if they should lose their sight they would at once become incapable of any activity. It is not easy for them to imagine that the blind, deprived of the resources of sight, find in exchange,

[a] Translated, by permission, from Revue des Deux Mondes (Paris) of March 15, 1909. The author, Mr. Villey, lost his sight when 4½ years old.

[b] Regarding Valentin Haüy, Louis Braille, and the Institution for Blind Youth, see the articles published by Maxime Du Camp in the numbers of the Revue des Deux Mondes for April 15, 1873, and March 1, 1884.

in the remaining senses, other resources, neglected by the greater part of mankind whom the prodigality of nature renders heedless, but precious to those who know how to make them fruitful. They ignore or forget the fact that benefactors have invented special processes and methods which enable the blind to diminish the gulf which blindness has fixed between them and others. The world at large regards the blind man as a peculiar being and a stranger to ordinary life. Contact with an adroit and distinguished blind person sometimes abolishes this abstract image, but it soon returns again and triumphs over contradictory experiences. It is perhaps necessary to be associated with blind people for a long time to be freed from it altogether, and, after all, this is natural enough when one considers how methods of action among the blind differ from those of persons who have their sight. It is difficult to persuade oneself that in perpetual obscurity our faculties can develop with perfect freedom.

If we had to do here merely with an unimportant psychological error, even then it would be of interest to note it. But it has grave consequences for the majority of the blind—musicians or piano tuners and workmen of all kinds, who endeavor to gain their livelihood by their labor. The distrust of the public paralyzes them. It is therefore a duty to denounce it on all occasions.

I.

As a result of seeing blind persons going to and fro, one becomes in the end convinced that in many of the acts of everyday life, the senses of hearing, touch, and smell, being substituted for that of sight, of which they are deprived, permits them to dispense with the aid of the latter. There are blind persons in nearly all towns. We know that they are able to dress themselves, to go into places which are known to them, to look after certain details of housekeeping, to prepare simple meals, in a word to engage in a great variety of occupations, of which one would at first believe them incapable. However, their dexterity in these affairs of material life varies much from individual to individual, and it is always quite limited. From a physical point of view, the best endowed blind man can never equal one who sees; he need not be entirely dependent on the latter; that is all. This is freely granted, but from the point of view of intellect and morals the blind man has the highest pretensions. He declares himself the equal of other men. There is little inclination toward belief on this point, for various reasons. In the first place, intellectual capacity is difficult to measure and can not be judged by mere inspection like physical capacity. Furthermore, since in our age intellectual culture presupposes very extensive knowledge, it does not seem possible that this can be acquired in the obscurity of blindness.

Notwithstanding, one should reflect that sight is not necessary to the free action of thought. If the disease that destroys it is confined to the eye and its immediate adjuncts, and does not reach the brain, the integrity of the intellect is secure. There are in the world very few ideas that the blind man (I mean, blind from birth) may not acquire, because there is very little that comes to us through the eyes alone. If we analyze the elements of visual sensation, we perceive that nearly all of it is within the reach of the tactile sense. Let us suppose that you look at a ruler which is in front of you on your table. The color strikes you first. That is a sensation which a person born blind never has. Although he may feel carefully all the surfaces of the ruler, his fingers will never tell him that it is black. But all the rest—its length, breadth, thickness, the form of the extremities, the sharpness of the angles and the edges, the polish of the surfaces, the place which it occupies on your table, the distance which separates it from you—all these other ideas will be given him by his exploring hand. Everything is, in fact, brought back to the elementary ideas, extension and solidity, which touch furnishes as well as, and even more exactly than sight. There are without doubt objects too far removed from us and of too small dimensions to be felt, but all the ideas regarding them which sight gives to man go back to those which we have indicated. All things, therefore, except the idea of color, are conceivable to an individual who is endowed with the sense of touch. In order to construct an idea of an object, and produce an exact image of it, it suffices to multiply and combine the ideas of space and extent given by touch. Sight is a kind of touch of long reach, with the sensation of color added. Touch is a kind of sight minus color and plus the sensation of roughness. The two senses give us sensations of the same order.

Those who see are not able to compass the earth in a single glance. For all that, however, they construct an idea from the data given them by geometers. In the same way the blind form ideas of objects they can not touch from the accounts of those who see, which can always be translated into tactile language.

The person born blind is, however, deprived of the notion of color. It is an elementary notion which no other sense can give, no language can render comprehensible, and no analogy can make intelligible to those who can not see. I will add also the idea of light, which is similar. These ideas, however, are of very slight importance from an intellectual point of view. They concern only the surface of objects. They do not enter at all into the composition of the essential ideas of human thought, such as space, time, cause, etc.

The blind man is without those impressions of pleasure or pain which certain combinations of form and color cause the mind. He

does not have the sensation of visual beauty. I do not know of a person born blind who has formed a precise idea of the beauty of a countenance, of a landscape, or of a statue, and I recognize that what he lacks here is very considerable. Many powerful emotions are denied him. But his loss can not properly be called intellectual. These relations do not give birth to any clear and distinct idea. They arouse only subjective impressions. When we speak of a blind artist, it is necessary to notice this capital defect, but in the study of his intelligence it is of little consequence.

I believe that I have enumerated all the blanks in mentioning light, color, physical beauty, and adding thereto perspective, which manifestly is connected with the function of sight alone. These defects are found only among those blind from birth and those individuals who have been affected at a very early age, which is not ordinarily the case. Only allow one a few years and he will acquire all these notions, and to the end of his life his memory will reproduce them in the darkness.

Let it be granted, then, that nearly all ideas can find lodgment in the brain of a blind person. But, it will be said, if it be not impossible for a blind man to conceive them, at all events he will have great difficulty in acquiring them. The obstacle is not in the nature of the ideas, but in the paucity of the means which the blind man has at his disposal for assimilating them. The person who can see owes them for the most part to his sight, and there is no other route by which they can be conveyed to the mind with equal rapidity and precision. It will be seen, therefore, that the stock in trade of the intellect must necessarily remain rudimentary. This is the capital objection, that which is at the bottom of all the wonders of which we speak. To those who mention it to me I always propound the same question, "Do you know Helen Keller?"

Helen Keller, as everybody knows, is a young American, who, from the age of 18 months, as the result of a severe illness, became blind and deaf, and dumb also in consequence of her deafness. Her little soul seemed, then, to be completely closed to impressions from without. Her intellectual equipment, it would seem, must be limited to a few rare ideas, ideas within the reach of her hands. It would be doubtful, furthermore, whether in the thick darkness she could ever have distinct conceptions of them. Notwithstanding, Helen Keller, to-day 28 years old, still deaf and still blind, is a very distinguished and cultivated person, who has followed the course of a university, passed examinations with brilliant success, and speaks many languages. It was only necessary to make certain signs on her hand while she touched some object to enable her in twenty days to comprehend the complete idea which a special sign represented, and, thanks to this convention, persons could communicate

their thoughts to her. A month and a half later she recognized the letters of the alphabet by touch. After another month she wrote a letter to one of her cousins. At the end of three years she had acquired a stock of ideas sufficient to enable her to converse freely, to read with intelligence, and to write good English. The idea was then conceived of having her feel the movements of the pharynx, the lips, and the tongue which accompany human speech, and, by imitating these movements, she reproduced the sounds which were articulated in her presence. A month sufficed her in which to learn to speak English correctly, and by merely placing her hands on the lips of her interlocutor she commenced to read with her fingers the words which were spoken. Thus, by the aid of touch alone, Helen Keller procured three openings into the external world, three routes which brought her ideas from without—the manual alphabet, reading in relief, and human speech. By these three means of acquisition she placed herself within that small intellectual aristocracy comprised of the very highly cultivated. Finally, not content with speaking her native language, she studied French—which she writes correctly—Latin, and even Greek.

If Helen Keller was able to do these things why should one be astonished that the blind, who hear and talk, progress daily toward a complete development of their intellectual faculties? Her example shows us how our brains come to us rich in hereditary endowments centuries old, fashioned for life, eager to receive ideas, and to develop them. It proves to us that sometimes a faint ray of light suffices to illumine the covering of darkness which envelops these endowments, and to fructify them. The intellect of the blind, which we readily look upon as entirely overcast, is illuminated through and through by light from without. Leaving out of account taste and smell, which, though rich in sensations, convey only elementary ideas, he has the sense of hearing and that of touch, the former for spoken thought and the latter for written thought—both precious as means of knowing external objects. Through these two large windows open on the world a flood of ideas enters. What matters that before the third a blind remains lowered? The daylight penetrates abundantly enough into the interior to rouse full activity within.

By the sense of hearing, not less than by that of sight, man is, as it were, plunged into a world of sensations which stimulate him. He is enveloped by them. However passive one may suppose him to be, he is aroused from his torpor and is led on to the common life. Excited without pause by the talk of his parents, his brothers, and his sisters, who mingle continually in the external life, the mind of the blind infant can not remain inactive. There is no reason why he should remain enervated by idleness. Provided that some care is shown him, that the things which are beyond the reach of his

senses are explained to him, he will not remain behind other children of his age. Later, when he becomes a man, conversations with persons around him draw him constantly away from himself as if they were spectacles, prevent his thought from becoming isolated, turned upon himself, or confined like a silkworm in its cocoon. Montaigne, who understood this, said, "I should rather lose my sight than my hearing;" and he doubtless said this because he enjoyed conversation more than any other pleasure. But this inquiring spirit, always in search of new ideas, and who found so much delight in the free play of the intellect, well understood that the ear feeds and stimulates our thought more than the eye. He found that conversation was the most fruitful of exercises. Is it paradoxical to think that the sense of hearing is a sense more intellectual, in a way, than sight? I do not believe so. The eye, after all is said, furnishes the mind only with images of external objects, the ear carries ideas to it—all the work of reflection which thought ingrafts on these objects. It is hearing which serves as a real bond between minds. In manual work a deaf person who can see is superior to a blind person, but from the intellectual point of view I am convinced that the position of the blind man who hears is preferable to this deaf man.

The sense of touch has been explored methodically by the blind for scarcely more than a century and a quarter. Valentin Haüy in 1784 established the first special school for their use, and it is this methodical utilization which has transformed their condition and permits them to-day to assume their rôle in society. The education of touch is the essential part of that which may be called the special pedagogy of the blind. It is reclaimed and domesticated in such a way as to make it fill the offices abandoned by sight, and this substitution is very important as regards intellectual development. In all times it has been touch alone which has given to the blind the notions of form, resistance, etc., from which are constructed those ideas of the external world, which sight conjointly with touch gives to those who can see. Spontaneously and without the need of study it has entered the ordinary domain of sight and brought to the mind of the blind the knowledge of objects which, in general, are beyond its reach. The efforts of the educators consist at first in systematically developing this tendency. It is necessary to cause a blind person to touch as many objects as possible, and to feel as often as possible the objects which men know ordinarily from sight, such as large animals, implements of all kinds, and the like. As far as possible objects of the natural size are placed in his hands. In their absence one has to be content with miniatures. Thus, for poor representations, always abbreviated, and often reduced practically to a single word, are substituted concrete and precise images. Lessons on objects are for the blind child a prime necessity.

But the principal office of this pedagogy by touch is to substitute tactile means for the visual means which ordinarily serve in studies and the transmission of ideas. Flat geographical charts are replaced by maps in relief; geometrical figures are also traced in relief, etc. Of all the exercises, reading is that which is most profitable to the intellect. Reading by touch is the most important of all its adaptations. It has made considerable progress during the last 125 years.

Valentin Haüy was content to have the ordinary characters of the alphabet traced in relief, but these characters are composed of lines, and lines, though easily perceptible to the eye, are only slightly felt by the finger. Furthermore, writing and reading were so slow that they were of very little service. The idea was then conceived of substituting for the system of signs borrowed from those who see, an entirely different system adapted to the special conditions of tactile sensibility. The line was succeeded by the point, which the finger perceives much more easily, and the system of Braille came into existence, in which each character is represented by a number of points, not exceeding six in all. Reading then became rapid, less rapid, of course, than reading by means of the eyes, but sufficiently so to enable one to read aloud, and very agreeable for reading to one's self.

But the printing of books is expensive, and the demand for them insufficient to cover the cost. Scarcely more than the really essential books could be printed, those which were necessary for the instruction of the blind and for the practice of their professions. The benefit to the reader by touch still remained too limited. Another step in the direction of progress was necessary. It has been realized by the foundation of the Braille library, a library composed of manuscript works in the Braille system, which, although it has not been in existence for more than a score of years, already numbers 25,000 volumes. Nearly all of them have been written by various persons, and especially ladies and young girls, who each week, sometimes every day, devoted some hours of leisure in preparing reading matter for the blind. These volumes, masterpieces of patience and charity, are sent in all directions to all those who desire to learn from them. They carry everywhere sound and beneficent diversion, a glow of joy in the darkness, a ray of light which illuminates the intellect and warms the heart. The Braille library also disseminates journals and reviews in relief, no doubt rather brief, but sufficient, not only to inform the readers regarding all which is of interest in the special world of the blind, but also to make them acquainted with the political, literary, and artistic news which no one should ignore.

Thanks to this library, one may say that an abundant intellectual nourishment has been placed within reach of all educated blind persons. Considerable progress has been made in this direction. Before

the library was established, when school days were over only those could continue to read daily who could command the services of a reader, and those fortunate persons were very rare who could afford so expensive a luxury. In consequence no reading was done. To-day it is only necessary to write to the library in order to have books sent, or to draw on the branch libraries which circulate in the larger towns of France. Upon leaving school one is invited to maintain the knowledge acquired and to cultivate one's mind. A characteristic fact witnesses the progress gained. The blind who are more than 40 years old nearly all read very badly, while nearly all good readers who are blind are less than 40 years old. The latter belong to the generation which has profited by the Braille library. The former were read to when they had the means; the latter likewise were, no doubt, read to, but they also read by themselves, and hence they read better and read more.

One can appreciate the benefits of such a work. They are such that we never cease to solicit all philanthropists in its favor. It needs to be much extended. All grades of intellectual culture are represented among the blind. To satisfy so many tastes, so many different needs, we require a large and constantly increased number of volumes. On this account we continue to ask authors who desire to manifest their sympathy, to send us copies of their works, so that we may have them copied; and to ask philanthropic persons to transcribe their favorite authors by the Braille method, which is learned without effort. At a small expense all can assist in a work which brings to the disinherited blind much prized diversion as well as instruction.

