FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN

PER ORBEM

SMITHSONIAN INSTITUTION

WASHINGTON 1846

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION

Showing the Operations, Expenditures
and Condition of the
Institution

FOR THE

YEAR ENDING JUNE 30, 1905

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

LETTER

FROM THE

ACTING SECRETARY OF THE SMITHSONIAN INSTITUTION

ACCOMPANYING

The Annual Report of the Board of Regents of the Institution for the year ending June 30, 1905.

SMITHSONIAN INSTITUTION,
Washington, D. C., June 26, 1906.

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, 1905, which includes the last Report prepared by the late Secretary, S. P. Langley.

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

RICHARD RATHBUN,
Acting Secretary.

Hon. CHARLES W. FAIRBANKS,
Vice-President of the United States.

Hon. JOSEPH G. CANNON,
Speaker of the House of Representatives.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1905.

SUBJECTS.

1. Proceedings of the Board of Regents for the sessions of December 6, 1904, and January 25 and March 6, 1905.

2. Report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year ending June 30, 1905.

3. Annual report of the Secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1905, with statistics of exchanges, etc.

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 1905.

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REPORT OF THE SECRETARY.

GENERAL APPENDIX.

LIST OF PLATES.

MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

Theodore Roosevelt, President of the United States.
Charles W. Fairbanks, Vice-President of the United States.
Melville W. Fuller, Chief Justice of the United States.
John Hay, Secretary of State.
Leslie M. Shaw, Secretary of the Treasury.
William H. Taft, Secretary of War.
William H. Moody, Attorney-General.
George B. Cortelyou, Postmaster-General.
Paul Morton, Secretary of the Navy.
Ethan Allen Hitchcock, Secretary of the Interior.
James Wilson, Secretary of Agriculture.
Victor H. Metcalf, Secretary of Commerce and Labor.

REGENTS OF THE INSTITUTION.

(List given on following page.)

OFFICERS OF THE INSTITUTION.

Samuel P. Langley, *Secretary.*
(*Director of the Institution and Keeper of the U. S. National Museum.*)
Richard Rathbun, *Assistant Secretary, in Charge of the U. S. National Museum.*
Cyrus Adler, *Assistant Secretary, in Charge of Library and Exchanges.*

REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief Justice of the United States, three members of the Senate, and three members of the House of Representatives, together with six other persons, other than Members of Congress, two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of the same State."

REGENTS FOR THE YEAR ENDING JUNE 30, 1905.

The Chief Justice of the United States:

MELVILLE W. FULLER, elected Chancellor of the Smithsonian Institution and presiding officer of the Board January 9, 1889.

	Term expires.
The Vice-President of the United States:	
CHARLES W. FAIRBANKS, ex officio March 4, 1905	Mar. 3, 1909
United States Senators:	
SHELBY M. CULLOM (appointed March 24, 1885; March 28, 1889; December 18, 1895, and March 7, 1901)	Mar. 3, 1907
Vacancy (death of Senator O. H. PLATT, April 21, 1905).	
Vacancy (retirement of Senator F. M. COCKRELL, March 3, 1905).	
Members of the House of Representatives:	
ROBERT R. HITT (appointed August 11, 1893; January 4, 1894; December 20, 1895; December 22, 1897; January 4, 1900; December 13, 1901, and January 12, 1904)	Dec. 27, 1905
ROBERT ADAMS, JR. (appointed December 20, 1895; December 22, 1897; January 4, 1900; December 13, 1901, and January 12, 1904)	Dec. 27, 1905
HUGH A. DINSMORE (appointed January 4, 1900; December 13, 1901, and January 12, 1904)	Dec. 27, 1905
Citizens of a State:	
JAMES B. ANGELL, of Michigan (appointed January 19, 1887; January 9, 1893; January 24, 1899, and January 23, 1905)	Jan. 23, 1911
ANDREW D. WHITE, of New York (appointed February 15, 1888; March 19, 1894, and June 2, 1900)	June 2, 1906
RICHARD OLNEY, of Massachusetts (appointed January 24, 1900)	Jan. 24, 1906
GEORGE GRAY, of Delaware (appointed January 14, 1901)	Jan. 14, 1907
Residents in the City of Washington:	
JOHN B. HENDERSON (appointed January 26, 1892; January 24, 1898, and January 27, 1904)	Jan. 27, 1910
ALEXANDER GRAHAM BELL (appointed January 24, 1898, and January 27, 1904)	Jan. 27, 1910

Executive Committee of the Board of Regents.

JOHN B. HENDERSON, *Chairman.*

ALEXANDER GRAHAM BELL. ROBERT R. HITT.

PROCEEDINGS OF THE BOARD OF REGENTS FOR THE YEAR ENDING JUNE 30, 1905.

At a meeting held March 12, 1903, the Board of Regents adopted the following resolution:

Resolved, That, in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that day falls on Sunday, when the following Monday shall be substituted.

In accordance with this resolution, the Board met at 10 o'clock a. m. on December 6, 1904, January 25, 1905, and March 6, 1905.

REGULAR MEETING OF DECEMBER 6, 1904.

Present: Mr. Chief-Justice Fuller (Chancellor) in the chair; the Hon. W. P. Frye, President pro tempore of the Senate, acting as Regent; the Hon. S. M. Cullom, the Hon. O. H. Platt, the Hon. F. M. Cockrell, the Hon. Robert Adams, jr., the Hon. Hugh. A. Dinsmore, Dr. Andrew D. White, the Hon. John B. Henderson, Dr. A. Graham Bell, and the Secretary, Mr. S. P. Langley.

MINUTES OF PREVIOUS MEETING.

The minutes of the meeting held March 7, 1904, were read in abstract and approved.

DISPOSITION OF THE REMAINS OF JAMES SMITHSON.

The Secretary stated that at the meeting of January 27, 1904, a committee consisting of the Chancellor, the members of the executive committee, and the Secretary had been appointed to act on the question of the final disposition of the remains of James Smithson and of the monument to be erected to him. The committee reported to the Board on March 7, 1904, recommending that a suitable tomb be erected and that Congress be asked to make an adequate appropriation for it.

Since that meeting the committee had decided to suggest in lieu of their former recommendation that the original tomb be brought to this country and used as a final resting place for the remains. Accordingly the Secretary had entered into correspondence with the officials at Genoa, and the tomb had been shipped and was expected by the end of the present month.

After discussion, Senator Cullom offered the following resolution, which was adopted:

Resolved, That the special committee having in charge the matter of the final disposition of the remains of James Smithson be authorized to receive the original tomb, and to place it, suitably inscribed, with the remains, in some proper position that they may select in the grounds of the Institution; the expenses involved in the matter to be met from the funds of the Institution.

NEW BUILDING FOR THE NATIONAL MUSEUM.

The Secretary stated that the preliminary floor plans and elevations were approved on January 27, 1904, and that the detailed plans for the construction of the foundation had been worked out during the spring. The excavation for the building was begun on June 15, 1904, the Secretary turning the first spade of earth, and the site of the building was inclosed with a high board fence. The excavation was completed during the last of the summer, and the work of laying the foundation was immediately begun, the material used being concrete. This part of the work was finished November 9, 1904.

Proposals for furnishing the granite for all parts of the building where this stone was to be used, were opened October 1. There were nine bidders, and after due consideration the following selections were made: For the basement story, pink granite from Milford, Mass.; for the main and second stories, the white Bethel granite of Vermont; for the upper story, white granite from Mount Airy, N. C.; for the trimmings of the court walls, the so-called Woodstock granite of Maryland. It was explained that the stones from these quarries would harmonize, and that the selection had the favorable recommendation of the superintendent of construction and of the architects.

Contracts were at once entered into for supplying the above material, cut and ready for laying, and it was gratifying to state that the total cost of the granite would fall below the original estimates.

It was expected that work on the lower story could be started by next February, and in case the season were an open one, the basement walls could be completed before the summer of 1905. At the present time the superintendent of construction was erecting, in wood, a narrow section of the south front of the building, of actual dimensions, in order to determine if the lines and proportions as shown on the plans were entirely satisfactory or subject to improvement.

PRESERVATION OF ANTIQUITIES.