Intellectual recreation is, indeed, especially dear to the blind, as one can readily conceive. Ordinary men get the greater part of their pleasures through their eyes. Deprived of these pleasures, the blind ask, in exchange, for others for their other senses. They ask not to be cheated of their share. Here, as elsewhere, we find the substitution of active functions for those which refuse to serve. They ask compensations especially through the sense of hearing, and everyone knows how numerous are blind musicians. They also ask much from the exercise of the intellect and of reflection. "I am so happy," writes Helen Keller, "that I could live always, because there are so many fine things to learn." In general the blind are very fond of reading, much more so at least than those of the same intellectual level who can see. In the schools for the blind the hours spent in reading in common are greatly enjoyed. I know blind persons who are occupied all day who devote a part of their nights to books. Letters of thanks which readers address to the Braille library are often full of singularly touching gratitude, well calculated to encourage those who labor to help them.

This taste for reading, this need of mental diversion, constitutes, if I am not mistaken, an intellectual advantage of much importance for the blind and favors their development. They are besides often well endowed as regards memory, and how great a prize that is everyone knows. In truth, it seems to have a tendency to decline among the blind from the time when they begin to write with ease, though it remains good, nevertheless, on the average. Shall I also take into account that their infirmity protects them from the invasion of the magazine? The substitution of the magazine for the book, of miscellaneous facts and patchy articles for the long matured work, seems in our age to be one of the obstacles to intellectual progress. The periodicals in "braille" are reviews rather than magazines, and the part devoted to miscellaneous news is very much condensed. If the blind are not coached by some person with sight who is in their circle, and who reads to them every day from a newspaper, they escape the contagion. They are able to give to books all the time for reading which is at their disposal. As I have done this much toward an endeavor to recognize their advantages, I must lay stress on the principal one, namely, as I believe, a tendency to reflection, to the concentration which is noticeable among so many of them.

I do not exaggerate at all nor do I, of course, pretend to lay down universal rules. We are not concerned at all in determining the character of the intelligence of the blind man as if this intelligence were a fixed quantity. Among the blind, as among those who can see, there are as many forms of intelligence as there are individuals. There are some who are dissipated, some who are capricious and inconsiderate. Among the best endowed, however, a certain poise is often observed. Intellectual culture being equal, there is often, I believe, more of equilibrium and judgment among the well-endowed blind than among those who see. This is not astonishing, because sight, as we have already said, is the sense of distraction. The less one is distracted, the less the internal reverie is interrupted by accidental happenings without, the more one is concentrated on himself, the more one takes time to mature one's reflections, to weigh the pros and cons of one's deliberations.

I have encountered in the world of the blind some of the most sympathetic intelligences that I have been privileged to know. I do not speak here of eminent scholars, but of men living wisely and intelligently, of men who perform feelingly their daily task, whatever it may be, and who constantly, in the practical affairs of life, give evidence of good sense and wisdom. Often their intellect has great steadiness joined to extreme flexibility. I will not mention any living person, but scarcely a month ago a man died who has left behind an ineffaceable memory among all those who associated with him. M. Bernus was professor of grammar and literature in the

Institution for Blind Youth in Paris. He lost his sight when he was very young. Educated in this school, where he later became an instructor, he had received an elementary education, quite insufficient for the needs of his mind. He was also seized with that thirst for reading of which I have spoken. He listened eagerly to reading and developed his faculties by himself. Appointed professor on leaving school, and almost without preparation, he owed to his reading the solidity and originality of a very personal instruction. He had a singularly delicate literary taste. He wrote nothing, partly from modesty and partly because from his point of view execution was much inferior to conception. Simple, courageous, he taught a primary class for eight years, and up to the time of his death. A little slow in mind as well as in body, he responded feebly to impressions from without, but he had singular powers of concentration, and his meditation was intense. When one had penetrated his rather cold exterior, one encountered a very active mind—a man of great penetration and original thought. He was also an excellent adviser. I dwell on this example because M. Bernus, whom so many of his blind pupils have loved, appears to have united in himself so many of the most salient characteristics which are ordinarily found in the mind of the blind.

Louis Braille, we are told, was of the same type of mind. His manner was reserved, his conversation was not brilliant, but the solidity of his thought caused all those who knew him to seek his opinion. From his youth he was able to concentrate his mind with so great tenacity on an idea that at the age of 17 years, after long groping and many fruitless combinations, he had already fixed on the marvelously simply alphabet with which his name will always be associated.

A goodly number of blind persons seem to have achieved a certain notoriety by their intellectual culture. Unfortunately, we are generally in ignorance of the conditions under which they developed and the means which they employed, and we lack precise data regarding their psychology. Many represent scarcely more than names to us. Among them are certain of the ancient Greeks and Romans, such as that Diodotus and that Aufidius of whom Cicero speaks in his Tusculanes. Didymus of Alexandria, who lived in the fourth century of our era, is a little better known. Toward the end of the middle ages various scholars of remarkable memory, Nicaise, of Malines or of Verdun; Fernand, of Bruges, and Pierre Dupont, of Paris. Regarding Ulrich Schomberg (1601–1648) we have the testimony of Leibnitz. "He taught philosophy and mathematics at Königsberg," says Leibnitz, "to the admiration of the whole world." Although he did not lose his sight until 2½ years of age, he did not retain any remembrance of light or of colors, so that visual impressions counted for nothing

in the formation of his intellect. In the eighteenth century the Swiss Huber obtained some reputation through Voltaire and, thanks to Diderot, we have become acquainted with the Englishman Saunderson. The former studied the habits of the bee, but it should be remarked that having enjoyed the use of his sight until the age of 15 years, he had received the greater part of his education while he could see, and that he was able to make use, without interruption, of the visual imagination. Saunderson, on the contrary, became blind in his early infancy, but it appears nevertheless that he carried his mathematical studies to a great length. Like Saunderson, who was a professor at the University of Oxford, many of the blind whom we have mentioned taught those who could see. It was the same with Penjon, who at the beginning of the nineteenth century was professor of mathematics at the college at Angers. As we have seen, mathematics and philosophy predominated in these cases. Among poets we can scarcely cite anyone but Malaval, who achieved a certain notoriety, for we can not name the great poet Milton, since he did not lose his sight until after he was 30 years old.

Though these names do not shine with a great luster, they suffice to prove that blindness does not contravene the full development of the intellectual faculties. Furthermore, any one who desires to assure himself on this point has only to visit a community of the educated blind. They can be found in all countries, and especially in the great institutions for the blind. In all countries also one encounters blind students, who perform various tasks with success. In France we know a doctor of philosophy, a master of literature, and a doctor of laws.

If, moreover, in the past such a number of blind men as we have mentioned and many others also whom we do not know, left to their own resources, without the aid of any method or tradition, have succeeded in cultivating their intellect, why should we be astonished that to-day, when they find institutions ready to receive them, when a complete system of pedagogy and methods of work have been devised for their use, if a large number reach the same result? All this does not prevent there being much labor wasted, as one may say, or many blind persons who are incapable of a normal development. As experience shows, blindness is not the cause of this. There are maladies which often accompany blindness. This waste will even, perhaps, increase in the future. In certain quarters, already, it is believed (incorrectly, perhaps) that a decline in the average intellectual development among the blind is perceptible. Recently, the progress made in the prophylaxis of blindness has rendered it possible to save some invalids who at another time would probably not have escaped disaster. Probably more will be saved later on. The territory thus gained will all be that of localized affections which involve only the

eye—in particular, the horrible ophthalmia of infants. In the generations of blind persons who will rise to the intellectual life doubtless a larger and larger proportion of unfortunates will be found whose sight will be obscured by some one of those deep-seated maladies which affect the brain and the nervous system. Far be it from us to complain of this intellectual decline, if such be the cause. With all our hearts we long for the time (alas, far off) when the oculists will permit only idiots to lose their sight. If that time should ever come it would be necessary to understand that it is not blindness which produces imbecility, but that imbecility and blindness both proceed from a deeper cause. To-day it is important not to forget this and if one meets a blind man of low mentality to resist the temptation of judging others by him.

Without doubt one great difficulty exists, and as we have pointed out the advantages which the blind, perhaps, enjoy, it is necessary to mention it in turn. Documentation is always much more difficult for the blind man than for the person who sees, and it is always liable to be rather deficient. Books are to a less degree at his disposal. They invite him less to reading. Many are inaccessible except by the intervention of a person who can see. Formerly this difficulty was less evident, because it was much less necessary to read than it is to-day. The transmission of knowledge was effected to a larger extent by means of speech. At present in most cases this inferiority does not appear to me to be of very great moment. The musicians trained by the Institution of Paris are certainly not inferior, from an intellectual point of view, to those with whom they associate, and the workmen are in general superior as to culture to the workmen who see. In average conditions, the evil is not a great one, although, of course, it becomes a much more serious obstacle to those who have pretensions to a great intellectual development. Provided, however, that the conditions are favorable, there is no doubt that the methods which for a century have been at the disposal of the blind, joined to those which they could command previously, enable them to triumph. Even for the advanced intellects there is nothing that is insurmountable.

II.

In an article in which he spoke very graciously of my books on Montaigne, M. Victor Giraud remarked[a] that it would be interesting to know the methods of work which a blind person employs when engaged in the minute inquiries which such works presuppose. I am very glad to respond to his suggestion, and the more so because it will enable me to show the marvelous services which we can derive from the method invented by Louis Braille, and its adaptability for our

[a] See the Revue des Deux Mondes for February 10, 1909, p. 628.

needs. In the lines which follow I am less concerned than Braille, because it is Braille who has enabled me to accomplish things, and others as well as myself. From a psychological point of view, or a typhlological point of view, as we say, the only interest which my books on Montaigne have is that owing to our special methods philological researches and works of erudition are not prohibited to the blind.

I lost my sight when 4½ years old. From my earliest years no clear visual remembrance has remained with me, perhaps because heedless infancy scarcely fixes its attention on anything. or, what is more likely, because in the total darkness in which I have lived since no visual impression could enter to wake the sleeping memories. In a large sacred history which was opened before me I remembered vaguely a picture of Abraham slaying his son, while an angel descends from heaven to stay his arm. Is it perhaps possible that the wings of the angel, which struck my childish fancy, may have left some traces in my memory? All is so vague, however, that I scarcely dare believe it, and especially because if I attempt to grasp my remembrance it vanishes immediately. It is more a remembrance of vision than a visual image. I have quite exact ideas of color, but for lack of means of comparison I do not know whether they are exact. When I lost my sight I did not know how to read. My education has therefore been entirely the education of a blind man.

I received my first lessons by listening to my brothers read aloud. It was found that I had a good memory. At the age of 8 years, an age when the sense of touch is still acute, I commenced to study Braille's alphabet, which costs a child less toil than the ordinary alphabet. Also while quite young I familiarized myself with the two methods of work which I should have to make use of later—reading aloud and reading by touch. A sojourn at the National Institution for Blind Youth at Paris initiated me more fully into all the special methods of the pedagogy of the blind, which are better taught in this school than in most others, and thus prepared me for the studies which I should have to make in the different colleges of Paris. There, even for Latin, Greek, and often even for French, I lacked books in relief. I transcribed and had transcribed those which were indispensable to me. The Braille library placed many at my disposal. In addition, my devoted friends aided me in this task. But more frequently than otherwise I learned my lessons through a secretary, or a comrade, who read them to me. I used continually the Braille system for all that I wished to preserve for writing rough drafts of my lessons, and especially for taking notes on the course given in the class room. In consequence of this continual exercise I managed the stiletto with rapidity, and by means of stenography,

which I enriched little by little with new signs, no sentence of the course escaped me. As for the papers which I had to submit to my professors, I wrote them with a writing machine, the same which I am making use of at the present moment. It is a typewriter which differs in nothing from the ordinary model. Of course I am unable to see the letters inscribed on the keys which I strike, but memory very easily supplies this defect. Moreover, typewriters who can see always write without looking at the machine.

For some years the blind have made much use of typewriting, and the process is so simple that less than an hour after I received my machine I wrote my first paper without assistance. The only difficulty consists in the fact that I am unable to read over what is written. For that I am obliged to call on a person who can see.

Owing to these methods, and also to the excellent teachers, some of whom have shown toward me an unlimited devotion, I had no difficulty in keeping pace with my comrades, and I passed my classes with success. At the same time, I have accustomed myself to make the most of the conditions under which I labored, to profit by reading which I heard as much as by reading which I did for myself; to multiply my notes in "braille," and to classify them in a methodical and practical manner. All this was of service to me later.

When I entered the higher normal school I felt at once that a change was effected in my studies. The work of assimilation, which was that of the secondary schools, was succeeded by the work of production, scientific work. I confess that at first I was disquieted by it. It was necessary to go to the sources, to handle a mass of books without any guidance. My tastes led me toward literary history, and in no kind of studies does documentation present so many difficulties as in history. I regretted at times not being of a philosophical turn of mind, because I was aware that a philosopher demands less from books and draws more from his own resources. Necessity also imposed on me the task of learning to use bibliographical aids as methodically as possible in order to guide with more certainty a secretary, who, moreover, became inseparable from me, who supplied me constantly with eyes, but eyes more and more passive in proportion as the needs became more personal and more complicated. Before leaving school I applied myself to the study of Montaigne.

In order that one may understand in what my task consisted, I am under the necessity (and for this I ask the pardon of my readers) of recalling briefly the point at which the study of Montaigne had arrived when I first took it up, and the object which I set before me.

It is generally the custom to read the essays of Montaigne as if they constituted a homogeneous work and form an entity. One sought in his philosophy a single idea, almost a system, and as one frequently encountered contradictory judgments, some contended that they were

stoical, others that they were epicurean. Some regarded them as skeptical, while others attributed them to dogmatism. Those who were religious affirmed that they were atheistical. In his style one ran against equally great contrasts. By the side of jejune chapters, devoid of originality, one found admirable essays, rich and full of personal feeling, as everybody knows. It seemed to me that all these apparent contradictions and these differences could be explained, that they corresponded to differences of date in the composition of the essays, and that the thought of Montaigne varied from time to time in the same way that the style of an artist changes. Retracing, as far as possible, the successive stages which his thought had traversed, the layers deposited one on another in his mind by the transformations of his work; in a word, to retrace the evolution of Montaigne as a philosopher and as an artist—such was my plan.

In order to realize it, the first thing to do was to determine the chronology of the essays. It was necessary to investigate the allusions to contemporary events which they contained, to identify these often obscure events, and to fix the date, often at the expense of extended research. Without a firmly established chronology there can be no historical studies. But to fix this chronology and to make clear the evolution which it should reveal to us, it was important to recover Montaigne's reading. Indeed, various chapters inspired by the same book were likely to be contemporaneous. His series of readings might reveal much concerning his series of compositions. I was obliged, therefore, to commence by reconstructing what could be found of Montaigne's library, his "libraire," as he called it, and, as fast as I replaced the books on the shelves, to examine each for the material which it had furnished.

This detailed and very extended inquiry was, then, the necessary point of departure of my task, and it constituted the most difficult part. In order to comprehend how it was possible, and how it furnished a solid foundation for the edifice which I wished to construct, it is important to recall that Montaigne usually quoted with much accuracy the authors who inspired him. One finds in the essays phrases copied almost verbatim from the books which he admired; in other places there are only allusions, but allusions so precise that one can sometimes trace the source with certainty. As besides, Montaigne spoke with pleasure of his reading, and has given us his impressions regarding much of it, such an enterprise has a good chance of success. It was begun by annotators of the essays, such as Coste and Victor Leclerc. It was only necessary to continue with more precision and more patience.

My first care, then, was to transcribe in braille Montaigne's entire work. My collection of the essays comprised twenty volumes. I was able, then, very easily and without any extraneous aid to study

them at first hand, to make myself thoroughly familiar with them, and to put on memoranda. My memoranda, written out in braille were divided, properly speaking, into two catagories. On those of the first group were written all the ideas which were expressed in the essays. On those of the second group, all the images, characteristic expressions, and figures—in a word, all the peculiarities of style. For the last group were reserved the historical examples, the anecdotes, and narratives of all kinds which swarm throughout the essays. Then, the three lots of memoranda were classified, each separately, in alphabetical order, and placed in a large box, which for many years remained constantly within reach of my hand.

All these memoranda were written out in relief in braille characters. The characteristic word of each of them, that which served to give it its place in the alphabetical classification, was written at the bottom. Thus, all being placed upside down on a slightly inclined plane it was only necessary for me to run my fingers rapidly over the edge which they presented toward me in order to immediately discover in these rather high piles the memorandum which I needed. The search did not take any more time, I believe, than would have been demanded of a practiced eye. Seated before my boxes, I had only to read over again the books with which Montaigne might have been acquainted. Every time that I was struck by an idea, an image, or an example which I had encountered in the essays, I extended my hand toward the memorandum on which this particular was written. This having been found, referred me to the exact page of Montaigne and permitted me to verify my recollection. If, as I supposed, there was a citation or allusion, I wrote my discovery, always in braille, on the memorandum, where several lines had been reserved for the purpose.

I should have read also, in order that my inquiry should be fruitful, nearly everything that had chanced to interest Montaigne—and his mind was one of insatiable curiosity. In his time Latin and Greek literature were almost entirely vulgarized, and his education inclined him particularly to borrow from the ancients. In addition, he read many French and Italian books. It was necessary for me, therefore, to pursue my inquiries in the Greek, Latin, French, and Italian works then published. The first point was to discover their titles by means of bibliographical aids which I had collected. The second was to search in the public libraries for books which might interest me, for these books were often very rare. Many of them have not been reprinted since the sixteenth century. For those which have been, it was necessary to have recourse to editions of that time, which sometimes differ materially from those which have been put out since.

It is not necessary to remark that all these were not transcribed in braille. I was not able, therefore, to read these works, but had

them read aloud to me. The practice which I had had, as already remarked, made this method of work so familiar to me that for works which are not of an artistic character, I prefer reading aloud to reading by touch.

However, as regards inquiries of this kind, I will not endeavor to deny that they present real difficulties. In the first place, and before all else, the impossibility of running over the matter is the great drawback to being read to aloud. The eye is quick to scrutinize a page, eliminate the whole of a useless chapter, and make sure that it contains nothing of any interest. Nothing can replace the eye for this purpose. It is necessary to resolve to listen carefully to useless developments for fear of imprudently skipping over an important idea. When I risked skipping passages, it was necessary that they should be short. It was necessary, indeed, to know all the different directions which the argument took. When one direction was sterile it could be abandoned, but it was important not to pass the exact point where the thought entered on a new path. Sometimes I employed a signal (a stroke of a ruler on the table, for example) for interrupting an introductory sentence, and it was understood that my reader was to begin further along, according to the character of the book, either at the beginning of the following sentence or at the next line, or five or six lines below. But these expedients were only moderately successful and had to be used very conservatively. Another difficulty is that borrowed eyes have never the docility of those which are under the direction of one's own will. A secretary, however devoted, grows weary of an extremely monotonous task, the interest of which escapes him. I do not attempt, therefore, to minimize the difficulties which a blind person encounters in such work. Taking all in all, however, they are difficulties only and not insurmountable obstacles. To succeed, it is necessary to have a little more patience, a little more perseverance, that is all.

Chronological researches can be made in the same way, and when the investigations of sources and chronology were completed, nothing remained to be done except to concentrate the results, assemble and condense them, and to make clear by their light the evolution of Montaigne's thought. This was merely a matter of reflection, the most agreeable task of all, because it was carried on without the use of books or any extraneous aid, and because it was all mental and depended on myself alone.

For the easy maturing of this reflection my memoranda in "braille" were both necessary and sufficient. I have already shown how easy their handling was to me. I believe that in this regard the blind man does not suffer from any inferiority, and the more he exercises his faculty of concentration the easier his task becomes.

Finally, we come to the work of editing. So many blind persons have published and are publishing remarkable articles and works that I have nothing really new to say on this subject. The editing of a work of erudition scarcely presents more difficulties than for a popular work. It merely requires more precision as concerns numbers, masses of dates—all things which require scrupulous care. It presupposes above all a mass of notes at the bottom of the pages, references to texts, and documentary proofs. All that may take one by surprise at first, but, by means of the notes in "braille," it is always possible, without too much labor, to attain a rigorous exactness. My volumes are studded with figures and exact references. My extracts having been made methodically, and the results drawn from them carefully recorded with all the indications arranged in proportion to and in accordance with the circumstances, it was easy for me to support my assertions with the critical proof which they demanded. There again it sufficed for me to refer to my memoranda, where everything was noted.

As to the mechanical execution and the actual composition, two methods were open to me. I could write out the work in "braille" in such a way that I could read and correct the matter myself, and turn the copy over to a typewriter to put into type, or I could copy my rough draft again on my own typewriter. I have used both methods, sometimes preferring the one and sometimes the other, according to circumstances. When I had to do with particularly difficult pages, requiring special accuracy, it seemed to me better to make a rough draft in relief, in order to be able to consider and compare it freely. For ordinary passages I much preferred the typewriter from the first.

One may be surprised that the rough drafts in "braille" were not always preferred. The writing, in spite of numerous abbreviations, was rather slow, and, furthermore, required a certain expense of physical energy. These two circumstances lessen the buoyancy of the mind and divert attention from the work of composition toward the details of mechanical execution. I am aware that some blind persons are less sensible of these inconveniences, but I know that there are others like myself who find themselves disconcerted by them. Typewriting, on the contrary, is quick and easy. It accompanies but does not interfere with the flow of the mind, which is scarcely conscious of its very flexible mechanism. Doubtless a person who can see finds it difficult to understand how anyone can write without being able to read over the paragraphs that are finished. I find that habit triumphs over this difficulty—at all events, with me it was a triumph without labor. The care involved in a methodical and rather rigid composition is in part the cause. When one has his plan well in mind, with even the details in order, one does not lose the thread of its

development, however lacking in exactness one's memory may be. It was very rarely that I found it necessary to seek the aid of other eyes to find my place, or to recall the form which I had given to any preceding sentences. Frequently I suspended the editorial work in the midst of the development of an idea. I left the sheet in the machine and sometimes after an interruption of forty-eight hours, or even more, took up the thought again without hesitation at the point at which I had left it. Moreover, I did not deprive myself of the opportunity of correction. The editing over, I had the matter read to me as many times as was necessary, dictating to my secretary modifications and sometimes very numerous additions, and adding everywhere a thousand finishing touches. I believe that I can say that my style was not less imperfect when I wrote the first draft in "braille." On the contrary, if it was perhaps a little more vigorous, it was also rather stiffer.

Finally, and this is what I particularly wish to note, the elaboration of these 1,250 very compact pages did not by any means cause me the prodigious labor that one might naturally expect. The one part which was long and tedious was the extensive preparation, all that which did not appear, the documentation which served as the basis of the work. I retain the hope that anyone who has followed my exposition is convinced that the undertaking can be carried on without any great difficulty and that the methods which are open to the blind lend themselves perfectly to its accomplishment. They have given me, I believe, means of conforming exactly to the course that any person who can see, desiring to treat of the same subject with accuracy, would be compelled to follow. In all my proceedings I have invented nothing. Any person with sight would, I think, be compelled to use some form of memoranda analogous to mine. I simply adapted a common and almost necessary method, I may say, to the special conditions of the blind. This adaptation was a very simple one and did not demand any great effort of the imagination. It was developed little by little, by successive steps, in accordance with the needs. It sprang in a certain way from circumstances.

My design, as one may suppose, is not to incite the blind to engage in the production of works of erudition. To succeed in this it is absolutely necessary to have the taste, the passion for learning, and most fortunately few persons are afflicted with this malady. What a strange life it would be if we were all metamorphosed into book-worms! Very fortunately, too, there are other works more accessible to the blind in which they have less trouble in rivaling those who can see. In all that I have recounted it is not necessary to see an example, but an experience—an experience which, certes, will not surprise the blind (who, at least, will see that everything here men-

tioned is quite simple), but may, perhaps, suggest to them some useful observations on certain applications of their own peculiar methods of work. It is, however, addressed especially to those who have sight. With so many other experiences which are renewed every day, it will contribute, perhaps, its little part to inspire them with more equitable judgments on the blind. It requires such an unending array of facts to combat a prejudice and to cause it to retreat step by step that we can never have enough. This will serve as one among many. Let us also hope that it will make an impression on the ranks of the enemy and work for the common welfare.

In conclusion, it remains for me to excuse myself for having spoken at such great length about my own affairs, but if the "I" (that of Montaigne excepted) is nearly always objectionable, the reader will pardon me when he notes that, in spite of appearances, I have mentioned much less regarding my own personal work than regarding that of the blind in general. What I have done any other blind person might have done in my place. Our methods of work are common to all. I have wished, by means of one example, to show the flexibility of our methods. Perhaps, after having read the foregoing, all will understand better how much we appreciate the inventor of an alphabet to which we owe the major part of our culture and our intellectual pleasures.

THE RELATION OF MOSQUITOES, FLIES, TICKS, FLEAS, AND OTHER ARTHROPODS TO PATHOLOGY.[a]

By G. Marotel.

It is a matter of common knowledge to-day that while there are many arthropods which live a free life, there are also many others which are parasites, causing in man and also especially in the domestic animals many and varied diseases, the origin and nature of some of which have been known for a long time. It would be banal to recall that phthiriasis is caused by lice, and that certain larvæ of Diptera, such as the œstrids, may occasion the disease called myasis.

This old pathogenic rôle, which has been taught to all the medical and veterinary generations of our time, is quite true. But it is not of this that I wish to speak. It is of a new rôle, brought to light only within the last ten years, the importance of which now grows greater every day, for scarcely a month passes, I might almost say not a week, that some work does not appear which adds some unknown fact or new theory relative to it.

It has to do with one of the questions which in the whole range of parasitic pathology can, with the greatest right, claim to be of practical importance. The danger from the arthropods is a direct consequence of their habits. It only exists in connection with those whose habits are to seek association with men and domestic animals, to bite them and to suck their blood.

Everyone knows that a number of species, such as mosquitoes and gadflies, pass a considerable part of their time in flying from one victim to another, in the same manner that bees wander from flower to flower. Let us suppose, then, that in the course of these wanderings one of them happens to fasten itself on an individual affected by a parasitic or bacterial disease, the agent of which lives in the blood. In sucking the blood it absorbs also the germs which are contained in it, and thus is infected. Should it then attack a healthy person there is danger that it will inoculate him with the disease. This is why

[a] Translated by permission from Annales de la Société d'Agriculture, Sciences et Industrie de Lyon, 1906, pp. 279–302.

the biting and sucking arthropods (I insist on these terms) recently considered as being simply troublesome, vexatious, uncomfortable, and disagreeable, have to be looked upon to-day as capable of becoming carriers of infection, agents for the propagation and dissemination of disease. This is why it will be understood henceforth that man and the domestic animals are exposed to certain affections, the germs of which are introduced by invertebrate blood-suckers which they have previously drawn from the sick vertebrate.

Such is the method of this new rôle, which I wish to try to explain here and which modern researches have shown to be of more consequence, especially in warm countries, than could have been suspected previously; so much so that the value of our colonial domain is subordinated (the word is not too strong) to the discovery of the proper means of neutralizing the pathological action of these animals.

Thus, these arthropods, which ten years ago had only an ordinary and purely zoological interest for us, have assumed prime importance both from a medical and a hygienic point of view, and especially in tropical countries. The principal forms connected with the latest discoveries belong to the order Diptera, or to the family Ixodidæ. It has now been established that they are the sole agents of inoculation of seven different maladies, namely, malaria, filariosis, yellow fever, trypanosomiasis, plague, piroplasmosis, and spirochaetosis.

A. PALUDISM, OR MALARIA.

Commonly called malaria, intermittent fever, swamp fever, or simply "fevers," paludism is, according to unanimous opinion, the one human disease which more than any other prevents the acclimatization of Europeans in warm countries. It is due to the invasion of the blood by extremely small sporozoans lodged in the red blood corpuscles, whence is derived the name of endoglobular hæmatozoans, which it is the custom to give them. They belong to the genus *Plasmodium* and comprise many species, such as *Plasmodium malariæ*, the agent of quartan fever; *Plasmodium vivax*, the agent of tertian fever; *Plasmodium præcox*, the agent of irregular, or spring and fall fever.

For a long time it was not known to what these fevers were due. Some said that they were due to marshes, whence the name paludism. It was also said that they were derived from the air, whence the name malaria, which means "bad air." Finally, it was said that they came from the soil, whence the name tellurism, which was also applied to the disease.

None of these was correct. All the etiological conceptions were wrong, and yet mankind for twenty centuries rested on these false

theories of which to-day nothing remains. The first ray of light appeared in 1880, at which date one of our members, Laveran, discovered at Constantine the hæmatozoan which to-day bears his name (fig. 1). But the veil of obscurity which enveloped this important question could not be completely dissipated until 1898.

It was at this time that a group of students, at the head of whom should be placed Grassi and Manson, demonstrated in an irrefutable manner that the parasite of malaria was introduced into man by mosquitoes; that is, passed from man to the mosquito and from the mosquito back to man again, and thus on indefinitely, without being for a single instant, even the thousandth of a second, liberated into the external environment. Consequently, in spite of what was thought for centuries, none of these mediums, neither the air, the water, nor the soil, can cause malaria, and these beliefs become henceforth a part of the history of medicine.