The Secretary recalled to the Board that bills for the preservation of antiquities on the national domain, had been introduced in the Senate by Senator Cullom, and in the House by Representative Hitt, at the last session of Congress, but that no action had been taken. It

had been learned that the Secretary of the Interior had in contemplation a bill which, while meeting the needs of the Department, would also be satisfactory to the Institution. The Institution had undertaken to prepare for the Secretary of the Interior the requisite maps giving the location of antiquities on the public lands. It was of interest to state that the Secretary of the Interier had already taken preliminary steps in the matter, so far as his authority extended, and had appointed guardians for important ruins.

EXPLORATIONS.

The Secretary said that since the last meeting of the Board two expeditions had been sent out by the Institution; one under the direction of Mr. A. G. Maddren for the purpose of studying the remains of the Alaskan mammoth and other large mammals reported as abundant in the "Bone-Yard" and at Elephant Point; and a second under the direction of Dr. W. H. Sherzer to study the glaciers of British Columbia. Arrangements had also been made to send Dr. J. Walter Fewkes to Vera Cruz, Mexico, for the purpose of studying the practically unexplored region in the eastern shore of that country, where it is hoped to discover the relationship of the mound-building tribes of our Mississippi Valley and the Pueblo peoples of the Rio Grande and Rio Colorado with the so-called civilized tribes of Mexico. The district was also interesting because of the presence there of a branch of the Maya race of Yucatan.

The sending of these expeditions was a recurrence to the old policy of the Institution which paid for them from its own fund. In this last case it was a joint work of the Bureau of American Ethnology and the Institution.

EXTENSION OF ETHNOLOGICAL WORK IN HAWAII AND SAMOA.

The Secretary explained that he had for several years, in connection with the estimates, urged the extension of the researches of the Bureau of American Ethnology to Hawaii and Samoa. Congress had apparently been unwilling up to the present time to authorize this. These researches were practically urgent, and the request had been renewed this year, and he hoped that its importance could be impressed upon the members of the appropriations committees. No additional appropriation was needed to accomplish this, it being only necessary to insert the proper phraseology in the appropriation bill.

The Board then adjourned.

ANNUAL MEETING OF JANUARY 25, 1905.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair, the Hon. O. H. Platt, the Hon. F. M. Cockrell, the Hon. Robert Adams, jr., the Hon. Hugh A. Dinsmore, Dr. J. B. Angell, the Hon. John B. Henderson, the Hon. Richard Olney, the Hon. George Gray, Dr. A. Graham Bell, and the Secretary, Mr. S. P. Langley.

MINUTES OF PREVIOUS MEETING.

The minutes of the meeting held December 6, 1904, were read in abstract and approved.

REAPPOINTMENT OF REGENTS.

The Secretary announced the reappointment of Dr. James B. Angell for a term of six years, by joint resolution of Congress approved by the President January 23, 1905.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Senator Henderson, Chairman of the executive committee, presented the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1906, 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 SECRETARY.

The Secretary presented his report of the operations of the Institution for the year ending June 30, 1904, which was accepted.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Senator Henderson, Chairman, presented the report of the committee for the year ending June 30, 1904, which was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

Senator Henderson, Chairman, reported as follows:

Hodgkins fund.—The O'Donoghue case is now in the court of appeals at Albany. The calendar has not yet been announced, but the prospect is that the case will be reached and argued this spring.

Andrews will case.—The hearing upon the application of the executor to have the will interpreted has not yet been had. Very recently a short brief was handed up to the supreme court of New York covering certain phases of the subject.

Addison T. Reid case.—The surrogate in Brooklyn has decided in accordance with the Institution's view of the construction of the will, and matters are left in shape for the Institution to avail itself of the bequest at some future time.

On motion the report was accepted and ordered filed.

REPORT OF THE SPECIAL COMMITTEE ON THE FINAL DISPOSITION OF THE REMAINS OF JAMES SMITHSON.

The Chancellor, as chairman of the committee, reported as follows:

At a meeting on December 6, 1904, the Board of Regents adopted the following resolution:

"*Resolved*, That the special committee, having in charge the matter of the final disposition of the remains of James Smithson, be authorized to receive the original tomb and to place it, suitably inscribed, with the remains, in some proper position that they may select in the grounds of the Institution; the expenses involved in the matter to be met from the funds of the Institution."