FIG. 1.—Red corpuscle, containing a hæmatozoan of human malaria (*Plasmodium malariæ*).

There is one extremely important fact: Not all species of mosquitoes can propagate malaria; only those which, in the family Culicidæ, belong to the tribe Anophelinæ can assume this rôle, and the most dangerous of the species from this point of view are first of all the *Anopheles maculipennis*, which is by far the most redoubtable; then *A. pseudopictus*, *A. superpictus*, *A. bifurcatus*, *A. funestus*, and finally a last species, *Pyretophorus costalis*.

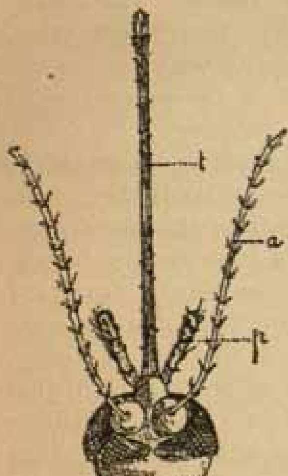

FIG. 2.—Head of a mosquito. (After Neveu-Lemaire.) *t*, Proboscis; *p*, maxillary palpæ; *a*, antennæ.

The proofs which one can give to-day of the mosquito theory are three. The first is that of Grassi, who, in 1898, in association with Bignami and Bastianelli, was able to follow the evolution of *Plasmodium* day by day in the bodies of mosquitoes which had been made to suck blood affected by malaria, showing thus that the parasite could penetrate the insect, remain there a certain time, and then leave to pass immediately to man. These students have also established the fact that while in the *Anopheles*, the hæmatozoan undergoes profound transformation, constituting a veritable evolution, and that the intimate mechanism of the transmission was as follows: The parasites sucked in with the blood lay eggs in the stomach, which eggs encyst themselves in the walls of the stomach, and produce a multitude of little vermicular spores. These, set at liberty

by the breaking open of the cyst, are carried by the blood toward the head, then into the proboscis of the insect, which inoculates them with every bite. The second proof is this: One can voluntarily produce malaria by causing healthy individuals to be bitten by *Anopheles* intentionally infected. This experiment was carried out by Patrick Manson on his own son. The third proof is as follows: Malaria can be avoided by taking the single precaution of protecting one's self from the bites of mosquitoes.

This results from the experiments of Sambon and Low, who, without the least accident, were able to pass an entire summer in one of the most insalubrious places of the Roman campagna, by simply covering the openings of the house with wire netting of sufficiently fine mesh to prevent the access of the Culicidæ.

In order to remove all doubts Sambon and Grassi undertook, in 1900, a series of experiments which showed absolutely the rôle of the *Anopheles* in the propagation of fevers. They were made on the disciplined personnel of the railroad companies south of Naples, in a region where the disease is so endemic that it is called "piano di pesto." They consisted exclusively in protecting all the inhabitants of a given zone from mosquitoes, while those of the neighboring localities, who were not protected, served as proofs. The results furnished by these experiments were marvelous. In 113 individuals of the protected zone not a single case was produced, while the persons in the neighboring unprotected zone fell sick in the proportion of 49 to 50. The proof could not have been more striking.

As regards the objections which have been made to the mosquito theory, the most serious is that in certain marshy lands there is no trace of *Anopheles*. In order to verify the truth of this observation Laveran organized, around the entire earth, a vast inquiry for the purpose of establishing a list of the mosquitoes peculiar to every marshy region. Thus far the inquiry has shown, first, that there are *Anopheles* in all insalubrious countries; second, that nearly always abundance is in direct ratio to the frequency of fevers; third, that the pretended absence of these dipterous insects was due simply to inadequate collecting, often undertaken but once and at a single point in the region.

Another objection is, so to speak, an inversion of the last. In certain salubrious localities there are *Anopheles* in abundance. That is readily explained, however, because it is evident that mosquitoes can not become dangerous until after they become infected—that is, after having sucked the swamp blood. But if there be no malaria in the country they can not become contaminated, and hence remain inoffensive.

To summarize, one can affirm to-day, without fear of being mistaken, that the doctrine of anophelism triumphs everywhere, and

that the law formulated in the beginning by Grassi, namely, that there is no malaria without Anophelines, is always true. At present, if one wishes to deny the rôle of mosquitoes in the propagation of fevers, it is necessary to deny the evidence.

Alongside the malaria of man, we place the malaria of birds, not that it is of great medical importance, but because, although it occurs in quite a large number of wild birds (sparrows, birds of prey, etc.), it has scarcely been noticed thus far in a single domestic bird except the pigeon, and in one game bird, the partridge. It has had a scientific interest of the first rank, however, because through it was first discovered the inoculation rôle of mosquitoes. It was this which opened the door to the important researches which we have mentioned on human malaria.

FIG. 3.—Red corpuscle of a pigeon infected by the parasite of avian malaria, *Plasmodium danilewskyi*. *n*, Nucleus of the corpuscle; *h*, growing hæmatozoan, containing its own nucleus and pigment granules.

Malaria in birds is almost always due to an endoglobular hæmatozoan very closely allied to that occurring in man—the *Plasmodium danilewskyi* (fig. 3).

Some months before Grassi's investigations were undertaken, Ross showed that this parasite was introduced into birds by mosquitoes belonging to the genus *Culex*, and especially by *Culex pipiens*, the common species so abundant in our part of the world. By this remarkable discovery, Ross became the real originator of the studies which followed relative to the rôle of insects in the transmission of disease. For this reason, I must mention his name in this review. in order to give him the credit that is due him.

B. FILARIASIS.

The filarias are round, filiform worms whose habitat, both as regards the organ and the species, varies extremely. Thus, one may find them in the blood, the lymph, the serous membranes, the glands, the connective tissue, etc., both in man and in the domestic animals. That which should be remembered from the outset is that whatever may be the location of the adult, the embryoes of many of these forms live in the blood. This is the case, notably, with a filaria of man, the *Filaria bancrofti*, which in adult age is found in the lymphatic vessels of the skin, while its embryoes spread through the blood.

Now, it is singular that these embryoes remain hidden during the day in the large, deep vessels, and that they pass out into the periferal circulation in the night, or strictly speaking, during sleep. This circumstance led Manson to think that the agent of transmission must be a bloodsucking insect of nocturnal habits, and to recall the mosquitoes. The mosquito hypothesis, put forward more than twenty-five years ago, could be completely verified only in 1900 by the simul-

taneous labors of Bancroft on the one hand, and of Manson and Low on the other.

These indefatigable investigators proved that if a man bitten by a mosquito was affected by filariasis, the embryoes taken in with the blood reached the stomach, the walls of which they at once traversed in order to lodge in the mass of the thoracic muscles. They remained twenty days in this situation, and were there transformed into larvæ, and then passed into the pharyngeal cavity of the insect. Thence they proceeded one by one into the proboscis, which inoculated them with every bite, in the same manner, consequently, as it inoculated the malarial plasmodium.

FIG. 4.—Embryos of *Filaria immitis* of the blood of the dog × 300. After Railliet.

The Culicidæ responsible for this transmission belong to the genera *Anopheles* and *Culex*. The same thing happens in the case of the filaria of the dog, *Filaria immitis*, which lives in the heart (fig. 4). Grassi and Noé established the fact that this worm was, like the preceding, conveyed by *Culex* and *Anopheles*, in which it accomplished an evolution comparable to that of the *Filaria bancrofti*, except that the embryoes were transformed into larvæ not in the thoracic muscles but in the malpighian tubes.

The same course is pursued by the following species: *Filaria recondita*, which lives in the fatty perirenal tissue of the dog, and is propagated by fleas and also, it is true, by a tick, *Rhipicephalus siculus; Filaria perstans* of the connective tissue of the base of the mesentery of man, which is common in Guiana and West Africa, and which, according to Feldmann, may be transmitted also by a tick which has been described but not named; *Filaria labiato-papillosa* of the peritoneum and eye of cattle, which is inoculated by flies closely allied to the common fly, the *Stomox; Filaria medinensis*, which lodges in the subcutaneous connective tissue of man, the horse, ox, and dog, and which is not conveyed by an insect, but by small crustaceans, the *Cyclops*.

C. YELLOW FEVER.

Yellow fever is a disease of man which belongs to the category of maladies called diseases due to invisible, or ultra-microscopic, microbes, because the latter are so small and attenuated that often they can not be discerned by the aid of the most powerful objectives. The most extraordinary suppositions have been made regarding the origin of this terrible disease. The celebrated experiments made in

1901 by the American commission in Cuba have shown that it is exclusively due to the bite of a mosquito, *Stegomyia calopus*. In fact, by forty different repetitions this commission was able to reproduce yellow fever experimentally by causing healthy individuals to be bitten by infected *Stegomyiá*. In addition these results, which constitute a striking confirmation of the mosquito theory, already advanced twenty years earlier by Finlay, were verified almost immediately in different places at the same time. In 1902 by Guiteras in Havana, in 1903 by Ribas and Lutz at St. Paul, as well as by a second American commission which worked at Veracruz; finally, in 1904, by a French commission sent to Rio de Janeiro. As a result the transmission of yellow fever by mosquitoes is no more doubted to-day than that of malaria and certain forms of filariasis.

D. TRYPANOSOMIASIS.

Trypanosomiasis, as one may guess, is a disease caused by the trypanosomes, that is to say, by miscroscopic infusorians with a fusiform, sinuous, or arched body, possessed of an undulating lateral membrane and a terminal filament, called a flagellum (fig. 5).

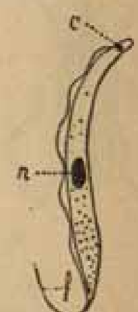

FIG. 5.—*Trypanosoma brucei* of Nagana × 2,000. After Laveran and Mesnil. *n*, Neucleus; *c*, centrosome; *f*, flagellum.

These parasites live also in the blood of their host, but with the difference, as compared with *Plasmodium* (which are lodged within the corpuscles), that they swim in the plasma. They therefore are exoglobular hæmatozoans.

At present, nine species of trypanosomes are known which are capable of attacking man and domestic animals. They cause, on almost the whole surface of the globe, the epidemics, the cause of which long remained a mystery, and of which the prophylaxis is one of the major problems of colonial expansion.

The most dangerous forms are: *Trypanosoma brucei*, the agent of an African trypanosomiasis, the "nagana," which attacks chiefly cattle; *Trypanosoma evansi*, which causes "surra" among horses and Asiatic cattle; *Trypanosoma equinum*, the agent of "caderas" among American horses; *Trypanosoma equiperdum*, agent of "dourine;" *Trypanosoma gambiense*, which causes in man an affection of which the two periods, the initial and the final, were quite recently still described as two absolutely distinct diseases, having nothing in common between them. The initial period was called Gambia fever, while the final stage was the famous "sleeping sickness," well known to the African colonists.

In addition to these principal species, there are others, less important, and also less studied, such as *Trypanosoma theileri*, which causes

in Transvaal cattle the "galziekte;" *Trypanosoma transvaliense*, of South African cattle; *Trypanosoma dimorphon*, of Gambian horses; *Trypanosoma nanum*, of the Soudanese cattle. The greater part of these parasites are transmitted by the bites of insects.

The *T. brucei* of "nagana" is inoculated by the redoubtable flies known in the country in which they are found by the name of "tsetse," but of which the scientific name is *Glossina*. A little larger than our common fly, *Musca domestica*, these tsetses are known by their enormous proboscis, which is longer than the head and is placed in prolongation of the axis of the body, as well as by their wings, which are twice as large as the abdomen. (fig. 6).

These insects, of which eight species have been described, are peculiar to tropical Africa, where they abound in forests located near water (streams, marshes, ponds, etc.), and where they remain concealed in the shade of trees and shrubbery, preferring certain kinds, such as the mimosa, for example. Eager for blood, they seize upon men and animals, which during the day traverse these wooded regions, and bite them unmercifully. These tsetses are an object of terror to the natives, and in fact they constitute one of the most serious scourges of the African tropical zone. All the explorers of the country, and Livingston in particular, have agreed in declaring that it was impossible to traverse a tsetse country, because the energies of men and beasts are destroyed almost certainly by most epizootics due to the bites of these Diptera. This suffices to show that the *Glossina* renders vast territories of Africa absolutely uninhabitable for cattle, and hence unsuitable for colonization, which are otherwise fertile and well-watered, and have a mild climate.

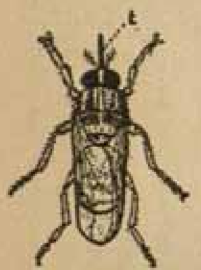

FIG. 6.—Tsetse fly, *Glossina morsitans* × 2½. After Bruce. t, proboscis.

For a long time the nature of this inoculated disease was unknown. It was said that the tsetses were dangerous because of a poison which they secreted, but no one was able to isolate this poison. It was also said that the tsetses were dangerous because they inoculated a bacterial virus, and charbon was spoken of. As in the case of malaria, there is nothing true in all this. It is known to-day, thanks to those memorable researches, the remembrance of which brings to my lips the name of the man who was the chief investigator, Bruce, that the tsetses are dangerous not because of a virus, or of bacteria, but of trypanosomes. To man they give the *Trypanosoma gambiense*, which is conveyed by a particular species, the *Glossina palpalis;* in animals they inoculate the *Trypanosoma brucei*, which is carried by all the other species of *Glossina*, notably by *G. morsitans*, *pallidipes*, and *longipennis*.

Many other trypanosomes are propagated by similar means. *Trypanosoma evansi* of "surra" is carried by fleas (*Tabanus tropicus* and *T. lineola*) and by the stomoxes (*Stomoxis nigra*). It is the same with *Trypanosoma equinum*, which is also carried by fleas and stomoxes; with *T. theileri*, inoculated by the hippoboses (*Hippobosca rufipes* and *H. maculata*). On the other hand, "dourine" seems to evade this rule, for up to the present it is considered as propagated entirely by sexual union of the insects.

E. PLAGUE.

It is known that the bubonic plague of man is due to a bacterium, the *Bacillus pestis*, and that for some time there was an agreement of opinion as to the importance of the rôle played in the propagation of this disease on board ship by the rats. The discussion centered around the essential mechanism of this transmission, when in 1898 appeared the famous theory of Simónd, according to which the plague virus was carried from the rat to man, not by the rat itself, but by the intervention of its fleas (fig. 7).

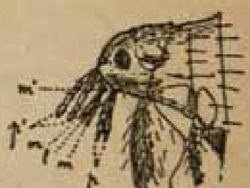

FIG. 7.—Head of *Pulex irritans* of man × 30. After Railliet. *m*, Mandibular lancet; *l*, lingual lancet; *m'*, jaws; *p*, labial palpi; *p'*, maxillary palpi.

Numerous attacks were made on this manner of explanation, and the special objection was brought forward that the fleas of the rat never bit men. This allegation was, however, false. It has since been recognized that fleas of rats and mice may, from the point of view of their relation to man, be classified in two categories. Those of the first group do not bite men even after a fast of three or four days. This is the case with *Pulex fasciatus*, *Ceratophyllus italicus*, and *Ctenopsylla musculi*. But others condescend voluntarily to attack human beings. These are *Pulex irritans*, the ordinary flea of man, which sometimes lives on the bodies of ship rats; *P. serraticeps*, the dog flea, which agrees with the preceding; then two other forms peculiar to the rat, *Pulex pallidus* (closely allied to *P. irritans*) and *P. murinus*. It is established, then, by observations made simultaneously in Italy, France, and Australia, that ship rats can harbor at least four species of fleas capable of attacking men.

It remained to ascertain whether these insects were able to carry the bacillus of plague. The experiments of Gauthier and Raybaud have, since 1902, answered this question in the affirmative, as they establish "that the plague could be inoculated from rats to rats by the intervention of their fleas." The experiment, it is true, has not been repeated from man to man, but this is really unnecessary. Proust did not hesitate to declare, with all the authority which at-

taches to his name, "that the necessary and sufficient condition for the experimental transmission of the plague was the biting of a man by the fleas of an infected rat."

What precedes concerns the present importance of insects in medicine, and I have endeavored to show how in recent years the ideas relative to the pathological power of these animals has been singularly improved. But there is in parasitology another subject of which the practical importance is just as great as that of the preceding one. This is the rôle played by ticks in the dissemination of certain diseases. Like the first, this subject has been so changed by recent work that if, in order to compare them, one should place side by side two of its classical expositions, the one made to-day and the other ten years ago, these expositions would not be in anywise similar. I shall endeavor to prove this in the lines which follow.

It is superfluous to recall here the old condition of the question, known to everyone; my shorter and simpler task should be confined to an indication of the actual state of the subject.

First, I desire to say a word or two to bring to mind certain necessary points of biology. The ticks, as everybody knows, are arthropods familiar to all, and especially to hunters, who call them by the name of "racins," or "wood fleas." They constitute in the order Acarina the family Ixodidæ, of which the principal genera are *Ixodes*, *Rhipicephalus*, *Dermacentor*, *Hæmaphysalis*, and *Argas*. The most of them, so far as domestic animals are concerned, are essentially only temporary parasites, for they attack them only during one phase of their evolution, that of the adult female. But, in exchange, these females can attach themselves almost indifferently to any of our larger mammals, and it is an error to believe, as is frequently done, that each species of animal has its peculiar species of tick. Indeed, there is not a dog tick, a cattle tick, a sheep tick, or a human tick, and if this be so, it is because, far from choosing their victims, the Ixodidæ cast themselves on the first vertebrate that comes their way.

These parasites fix themselves on the body of their hosts, in the integuments of which their beak is firmly implanted. They remain in this situation for a fortnight, during which they constantly suck blood, and they are then found under the double influence of the nourishment imbibed and the progeny which develops, swollen progressively to such a degree that an individual measuring 3 or 4 millimeters long at the outset ends by becoming from 12 to 15 millimeters long.

At the end of this period the female is ordinarily satiated. She detaches herself spontaneously, owing to inflammation and gangrene, which softens the borders of the place of implantation. She tumbles to the ground, reaches a hiding place, such as the base of a tuft of

grass, and there lays thousands of eggs for a month, when she dies. At the end of four to six weeks these eggs produce little hexapod larvæ about as large as the point of a pin, which as soon as possible pass to the body of a vertebrate of small size (reptiles, birds, or small mammals, such as moles, mice, or rats). There they grow and are transformed into eight-footed nymphs; then into adult males, or females, which mate together. From this time the fertile females leave their first host, fall on the ground again, climb the shrubbery, and from thence attach themselves to the first large animal that comes within reach. They then make their way into the hair and fix themselves in place by implanting their beak in the skin.

In tracing this course of development we return again to the stage of the female fixed and immovable; that is to say, to our starting point. Of this summary, let us remember two things which we shall need to recall a little later, namely:

First. The adult females alone are parasites of man or the domestic animals; the males, nymphs, and larvæ remain ordinarily on the small wild vertebrates, and only occasionally pass to the bodies of our large mammals. When they do so, it is simply to move about, and never to fix themselves or to suck blood.

Second. These females have during their whole life only a single large mammalian host, and never two, as when they detach themselves from this host and drop to the ground it is to lay eggs and die, and not to pass to a second host. They do not go from one to another, and can not, therefore, be carriers of virus in the manner of biting flies.

But it is necessary to say at once that all kinds of ticks do not develop exactly in this manner. There are some which in the nymph stage are parasites of a domestic animal. At the moment of becoming nymphs they leave their first host to secure a second, so that the species of this group have among the large mammals two successive hosts, one for the nymph and one for the adult. Others are parasites of domestic animals in the larval stage. They have, therefore, three successive hosts, one for the larva, one for the nymph, and a third for the adult.

It is established, in consequence, that from the point of view of their parasitism as regards man or the domestic animals the different species of the Ixodidæ group themselves in three catagories, according as they seek one, two, or three hosts. As we shall see in a moment, it is a biological fact of the first importance in that which concerns the explanation of the pathogenic rôle of the ticks.

This zoological preface being finished, it is necessary now to go to the foundation of the subject, which comprises two parts. In the one, we shall indicate the facts. In enumerating the inoculated dis-

eases we shall show the magnitude of the rôle of the pathogenic ticks. In the other we shall seek the explanation of these facts; that is to say, the mechanism by the aid of which this rôle can be played.

THE PATHOGENIC RÔLE OF THE TICKS.

It was believed for a long time, and many persons still believe, that the ticks are inoffensive parasites. This is an absolute error. It has been completely established, indeed, that they are the necessary agents in the propagation of many parasitic diseases—for example, piroplasmosis, spirochætosis, and "water-heart."

A. Piroplasmosis.—The piroplasmoses are contagious affections due to an invasion of the blood by sporozoans allied to the plasmodii, the species of *Piroplasma.* Composed of a small mass of protoplasm, globular, or pyriform, of from 2 to 4 microns in diameter, surrounding a minute nucleus (caryosome), these parasites are inclosed in the red corpuscles, where they are generally grouped by twos. Sometimes, however, they are single, or, on the other hand, united in groups of 4, 8, or 16 (fig. 8).

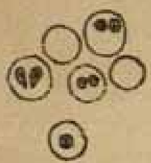

FIG. 8.—Six red corpuscles of an ox affected by piroplasmosis. Two corpuscles are sound, while the four others are invaded by one or two round or pyroform parasites. Enlargement: 800. After Lignières.

At present six different species of *Piroplasma* are known: *Piroplasma bigeminum*, the agent of bovine piroplasmosis; *P. canis*, the agent of canine piroplasmosis; *P. equi*, the agent of equine piroplasmosis; *P. parvum*, the agent of a special bovine piroplasmosis, called tropical or bacilliform (East Coast fever); *P. donovani*, the agent of human piroplasmosis (Kala-azar and, according to Mesnil, probably also of *bouton d'Orient*, or tropical ulcer; Biskra carbuncle, Aleppo carbuncle, Delhi carbuncle, etc.). But this parasite differs sufficiently from the other piroplasms to cause certain authors to make it the type of another genus, *Leishmannia.* At all events, all these hæmatozoans are inoculated into their hosts by the punctures of ticks.

This fact has been more than abundantly proven, especially by Smith and Kilborn, and confirmed by Koch and Lignières, for the ordinary bovine piroplasmosis; by Lounsbury for the canine piroplasmosis; by Motas for the ovine piroplasmosis; and by Theiler, confirmed by Laveran and Vallée, for the tropical piroplasmosis. These experimenters have shown that one can voluntarily produce the piroplasmosis by causing healthy animals to be bitten by ticks intentionally infected. The species concerned, however, vary according to the piroplasm employed, and also according to the region in which it is examined.

Thus, bovine piroplasmosis is inoculated by *Rhipicephalus sanguineus*, *R. annulatus* (fig. 10), and *R. decoloratus;* canine piroplasmosis by *Ixodes ricinus*, *I. hexagonus* (fig. 9); *Dermacentor reticulatus* (fig. 12), and *Hæmaphysalis leachi*. Ovine piroplasmosis is transmitted by *Rhipicephalus bursa;* equine piroplasmosis by *R. evertsi* (Theiler, 1904); tropical piroplasmosis by *R. appendiculatus* and *R. simus* (Lounsbury, Theiler, 1904); and, finally, human piroplasmosis may be conveyed, at Madras, by an ixodid allied to Argas, the *Ornithodorus savignyi* (Christophers and Donovan, 1905).

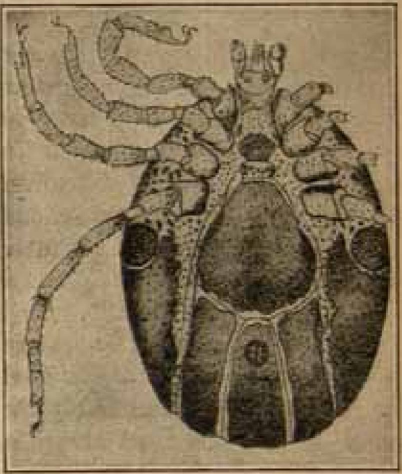

FIG. 9.—*Ixodes hexagonus.* Male. Ventral aspect. After Salmon and Stiles.

B. Spirochætosis.—The spirochætes are spiral micro-organisms, the excessively slender body of which possesses a filiform nucleus and a lateral, undulating membrane, without a flagellum (fig. 11). Classified to-day among the bacteria, consequently in the vegetable kingdom these microbes have been quite recently associated with the trypanosomes by Schaudinn and others; that is to say, are regarded as animals. The greater part of them live a free life, being aquatic animals, but some are parasites of the blood, where they swim in the plasma. These are, therefore, exoglobular hæmatozoans.

FIG. 10.—*Rhipicephalus annulatus.* Male. Ventral surface. After Salmon and Stiles.

But it is known already that many diseases caused by them are propagated by the ixodids. Thus, recurrent fever in man, due to *Spirochæta obermeieri*, which in Europe is transmitted by bedbugs (*Acanthia lectularia*), is transmitted in West Africa by certain ticks which are still unidentified (Wellmann, 1905). Tick fever, another spirochætosis of Central Africa, due to a spirochæt very closely

allied to, if not identical with, *S. obermeieri*, is inoculated by punctures of *Ornithodorus moubata* (Ross and Milne, 1904, confirmed experimentally by Dutton and Todd). Karapatti, a third human spirochætosis, which afflicts the basin of the Zambesi, is carried by the "kufu," a tick which is not well identified.

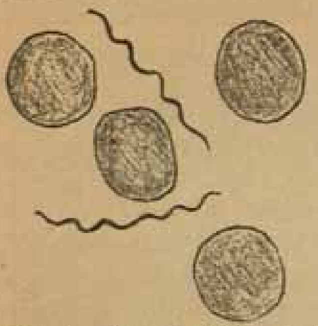

FIG. 11.—Two spirochæts of a bat. The rounded figures represent blood corpuscles. Enlargement: 2,000. After Nicolle and Comte.

The spirochætosis of fowl, due to *S. gallinarum*, is disseminated among Brazilian fowl by *Argas miniatus* (Marchoux and Salimbeni, 1903). Bovine spirochætosis, due to *S. theileri*, which was observed in the Transvaal by Theiler and in the Cameroons by Ziemann, is carried by *Rhipicephalus decoloratus* (Theiler, confirmed by Laveran and Vallée, 1905). It is probably the same for *S. ovina*, which has been found in the blood of sheep in Erythrea and in the Transvaal (Theiler).

C. Heartwater.—Finally, to close this list, which is already too long, it is necessary to add a disease, the origin of which is quite different from that of the preceding ones. This affection, which afflicts South African ruminants, is due, like yellow fever, to an invisible microbe, and Lounsbury, the expert entomologist of the Cape government, showed in 1905 that it is propagated by a tick allied to the ixodids, *Amblyomma hebreum*. Such in its entirety is the pathogenic work of the Ixodidæ. Let us now see the minute mechanism of this action.

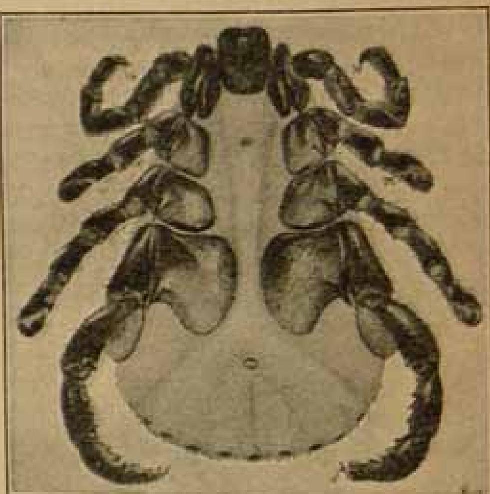

FIG. 12.—*Dermacentor reticulatus.* Male. Ventral aspect. After Salmon and Stiles.

THE MECHANISM OF THE PATHOGENIC ACTION.

The rôle of the ticks in the transmission of piroplasmosis and spirochætosis is to-day irrefutably demonstrated as much by fact as by observation and experience. Notwithstanding, it is contested by

some biologists, at whose head is an indefatigable practitioner, Mégnin, who, to the time of his death, remained one of the most ardent and persevering adversaries of the ixodid theory. It is necessary to confess that this hesitation is comprehensible, because a goodly part of the history of the intimate mechanism of this transmission still escapes us, while another part is very strange.