Your committee having directed the shipping of the tomb to this country, it arrived in the port of New York and has just been brought on here. It is temporarily set up near the Institution. It is a most modest structure, but sufficient in its place in a cemetery surrounded by other tombs. Your committee would like to have the Regents see it before they place it permanently in any conspicuous external position. Should the Regents please to authorize the committee to place it within the Institution, at least temporarily, they will find a place for it.

After realizing the insufficiency of the tomb for an external site, your committee have some hesitation in choosing a place for it in the open grounds of the Institution under the terms of the resolution, but would probably place it immediately north of the present building. Your committee feel that in that case, some accessory would be necessary.

The adoption of this report will be considered by the committee as authorizing them to place the tomb and remains within the Institution, at least temporarily.

Repectfully submitted.

MELVILLE W. FULLER, *Chairman.*

On motion the report was adopted.

FREER COLLECTION.

The Secretary said that during the early part of the year 1904 he had had an interview at the Institution with Mr. Charles L. Freer, of Detroit, who was desirous of giving his valuable collection of objects of American and oriental art to the Smithsonian Institution or to the United States Government on certain conditions. Mr. Freer had outlined orally the extent of the collection, its cost, and the conditions under which he proposed to make the offer.

The Secretary had brought the matter before the executive committee, and he read a letter which he had sent to Mr. Freer reciting his understanding of the collection and conditions of gift, and which, further, contained the following action of the committee:

The executive committee, having heard with interest and appreciation the statement by Secretary Langley of the proposition and views of Mr. Charles L. Freer,

of Detroit, to intrust to the Smithsonian Institution a collection of works of art, now in his possession, which has already cost $600,000 and to which he proposes to add almost as much more and to construct for housing it a hall costing $500,000, upon condition that all the expense and responsibility for its care and maintenance shall be provided, are of the opinion that it would be well for the Board of Regents to consider such a proposition in sympathy with the broad and cultivated spirit in which it is made; but as it is presented only as a statement of a conversation with Mr. Freer, it is requested by the committee that Secretary Langley communicate with Mr. Freer and suggest to him that he put in more precise form his views and his wishes, so that the action which the committee may recommend to the Board shall be such as will exactly set forth Mr. Freer's purposes and be given the careful consideration appropriate to such an enduring benefaction.

To this letter the following reply was received:

Detroit, Mich., *December 27, 1904.*

S. P. Langley, Esq.,

Secretary Smithsonian Institution, Washington, D. C.:

Dear Sir: In replying to your kind letter of the 16th instant, and in further reference to the conversation had with you on March 24 last, I beg to say that my permanent collections consist of the following art objects, namely:

By James McNeill Whistler:
- 100 framed paintings in oil, water-color, and pastel.
- 60 unframed drawings in pencil and water color.
- 150 lithographs.
- 575 etchings.
- The entire decorations of the Peacock Room.

By D. W. Tryon, T. W. Dewing, and A. H. Thayer:
- 50 framed paintings in oil, water-color, and pastel.

By various masters of Chinese and Japanese schools of painting, beginning with the tenth century and ending with the nineteenth century, including specimens by Ririomin, Sesshiu, Sesson, Motonobu, Tanyu, Koyetsu, Sotatsu, Korin, Kenzan, Hoitsu, Okio, Hokusai, and various other masters:
- 400 kakemono, many of which are in pairs.
- 80 screens, many of which are in pairs.
- 30 panels.

By various potters of the Far East and Central Asia, including Chinese, Japanese, Coreans, Persians, Arabians, and others as yet unidentified:
- 950 pieces of pottery.

Also a small group of ancient Chinese and Japanese bronzes, a few early Japanese and Corean wood-carvings, and some lacquer by Koyetsu, Korin, and Ritsuwo.

These several collections include specimens of very widely separated periods of artistic development, beginning before the birth of Christ and ending to-day.