However, here are some of the peculiarities which are observed:

(*a*) The study of the evolution of ticks has shown us that in species having a single large mammalian host the adult female alone sucks blood. Consequently, they alone can inoculate the parasites which this fluid contains. The males, nymphs, and larvæ remain ordinarily on small wild animals. At all events they never bite men nor domestic animals. They are, therefore, inoffensive, and the females alone are dangerous. That the noxiousness is confined to one sex is the first peculiarity; the second is as follows:

(*b*) A priori, the rôle of a carrier of virus seems to necessitate for ticks, as for insects, successive transfers from one host to another. Thus it can easily include the species of groups 2 and 3, which, in turn, are transferred to two or three hosts. One can conceive, for example, that equine piroplasmosis may be carried by *Rhipicephalus evertsi*, which has two successive hosts, and which, consequently, may be infected as a nymph and inoculate as an adult. Thus, also, *Piroplasma parvum* may be inoculated by *Rhipicephalus appendiculatus* and *R. simus*, which have three successive hosts, and may be infected as larvæ, or nymphs, and in consequence transmit the infection in the succeeding stage; that is, when nymph or when adult. But for the species of the first group, which during their whole life have only a single large-mammal host, and consequently never pass from one to another, the rôle of necessary carrier which is attributed to them is in direct contradiction to their habits. However, this rôle is an incontestable reality, but it is carried out by an indirect process of a most singular nature. It is known to-day, owing to experimentation, that the young female ticks of an infected mother are themselves infected, and that they can inoculate their parasites when, having become adult, they in their turn, like their mother, pierce the skin of an animal. The proof is furnished from different quarters so far as piroplasmosis is concerned. For example, Lounsbury writes that the progeny of adult ticks (*Hæmaphysalis leachi*) fed on sick dogs can transmit the disease when they become of adult age, but at this age only. In the larval and nymph stages they are absolutely innocuous. The same has been established for bovine piroplasmosis by Smith and Kilborne and for ovine piroplasmosis by Motas.

It results, therefore, from these researches that the ixodids of the first group can only transmit the germs of disease by the intervention of their descendants when the latter arrive at adult age. These

parasites can only be inoculated by the young female ticks of those which are infected, and the propagation of piroplasmosis affords the particular information that the piroplasm passes from invertebrates to vertebrates, not by the invertebrate itself, but by its progeny.

In order to understand this it is necessary to admit that the disease germs gathered by the young acarian progeny of an infected mother have been transmitted to them by their parents, which is equivalent to saying that among ticks piroplasmosis is hereditary. This, then, is the peculiarity in the mode of action of ticks, that the transmission of the parasites is effected not by the acarians which have sucked blood, but by their descendants as the result of heredity. How is this heredity produced? This is a question which science has not yet answered.

One may believe, however, a priori, that it is due to the fact that the infection of the body of the tick by the piroplasms affect, among other organs, the ovary and in consequence the embryos. In return the eggs derived from these ovules are themselves parasitized, as the infection may then be transmitted from the egg to the larva, from the larva to the nymph, and finally from nymph to adult.

If this supposition be correct, all the individuals born of an infected mother should be infected, but as among these individuals the adult females alone bite domestic animals it results that they alone are dangerous. This is a fact which we have already noted, and which here finds its explanation. The hypothesis of an infection of the eggs received valid support from the observations made by Siegel in 1903 on an hæmatozoan allied to the piroplasms—*Hemagregarina stepanovi*. It lives in the blood of the marsh tortoise, and its immediate host is a leech, *Hæmentaria costata;* for Siegel found the germs of this parasite in the œsophageal glands and in the embryoes of the leeches, which proves that there was an infection of the egg.

Similar facts were pointed out by Schaudinn in the same year, as regards the hemogregarine of the lizard, but they are more convincing, because this time the intermediate hosts, as far as observed, are not only leeches, but ixodids like the piroplasms. The strong light thrown on the subject by these discoveries clearly permits us to suppose that for the piroplasms, as for the hemogregarines, heredity is due to an infection of the egg.

The question may be asked, Is it the same for the spirochæts? No one knows at present, but at all events it is indicated by the researches. Already in 1905 Borrel and Marchoux showed that spirochætosis of Brazilian fowl indicated a generalized infection of the tick by the spirochæt, and that this infection involved especially the ovary, so that it is probably hereditary, like all the piroplasmoses. However that may be, the heredity of piroplasmosis among ticks is of prime importance, as without it these diseases would not be contagious,

being produced by ixodids of the first group, which attack only a single domestic animal and do not pass from one to another, consequently being unable to carry the virus. It is, then, alone due to the heredity of infection among arachnids that piroplasmosis is transmissible from a sick animal to a healthy one, and this heredity appears to us, therefore, as the necessary condition of the propagation of infection.

Piroplasmosis is the best type of hereditary diseases, in the proper sense of the word; that is to say, those which are transmissible from parents to offspring by means of infection of the eggs, an infection sufficiently limited, of course, not to arrest the development of the eggs, cause their death, and hence produce a parasitic castration. On the contrary, many of the diseases considered as hereditary—tuberculosis and syphilis, for example—are transmissible from mother to child only through an accidental lesion of the placenta, permitting passive passage of germs.

(*c*) Finally, a third point in the ixodian theory will detain us, namely, Under what form is the parasite transmitted by the ticks? Is there a simple inoculation of germs, as by a lancet, in the same form in which they have been received by the acarian, or rather is there a veritable development of the *Plasmodia* in the mosquitoes? This question is still one of those which it is impossible for us to answer, because in spite of the most assiduous efforts it has not yet been possible to find the least trace of piroplasms in the body of ticks. Quite recently, it is true, the celebrated German microbiologist Koch announced that he had seen "something," but the description which he gives is so vague that really nothing positive can be gathered from his communication.

Simple inoculation, that is, the mechanical transportation of the virus is perhaps possible in certain cases, notably for the ticks of the second and third groups, which transmit as nymphs, or as adults, the germs taken in in the preceding stage, but it is not probable as regards the ticks of the first group. Lounsbury, indeed, has shown that adult ticks, transferred from a sick dog to a healthy one, never transmit the disease. On the other hand, we have seen that the inoculation of piroplasms by the progeny of an infected tick is possible only in adult age. It is true that this is not altogether general. Theiler, confirmed by Laveran and Vallée, showed that bovine piroplasmosis and spirochætosis are, in the Transvaal, inoculated by *Rhipicephalus decoloratus*, which are the progeny of infected mothers when they reach the larval stage. Further, the limitation of danger to the adult females may, as we have already shown, be explained by the fact that normally these females alone are parasites of domestic animals. Nevertheless, this peculiarity leads one to suppose that there is an evolution and permits one to ask whether in the course of its migra-

tion through the different evolutionary stages of the ticks (egg, larva, nymph, and adult) the sporozoan does not itself undergo a series of transformations more or less comparable to those undergone by the paludic plasmodium in the body of the mosquito. Probably, then, this evolution can only reach the final stage (which is the formation of spores that are still hypothetical because they have not been seen) in the organism of the adult ticks. It could thus be explained why the larvæ and nymphs are incapable of inoculating the disease. They contain only the piroplasms at an intermediate stage, in which their inoculation into vertebrates would be insufficient to reproduce the affection.

Here, again, the hypothesis of a development is rendered more probable by comparison with the facts regarding the hæmogregarines of the tortoise shown by Siegel. As we have already said, the sporozoans perform a true evolution in the leeches with the formation of eggs and spores, and this scarcely leaves any further doubt regarding the reality of a similar evolution of the piroplasms in the body of the acarian.

To summarize, we ought, indeed, to recognize that it is still unknown how the young female ticks of infected mothers propagate the disease. It is probable that the spores exist in the salivary glands, but it has not been possible to establish this so far. As we said at the beginning of this chapter, the intimate mechanism of the ixodian transmission still remains mysterious in many respects. Nevertheless, there is not a single reason to deny this transmission itself, which is demonstrated by so many facts, as some still do.

Such is the real relation of the arthropods to pathology. Without doubt, unfortunately, the list of dangerous species is far from being complete, and the redoubtable faculty of propagating diseases does not belong exclusively to those animals in which it has been recognized thus far.

In closing, I would inquire whether the discoveries which I have recalled, and which have so great an interest from the point of view of pure science, have not already had some practical effect on prophylaxis. Fortunately, one is able to say that it is due to them that protection against diseases can be turned entirely in another direction than has been done. Owing to them, one can understand that, in order to be established on a rational basis, the combat against these affections should take note of two things; first, the destruction of biting arthropods wherever it is possible, and to as great an extent as possible; second, the protection of man and the domestic animals against the attacks of those which escape this extermination.

To give an idea of the results which can be obtained by the systematic practice of these two principles we will recall in a few words

what has been done against mosquitoes. In order to develop, these dipterous insects have absolute need of still, stagnant water. It is on the surface of these waters that the females lay their eggs and that the larvæ and nymphs live. The presence of quiet waters, such as lakes, swamps, ponds, pools, or puddles is necessary for the evolution of the Culicidæ and this necessity is felt by them all. Thus, it is well known that there are certain towns which have an abundance of water have also the doubtful advantage of being literally overrun by mosquitoes so that they are rendered almost uninhabitable. This is the case with Venice, Mantua, and Livourne. It is also well known that at Majunga, Madagascar, for example, which lacks fresh water, there are few mosquitoes and the place is very healthy. Nossy-Bé, on the contrary, possesses an abundance of fresh water and beautiful, luxuriant vegetation, but also an abundance of mosquitoes and constant malaria. It is also, for the same reason that in our great African island the presence of rice plantations causes a recurrence of fever. Soon after the rice is cut these plantations are flooded with stagnant water intended to hasten the decomposition of the roots. The whole region is then transformed into a veritable putrid marsh, very favorable to the development of mosquitoes. The insalubrity of rice culture has always been recognized and it is this which caused Vivarelli to say, "the rice plantations produce two things—rice and fever. The crop of rice may be deficient, but that of fever is always abundant."

Consequently, there is no doubt that the presence of standing water is indispensable to the development of mosquitoes, and it is no longer doubtful that in principle the exclusion of such waters results in the suppression of Culicidæ. This suppression is possible in a number of cases in which ponds, pools, wells, and reservoirs are unnecessary. When it is not possible because the reservoirs are necessary, the mosquitoes can still be destroyed by a simple process. It suffices to pour a little kerosene on the water. This substance kills the larvæ and nymphs as they come to the surface for respiration. The two measures which we have mentioned, the suppression of the stagnant waters and the use of kerosene, cause the extermination of the mosquitoes. They should be supplemented by a third, the protection of individuals against the bites of those that remain.

The Culicidæ are nocturnal insects which conceal themselves during the day and fly only after sunset. It is only necessary, then, to protect one's self against them during the night. This protection can be obtained mechanically by closing the openings of houses by means of metal screens sufficiently fine to exclude the insects, by covering the face by an ample veil attached to the hat, and by covering the hands with thick gloves. Wherever this triple means of protection is used thoroughly, the diseases caused by mosquitoes have disap-

peared. Havana, which was overrun with yellow fever, is to-day healthful. Entire regions of Italy where malaria was endemic, are entirely freed from it. One can thus judge of the enormous progress realized by the prophylaxis resulting from this single zoological discovery, the rôle of mosquitoes in the propagation of diseases. It is true that equally brilliant results have not been obtained in connection with diseases transmitted by other insects, but the example of the mosquitoes justifies great hopes, and it is only proper to remember that the biological study of tsetse flies and fleas is hardly more than begun.

Much remains to be done in a branch of medicine where progress is necessarily slow, for it is specially concerned with exotic tropical diseases, which can only be well studied on the spot by the aid of missions, not only dangerous, but also very expensive.

In closing, I can affirm that the friends of science can never put too much money at the disposal of those students who devote themselves to the study of colonial medicine.

NATURAL RESISTANCE TO INFECTIOUS DISEASE AND ITS REINFORCEMENT.[a]

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Common observations early indicated that individuals of all animal species, and of the human species especially, were very unequally subject to disease. This elementary fact is impressed every day upon the thoughtful and has been, from the earliest times, the object of much ingenious speculation. Even to-day, and in spite of the acquisition of a wealth of new facts in physiology and pathology, we are not able to define fully the conditions that make for or against disease. However, the new knowledge which has been acquired enables us to see much more deeply and clearly into the complex mechanisms of disease than could be seen half a century ago; but unfortunately our insight has not been strengthened as regards all diseases, but almost exclusively in relation to the infectious diseases. In respect to the other class, or noninfectious or chronic diseases, among which are Bright's disease, vascular disease, malignant tumors, the gains in fundamental knowledge are far less great.

It may be axiomatic to state that all actual progress in unraveling the complicated conditions of disease depends upon precise knowledge of its underlying causes; and yet in an age in which comparative ignorance still requires that a certain amount of practice shall be empirical, it is well to bear in mind this notion, so that what is undertaken through knowledge may be kept distinct from what is adventured through ignorance. It has been to the lasting credit of the medical profession of an early period, when actual knowledge of the underlying causes of disease had not, and in the then state of development of the physical sciences could not, have yielded a single concrete fact, that one method—vaccination—and the most perfect one yet discovered of preventing a disease, and two drugs—quinine and mercury—specific for two other infectious diseases, should have been

[a] Read at the university lectures on public health at Columbia University, New York City, March 1. Reprinted, by permission, from The Popular Science Monthly, July, 1909.

found and so successfully applied. But in contrast to this slow, painful, and halting advance in practical means for the relief of suffering, is to be placed the body of robust facts, acquired in a quarter of a century, during the present or bacteriological era in medicine, which enables us to view in some measure the mechanisms of disease and defense against it, and which has pointed the way to efficient modes of prevention, and, in a few brilliant instances, to the production of biologically perfect means of combating certain infectious maladies. To produce a means, as has been done through the perfection of curative sera, that shall strike down myriads of living parasitic organisms within the interior of the body, amid millions of sensitive and even sentient cells of the organs, without inflicting on them the smallest injury, is indeed a great accomplishment. And if I am successful to-day in placing before you the main facts, now revealed, of the body's manner of defense to parasitic invasion, you will, I think, come to see that it has been by imitating nature's methods and by augmentation of the natural forces of defense that good has been achieved.

The facts laboriously acquired, on which this presentation will rest, have been drawn from the study of spontaneous disease—so-called natural disease—among man and animals, and from experimental diseases produced in animals. I need scarcely point out that there is really no unnatural form of disease any more than there is a really natural one; in all instances we are dealing with natural laws of health and disease, the difference merely being that in one case we are often ignorant of the time and manner of entrance of the infecting germs into the body, and in the other they are purposely introduced, in a predetermined efficient manner, in a pure state into the animal body. Since we are so often ignorant of the precise manner of ingress of the germs in the nonexperimental forms of disease, we conclude from the identity of the conditions present in the experimental and nonexperimental forms of the disease that in effect they are identical. This power exactly to reproduce at will, by pure bacterial cultures, infectious disease in animals has been of inestimable benefit in investigating disease.

To escape disease is not merely to remain without the zone of influence of the germs of disease. To do this in all cases is impossible, because with certain germ diseases—tuberculosis, for example—the germs are ubiquitous; and with several other diseases the germs are constant if not naturalized inhabitants of the body. Thus we carry on our skin surfaces constantly the germs of suppuration; on the mucous membranes of the nose and throat the germs of pneumonia, and sometimes those of diphtheria, tuberculosis, and meningitis. The intestinal mucous membrane supports a rich and varied bacterial flora among which are several potentially harmful species and sometimes, even under conditions of health, the bacilli of typhoid fever, of

dysentery, and in regions in which cholera is endemic, or during its epidemics, of cholera bacilli.

It is obvious, therefore, that it is practically impossible to escape the dangers of bacterial infection, and withdrawal absolutely from other human beings and from all human habitations would be powerless to accomplish this result. It is equally obvious that with such constant and universal exposure to bacterial infection the body must, for the greater part, easily defend itself against this class of its enemies. It is now known that this defense is not merely by exclusion of the bacteria from the interior of the body, although in itself this is an important means of protection for which special mechanisms are provided, but that constant small escapes of bacteria into the blood are taking place from the mucous membranes chiefly, and that there rarely ensues disease from this cause.

On the other hand, there is another class of disease germs that do not regularly inhabit the body and whose influence is occasional only. Some of these germs are exquisitely infectious, as, for example, those causing smallpox, measles, and scarlet fever; and others require an intermediate agency to inoculate them as in malaria, yellow fever, and possibly bubonic plague. And yet, excluding smallpox, which in ante-vaccination days overlooked few if any persons in infected regions, a great diversity of susceptibility to infection has been noted again and again among exposed persons and animals. This variability of infectivity affects difference in species, race, and individuals and constitutes one of the fundamental problems of disease. Certain diseases are naturally limited to certain species and can not at all, or can only with great difficulty, be transferred to another, although related species; other diseases appear among several species widely separated from each other; still other diseases choose by preference or are quite restricted to certain breeds of a species; and finally, individuals of a homogeneous species exhibit wide differences of susceptibility to infection. A worked-out theory of infection to and immunity from disease would include and explain all these and many more diversities which have been observed. I need not offer an apology for this at present unattained ideal.

It was early apparent that bacteria must sometimes escape into the blood and yet that infection did not follow. It was observed that frequently at death the interior of the body was free of bacteria and might remain so for many hours and until signs of putrefaction began to be apparent. The deduction from this observation was to the effect that the blood and organs must protect themselves during life and for a period after death from bacterial development. The remarkable antibacterial power of the blood was demonstrated directly by injecting putrescent fluids into the veins of rabbits and noting that not only might they survive the infections and remain quite normal,

but that the blood drawn soon after the injection was made need not, when carefully collected, undergo putrefaction. This fundamental experiment, performed before pure cultures of bacteria were available, left no doubts that the body possesses internal means of ridding itself of large numbers of bacteria.

It is apparent that the body possesses two possible distinct ways of freeing itself of these bacteria: It might remove them through the excretory organs—the kidneys or liver; it might rid itself of them by destroying them inside the body. It was with the rise of modern bacteriology that proof was brought that the blood and certain other body fluids—peritoneal, pleural, pericardial transudates—possess a remarkable power of destroying bacteria. This power resides in shed blood, in the other fluids withdrawn from the body, and even in the fluids deprived of all their natural cellular constituents. Here was then a concrete fact—the fluids of the interior of the body are capable of killing large numbers of bacteria. It could now be shown that the bacteria introduced in large numbers into the blood of a living animal are not excreted, but are destroyed within the body. This power of the blood is, however, not indefinite and is not exercised equally against all kinds of bacteria. Even with bacteria that readily succumb a very large number may exceed the blood's capacity to destroy, so that survival and multiplication would result; and certain bacterial species proved highly resistant to this blood destruction. Moreover, it was observed that the blood of all animals tested did not produce the same effects on given kinds of bacteria, that this power to destroy bacteria was lost spontaneously in a few days by the fluids removed from the body and was destroyed immediately by a temperature of 60° C. It is, therefore, a highly labile quality.

Apparently the way was opened up for the detection of the conditions which underlie infection and immunity and the various peculiarities determined by species, race, and individual. Unfortunately, there proved to be no sharp relation between the bactericidal powers of shed blood and immunity from or susceptibility to infection. And important as these blood phenomena proved to be in accomplishing protection from infection, they do not in themselves account for all observed conditions.

The factors upon which the bactericidal properties of the blood depend have now been clearly ascertained. The chief substance has been called alexin or defensive substance, but in reality the alexin is a compound and consists of a sensitive body—complement—and a more stable substance—intermediary body. Bacteria are killed and disintegrated when the intermediate body can attach itself to them and bring them under the influence of the complement—a digestive enzymotic element, to which the intermediary body also attaches itself.

Moreover, it is now quite certain that of the two principles the intermediary body alone is a fixed, native element of the blood plasma, and the complement is subject to considerable fluctuations in quantity. The origin of the intermediary body has not been determined, while it is quite established that the complement is yielded by the white corpuscles, or leucocytes, of the blood. This matter of the origin of the complement is very important because the protective value of the blood fluid is determined by the quantity of complement available at any one time and not so much by the more constant intermediary body which is usually in excess of the complement. The complement would appear to arise from the leucocytes partly as a secretion; but the quantity derived in this way would not appear to be considerable. It also arises from leucocytes which are brought by any cause to degeneration and disintegration, and this would seem to be a richer source than the other. Leucocytes are constantly being worn out by physiological use and as constantly yielding up their complement to the blood as they go to pieces. It would appear, then, that the very essential complement which exists in the circulating blood and passes from the blood into the lymph and serous cavities, will be more or less determined in quantity by the number of blood leucocytes and the conditions to which they are exposed, and as they are brought to slower or faster degeneration; and it is extremely probable that the secretion of complement is influenced also by the nature of the stimuli to which even the living leucocytes are exposed. It has been shown beyond peradventure that the blood plasma contains less complement than blood serum, as would now be expected since the origin of complement from degenerating leucocytes has been abundantly shown, and because in the clotting of the blood the leucocytes are so greatly disintegrated. But I do not think that even the most ardent adversaries of the view that the fluids of the interior of the body do not exert direct bactericidal effects have been able to show that the plasma contains no complement. The complement is such a labile body that doubtless it is constantly used up physiologically and must therefore as constantly be renewed, and it is highly probable that the balance between production and destruction may not always be maintained, whence a considerable fluctuation may occur even in health. Whether the fluctuations ever synchronize with intending infections in such a manner as to promote them is not really known, but is not impossible.

It is, however, patent that the naturally operative defensive mechanisms against bacterial invasion must contain other factors than these humoral ones. We are all now prepared to admit that in the phagocytes, or the devouring white corpuscles of the blood, the body possesses another defensive system of high efficiency. The motile nature of these cells and their presence in the circulating blood ac-

cord them a high degree of mobility, so that they can be quickly dispatched to any part of the body threatened by invaders, and are hardly behind the fluids of the blood in this ability to be massed or delivered where needed. The phagocytic mechanism of defense operates through all the orders of the metazoa; and while it can hardly have been developed originally as a protective system against parasites, and doubtless represents a mechanism for disposing of effete and useless particulate matter in the body by a process of intracellular digestion, yet it has reached through evolutionary selection a high state of perfection and must have exercised no small influence in protecting from extinction certain living species.

There is good reason to believe that in the final disposal of bacteria intruded into the body the phagocytes play the terminal rôle—i. e., under favorable conditions they are attracted through chemical stimuli furnished by the bacteria to which they respond to englobe them, after which the bacteria are often disintegrated. But there is equally good reason to believe that, with few exceptions, this engulfing can not take place until the bacteria have been acted on by certain plasmatic constituents that prepare the bacteria to be taken into the body of the phagocytes. The further the phenomena of bacterial destruction in the body are probed the more certain does it become that there is no single and uniform process of their disposal. The humoral doctrine of bacterial destruction contains much of fact, the phagocytic doctrine much of fact, and it is quite certain that the practical defensive activities of the body constantly imply the use of both mechanisms.

And when we push the analysis of the manner in which bacteria injure the body and enumerate the various bactericidal substances which have now been determined as existing in the plasma and in the cells, we find that this interaction must be supposed to take place. Plasmatic bactericidal action and phagocytic inclusion are cooperative functions; plasmatic antitoxic action and phagocytic detoxication are cooperative functions; plasmatic opsonization and phagocytic ingestion are complemental functions; plasmatic agglutination and phagocytic engulfing are also complemental, although less essential functions. And although in intending infections the toxic action of the bacteria to be dealt with is less a matter of great consequence, yet in principle the disposal of a few bacteria is not different from the disposal of many; and in dealing with the poison or toxic elements of bacteria, the plasma possesses distinct power of direct neutralization as the phagocytes possess distinct ability to transform poisonous into nonpoisonous molecules.

I desire now to refer again to the subject of racial and species immunity for which the the humoral factors of bacterial destruction afforded an imperfect explanation, in order that I may point out that

the introduction of bacteria, incapable of causing infection, into immune species is followed by immediate phagocytic ingestion and destruction of the microorganisms. The rapidity and perfection of the phagocytic reaction in insusceptible animals are very impressive and might readily lead to the decision that they suffice to explain the resistance or immunity. However, the matter does not permit of such summary disposal, since there appear to be other factors that enter into the phenomena. The frog that does not become tetanic when inoculated with tetanus bacilli or poison, develops tetanic spasms when the temperature is raised somewhat; the hen that does not respond to an anthrax inoculation develops the infection when the temperature is lowered somewhat. Even for the final ingestion of bacteria by the phagocytes of alien and insusceptible species the plasma principles are required.

Undoubtedly the phenomena of racial and species immunity are affected by phagocytosis. But our present knowledge does not justify us in disregarding other possible and contributing agencies. We are still so little informed of even the grosser features of the body's metabolism that it would be premature to deny to it influence on susceptibility to infection. Between the metabolism of birds and mammals there is such wide disparity that an influence could easily be conceived; but the metabolic disparity is less between the herbivora and carnivora, and still less between some closely related species which yet show marked differences in susceptibility to bacterial infection; and as between individuals of the same species it could only be the finer intramolecular variations that conceivably could come into play.

Although the properties of the defensive mechanisms of the blood have not been exhausted, yet they have been defined in such detail as to suffice for the moment and to permit us to turn attention, for a brief space, to some of the properties of the intending invading bacteria. It is matter of common experience, which each of us has suffered, that the elaborate mechanisms provided for our protection from bacterial infection do not always suffice, and now it becomes necessary to explain why they do not. In the first place, there are very great differences between the bacteria which seek to enter the body. Some species are never very harmful and are readily combated, excluded, or destroyed; other species often possess only a moderate degree of virulence or potential power of doing injury and can also, as a rule, be overcome; while these second species sometimes acquire such highly virulent or invasive powers that the defenses prove quite inadequate to exclude or combat them. During the prevalence of great bacterial epidemics it is probable that this factor, virulence, plays a considerable rôle. Of course, in epidemics the bacterial causes are, by the exigencies of the situation, more widely diffused than at other times,

so that more individuals come under their influence; but with even such a common bacterium as the diplococcus which causes pneumonia and the bacillus which produces influenza, there arise conditions in which severe and often very extensive outbreaks, or localized epidemics, occur which are probably to be attributed to an accession in virulence of these germs, although the precise causes leading to the increase may not be discovered.

Now this quality of virulence, which is often evolved so quickly and apparently so mysteriously is expressed biologically in various ways besides in that of greater infective power; virulent bacteria may prove incapable of being charged with opsonin so that they can not be ingested by phagocytes; they may show unusual power to resist plasma or serum destruction; they may drive away or repel or act negatively in respect to chemical attraction on the phagocytes; and being thus unopposable they tend to multiply quickly and with little restraint and thus still further to break down and render ineffective the normal defensive mechanisms, and ultimately to damage seriously the sensitive cells of the organs. This constitutes disease.

Another power resides in the body that should be regarded, namely, the power to neutralize or destroy poisons as distinct from parasites; for the body is exposed to the deleterious action of poisons generated by living parasites that do not themselves penetrate within the body. Some of these poisons are generated away from the body, as is the case with certain food poisons; some by bacteria in the intestinal canal that do not seek to invade the blood; some by bacteria, like the diphtheria bacillus, that first kill tissue, usually of the mucous membranes, and then develop in the dead tissue and send the poison into the body. And besides this, every bacterial disease resolves itself ultimately into a process of poisoning—of intoxication. In typhoid fever, in pneumonia, in meningitis, and in the multitude of other bacterial invasive diseases of man and the lower animals, the severe symptoms are caused by the poisons liberated through disintegration of the invading bacteria, which, however, continue by multiplication to recruit their numbers.

The condition of susceptibility to poisons varies with different races and species, very much as bacterial susceptibility does. The cold-blooded animals are indifferent to poisons that are very injurious to warm-blooded animals, but not all cold-blooded animals behave alike. Tetanus toxin is alike innocuous for the frog and the alligator, but by raising the temperature artificially the frog develops tetanus, but the alligator does not. Sometimes the effects depend merely upon the mode of entrance of the poison into the body. Tetanus toxin, diphtheria toxin, and snake venom have no effect on mammals when swallowed unless the intestinal epithelium has been injured. These poisons can not pass through the epithelium to reach the blood, where alone

they can exert their action. The toxin of the dysentery bacillus passes readily in the rabbit from the blood into the intestine, which it injures, but can not pass from the intestine into the blood. Tetanus toxin can be injected into the circulation of the hen, but does no harm. Injected into the brain it produces tetanus. Introduced into the blood it remains there for many weeks, hence the failure to act can not be due to destruction, but probably is due to inability to pass through the blood vessels in order to reach the cells of the central nervous system in a sufficient state of concentration. The physiological state of the animal also exerts an influence—certain hibernating species are susceptible to tetanus poison in the summer, but not during the winter sleep. There exist, therefore, different mechanisms for excluding poisons from the sensitive and reacting cells, and among them are certain quantities of neutralizing, or antitoxic substances, normally contained in the blood. We know at least one such definite antitoxin, namely, the diphtheria antitoxin, which exists in minimal quantities in the blood of man and the horse.

The absence of numerical relation between the mechanism which destroys bacteria and neutralizes poisons sometimes works sad havoc for the body. The two capacities may differ naturally or are enhanced in different degrees by artificial means. The matter is one of great importance, because almost without exception all bacterial diseases are examples of poisoning. The mechanical obstructions produced by the bacterial bodies are relatively unimportant. The body is more readily defended from the invasion of bacteria, with very few exceptions, than from the effects of their poisons. The capacity to dispose of typhoid and cholera bacilli is more easily produced than the power to neutralize or otherwise render innocuous the poisons liberated by the dissolved bacilli. It is precisely because we have not yet learned how to overcome this class of bacterial poisons within the body that we have not mastered the bacterial diseases as a whole. There are, however, certain bacterial poisons for which adequate antidotes are readily produced, thus, for example, for the diphtheria, tetanus, botulism, and possibly the dysentery poisons. Here the poisons can be more easily neutralized than the bacilli can be got rid of, but by neutralizing the poisons we succeed in arresting the multiplication of the bacteria and often in curing the disease.

The normal body possesses a mean resistance to bacterial invasion and to bacterial poisoning which, while somewhat fluctuant, is of high value except under certain exceptional conditions in which infection readily develops. We know that certain general states of and influences exerted on the body are associated with a rise or a fall of this mean value. But we are not equally informed of the physical basis of this rise and fall. This particular topic is peculiarly difficult because of the large numbers of factors which enter into it. We know

from observation that proper clothing, wholesome food, good hygienic surroundings, avoidance of overfatigue and of depressing psychic impressions, and that physical care of the body, all contribute toward maintaining health as the reverse conditions predispose to establishing disease. In seeking the physical basis of this difference we must avoid confusing cause with effect. Good hygienic surroundings may act chiefly by excluding the sources of infection rather than by enhancing resistance. Yet there is experimental as well as observational foundation for the belief in these general influences to affect the disposition to acquire or escape infectious disease. Animals which are made to fast, to overexercise, are made anæmic, are given excessive quantities of alcohol and other poisons, or are exposed to abnormal cold by shaving of the skin, are more subject to certain infections than animals not so treated. If, now, it were found that the blood factors governing resistance fluctuated with these influences, became smaller and less conspicuous when the influences were bad and larger and more efficient when the influences were good, we should then have established an important concrete fact.

But the alexinic activity of the blood varies normally within such wide limits that only maximal changes could be regarded as significant, and it appears that it is only as the fatal termination of certain severe infections are reached—such as experimental anthrax and pneumococcus infections, for example—that the alexinic power falls greatly or disappears altogether. The determination of phagocytic activity outside the body has not thus far been carried out in such a manner as to indicate a functional depression which either precedes immediately or develops in the course of severe infections; although certain infections which take a severe course are characterized by a persistent reduction in the number of leucocytes in the circulating blood. This latter phenomenon must, however, probably be regarded as an effect and not as the cause of the infection. There is, however, known at least one example where paralysis of the phagocytes leads to a fatal infection under conditions in which the normal phagocytes are entirely competent to prevent infection. If to a guinea pig a small dose of opium be administered and this is followed by the injection of a nonlethal quantity of a culture of the cholera bacillus, death will ensue because the sensitiveness of the phagocytes to the chemical stimulus exerted by the cholera poison has been diminished by the narcotic influence of the opium.

The mean phagocytic value of the blood can, however, be definitely raised by certain agencies, that are at the same time and through the rise in the number of phagocytes produced, useful in warding off and sometimes even in overcoming infection. The means employed to bring about an increase of leucocytes, or to establish a hyperleucocytosis, suffice to maintain the high value for short period relatively only, unless the stimulus is frequently repeated. A cold bath, a sun

bath, the injection into the circulation of a number of simple chemical substances—peptone, albumose, nucleinic acid, spermin, pilocarpine—are all followed under physiological conditions by hyperleucocytosis and by a temporary state of increased resistance to bacterial invasion. Moreover, in certain experimental infections, at least, there can thus be aroused a heightened power to overcome established infections—those caused, for example, by the cholera, meningitis, and pneumococcus germs. Perhaps the most striking example of the protective influence of hyperleucocytosis is afforded by the experimental infection described under the name of cholera peritonitis of the guinea pig. If a fatal quantity of cholera germs be injected into the peritoneal cavity of a guinea pig, symptoms of poisoning quickly set in and death results in a few hours. A study of the conditions present in the peritoneal cavity shows that the bacteria have developed freely, that some have been broken up and disintegrated, and that very few preserved phagocytes can be found. Examination of the blood reveals that the number of leucocytes in the general circulation has been reduced; and all the evidences point to the conclusion that not only has phagocytisis not taken place, but that there has been a general destruction of leucocytes produced by the cholera poison. If, however, there be introduced into the peritoneal cavity of a guinea pig twelve to twenty-four hours prior to the inoculation of the cholera bacilli, a small amount of sterile salt solution, or bouillon, or one of the other chemicals mentioned, which procedure will bring into the peritoneum a considerable number of leucocytes at the same time that it causes a rise of leucocytes in the circulating blood, then the cholera germs are quickly taken up by the phagocytes, multiplication is prevented, and the animal escapes severe illness.

The value of hyperleucocytosis as a defensive measure against infection must, probably, always remain greater than its value as a cure for established infection. There are several reasons that make this conclusion probable—the capacity of the blood is increased in the direction of destroying bacteria without being augmented at the same time in the direction of neutralizing bacterial poisons; the organism that is already severely poisoned by infection reacts less certainly to the chemical agents that provoke hyperleucocytosis than the uninfected organism. And yet we may see the operation of the benign influence of hyperleucocytosis, associated with an increased passage of alexin-containing lymph through the vessels, upon certain local infections at least, in the results of measures that determine an augmented supply of blood to a diseased part; in the mechanical hyperæmias produced through posture or superheated air; the influence (in part) of tuberculin injections; and the effects of poultices and embrocations, of counterirritants, and of certain of the phenomena of local inflammation.

The facts at our command point to the great potential power of the normal organism to resist infection and indicate that the normal body possesses the capacity, on demand, to increase this power beyond the mean value, chiefly by opposing intending infection by hyperleucocytosis and also, probably, by the strengthening of its plasmatic defensive action through the additional soluble alexin substances thrown off by the augmented leucocytes. This defensive mechanism acts in the same manner on all bacterial invaders and is not specially adapted for any one or group of bacteria. The form of activity is strictly nonspecific.

Let us now ask ourselves if in overcoming infectious disease, which luckily the organism is frequently able to accomplish, the mechanism put into operation is similar and only more intense than the one we have considered for warding off infection. The answer to this question is that recovery from infection consists in the bringing into being of a new set of phenomena that gradually reenforce the resistance; that recovery from infection is accomplished through a process of immunization. The evidences of this condition of immunization are found in the appearance in the blood some time between the fourth or fifth to the tenth day of the disease, and somewhat later than they have appeared in the spleen and bone marrow, of chemical substances which are directed in a specific manner to the neutralization of the poisons having been and still being produced by the bacterial causes of the disease, to the destruction of the bacteria themselves either outright by the plasmatic fluid which has now been enriched by a new quantity of intermediary substance of high potency that may bring the bacteria more readily under the dissolving influence of the complement, or by the phagocytes to which they are exposed in greater measure through the production of opsonins of higher strength and stability. As recovery progresses these immunity substances continue to increase until at the termination of the disease they are present in quantities that suffice often, by a passive transfer to another individual, to protect other animals more certainly from an infection, or to terminate abruptly an infection already established in them.

When the infectious disease is the expression not of the combined effects of poison and bacteria, but of the poison chiefly which enters the blood, the bacteria remaining without, as in diphtheria, then the blood changes characterizing the immune state are simpler and consist in the accumulation there of antitoxins that constitute the most perfect antidote to poisons that are known. The condition of immunity produces no demonstrable change in the properties of the phagocytes through which they are better enabled to overcome the poisonous bacteria. They do become, in course of the immunization, more sensitive to positive chemotactic stimuli; but it is still an un-

settled question whether they are altered qualitatively by the immunization, or whether the plasmatic changes do not really react upon them and thus increase their efficiency.

It must now be patent that between what may be termed the process of physiological resistance and what is termed the condition of immunization, a wide distinction exists. The one is nonspecific in its action, the other highly specific in its effects; the one is subject to a limited augmentation, the other may be carried to a high degree of potency and perfection; the one often fails to protect the organism in which it is developed, the other suffices to protect both itself and another organism. If therefore we were to be asked in what manner can the animal organism best be reenforced against infection, we should be compelled to answer by passing safely through the infection itself. This conclusion, which has been reached by purely experimental biological methods, is supported on every side by common observation and experience with the acute infectious diseases of which one attack protects from a subsequent attack of the same disease.

It may conduce to clearness if we should enumerate the factors that have been described and assigned on the one hand to natural resistance, and on the other hand to acquired resistance or immunity. We can tabulate the factors in the following manner:

NATURAL OR PHYSIOLOGICAL RESISTANCE.

Alexin $\begin{cases} \text{complement.} \\ \text{intermediary body.} \\ \text{opsonin.} \\ \text{agglutinin.} \end{cases}$

Phagocyte.

INCREASED NATURAL OR PHYSIOLOGICAL RESISTANCE.

Alexin $\begin{cases} \text{complement, probably increased.} \\ \text{intermediary body.} \\ \text{opsonin.} \\ \text{agglutinin.} \end{cases}$

Phagocyte—increased (hyperleucocytosis).

ACQUIRED IMMUNITY.

Complement—probably increased.
Intermediary body—specific one produced.
Opsonin—specific, stabile one produced.
Agglutinin—specific one produced.
Antitoxin $\left\{\begin{matrix} \text{for exotoxin} \\ \text{for endotoxin} \end{matrix}\right\}$ produced.
Phagocyte—often increased but qualitatively unchanged.

This tabulation exhibits the distinction between the physical basis of physiological resistance and of the state of immunity. There is another difference between them; any increase that can be called out beyond the mean of physiological resistance is accomplished in a few hours; and having been called out to meet a particular condition of need of the body and the effect having been exerted, it passes off very soon. It is rare that the effect of a hyperleucocytosis can be detected

for more than three or four days after it has appeared. The development of the state of immunity, on the other hand, is a slow process relatively and depends upon the setting into motion of certain cell functions, through which new substances are produced, which, being first retained within the cells producing them, eventually are passed into the blood. Hence it is that these new substances can be detected at an earlier period of the infection in the spleen than in the blood. But once they have been produced, the substances endure either for an indefinite period, or the capacity to produce new ones of the same sort is retained by the organism often for years. The blood may grow weak in the typhoid immunity principle in the course of years following an attack of typhoid fever, or a rabbit immunized with typhoid bacilli may show after a time a great diminution of the blood agglutinins for typhoid bacilli; but the typhoid immunity persists in the one, as in the other minimal quantities of typhoid bacilli will bring out, and without the original delay, a new production of agglutinin that will restore the lost amount.

The facts on immunity which I have presented to you constitute the physical basis, also, of all artificial methods which are being pursued so successfully in preventing certain infections through vaccination, and in curing them through the use of immune serum products. The facts also account in an eminently satisfactory manner for the suppression of smallpox by cowpox vaccination. The "vaccines" so-called for bacterial diseases, which are, I might say, at present being employed chiefly in protecting animals from epidemic infectious diseases to which they are much exposed, consist for the most part of bacteria either killed outright by heat or chemicals or of bacteria whose virulence has been diminished by special methods of cultivation or treatment. In human beings this method of vaccination has been employed only when large numbers of persons have been exposed to infections from the zone or focus of which they could not be removed, or from which, owing to the peculiar circumstances surrounding the infections, they could not readily or at all be protected by the suppression of the diseased germs at their sources. Thus, it has been found advantageous in a few instances to employ vaccination against cholera and bubonic plague, on those especially exposed to these epidemic diseases, and against typhoid fever on troops going in time of war into heavily infected endemic zones of that disease.

In a few instances this method of vaccination has been successfully carried out in animals with infectious diseases in which the germs causing them have not been discovered. Thus, it is possible to vaccinate cattle against the destructive rinderpest of Africa, the Philippines, and other tropical countries, by employing the bile of animals which have succumbed to the infection, which contains the parasite of the disease somewhat modified by certain immunity principles

contained within it along with parasites. In fact, this method of conjoint vaccination with the parasite of the disease and the blood containing immunity principles is one that offers a considerable field of practical application. On the one hand, there is accomplished a passive immunization of the body that becomes operative immediately, and, on the other hand, a vaccination that after the usual interval leads to the production of a state of active immunity that rises to a higher level and is far more enduring than the passive state.

Incidentally we have discovered from this process of mixed or conjoint vaccination that immune sera prepared for bacteria or other parasites which are not toxin producers in the manner of the diphtheria bacillus, but which contain endotoxin, act not especially by neutralizing toxins, or by destroying outright the bacteria, but by exercising an efficient protective control over the injury which these parasites or their poisons tend to inflict on certain sensitive body cells. For example, if cattle are inoculated on one side of the body with virulent blood from animals dying of rinderpest, and on the other side with blood serum taken from animals that have recoverd from the disease and subsequently have had their immunity intensified by injections of highly virulent blood, the cattle so vaccinated will develop rinderpest in a mild form and will subsequently on recovery be also immune; and yet during the process of immunization their blood contains highly virulent parasites, so that if a little of it be introduced into nonprotected and healthy cattle, they will be given rinderpest and will die of it.

The reaction of the body to the bacterial vaccines injected is out of proportion to the quantity of culture introduced. Thus two milligrams of dead cholera bacilli injected under the skin of human beings will yield enough of the specific immunity substance for these bacilli to bring about the destruction of 60,000 or more milligrams of the culture. There can be, therefore, no direct tranformation of the cholera bacilli into immunity bodies, but they must exert a stimulus on certain cell-functions through which the immunity principles are produced; and the quantity of their formation depends not on the weight of crude bacilli introduced, but on the strength of the stimulus impressed upon the sensitive cells to which they react in a specific and remarkable manner.

Is it possible in the course of an established infection to reinforce the resistance of the body? I have already stated that it is not practicable to bring out at the height of an infection an efficient heightened reaction of physiological resistance; but from this it does not follow that under these conditions a special form of immunity reaction may not be elicited. The tuberculin reaction, or that part of it which is specific, may be cited as an example of this kind of reinforcement; and whatever there is of value in the treatment of infec-

tious diseases by means of dead cultures of their specific bacteria—vaccines, so called—must be of the nature of an intensified immunity reaction. What is sought to be accomplished in the latter case is the formation in certain uninfected localities—in the subcutaneous tissues, for example—of immunity principles that afterwards by escaping into the blood shall assist in the termination of an infectious process situated elsewhere in the body. Such local foci of immunity as it is designed to create in the subcutaneous tissue are not unknown. The pleura can be given a local immunity to the typhoid bacilli; the subcutaneous tissue to tetanus toxin, and it is highly probable that the normal resistances exhibited by our mucous membrances to the pathogenic bacteria they harbor are examples of such local immunities.

I fear that I have carried you far afield and into somewhat devious paths of immunity to disease. You will, I know, not complain and hold it to the detriment of medical science that these paths have not been already converted into fine open roads. But you will prefer to recall how brief is the time since where the paths now are there were only wood and tangle.

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