No attempt has been made to secure specimens from unsympathetic sources, my collecting having been confined to American and Asiatic schools. My great desire has been to unite modern work with masterpieces of certain periods of high civilization, harmonious in spiritual and physical suggestion, having the power to broaden æsthetic culture and the grace to elevate the human mind.

These collections I desire to retain during my life for the enjoyment of students, my friends, and myself, and for the further purpose of making additions and improvements from time to time. Believing that good models only should be used in artistic construction, I wish to continue my censorship, aided by the best expert

advice, and remove every undesirable article, and add in the future whatever I can obtain of like harmonious standard quality.

I now repeat my offer to bequeath these collections to the Smithsonian Institution, or to the United States Government, and also the sum of $500,000 in money for the purpose of constructing a suitable building in which to house them, upon the following terms and conditions:

First. The sum of $500,000 shall be paid by my executors to the Regents of the Smithsonian Institution or the United States Government promptly after my decease, and shall be used forthwith for the construction of a fireproof building connected with the National Museum, the construction of which has recently been authorized, or reasonably near thereto.

Second. The interior of this building shall be arranged with special regard for the convenience of students and others desirous of an opportunity for uninterrupted study. A suitable space shall be provided in which the Peacock Room shall be reerected complete. The whole interior arrangement of the building shall be agreed upon between the Regents of the Smithsonian Institution and myself within a reasonable time after the acceptance of this offer.

Third. The collections, with such changes and additions thereto as shall be made during my lifetime, shall be delivered by my executors to the Regents immediately after the building is constructed and ready to receive them.

Fourth. The collections and the buildings shall be cared for and maintained perpetually by the Smithsonian Institution or the United States Government at its own expense.

Fifth. No addition or deduction shall be made to the collections after my death, and nothing else shall ever be exhibited with them, or in the same building, nor shall the said collections, or any part thereof, be removed at any time from the said building except when necessary for the purpose of making repairs or renovations in the building.

Sixth. No charge shall ever be made for admission to the building or for the privilege of examining or studying the collections.

Seventh. The collections and building shall always bear my name in some modest and appropriate form.

In lieu of the foregoing offer I am willing, upon the conditions above expressed, to make a present conveyance of the title to said collections to the Institution or the Government, and a bequest of the sum of $500,000 for the building, provided:

1. The collections shall remain in my possession during my life, and in the possession of my executors after my death until the completion of the building.

2. I shall have the right to make such changes in the collections, by disposing of any part thereof, or by adding thereto, as may seem to me advisable or necessary for the improvement of the collections, or any of them.

3. Both I and my executors shall be free from any liability on account of any loss in or damage that may accrue to the collections while in my or their charge, even though such loss or injury shall occur by reason of my or their negligence, or the negligence of my or their servants, agents, or employees.

The exact form of the bequest or gift and the details for carrying it into execution are legal questions that can be agreed upon by counsel representing the Institution or the Government and myself.

I suggest that the Institution or the Government, before coming to a decision regarding the above offer, send a committee of experts to Detroit to make an examination of the collections. It will be a source of satisfaction to me to exhibit the collections to such a committee, and the report it may make will be of great value to the Institution or Government in reaching a conclusion. I remain, with great respect,

Very truly, yours,

CHARLES L. FREER.

After conference with the chairman of the executive committee the Secretary addressed Mr. Freer, asking if he could see his way to modify the requirements of the fifth clause of his conditions, to which a reply was received that after serious consideration no modification could be made in the terms of the clause referred to.

A very general discussion arose as to the matters involved under the terms of the proposed donation, the prevailing opinion being that more information was necessary before the Board could come to a conclusion. It was pointed out that Mr. Freer had asked that a committee visit him for the purpose of seeing the collection, and the Board decided to accept the suggestion. The following resolution was accordingly adopted:

Resolved, That the Chancellor appoint a committee of three Regents, whose duty it shall be to make personal examination of the collection of art objects which Mr. Charles L. Freer has proposed to give or bequeath to the Smithsonian Institution, and make report to the Board of its value and merits, and said committee is further instructed to ascertain from Mr. Freer what alterations, if any, can be made in the conditions of his very generous proposal; and the Secretary of this Institution is hereby added as an additional member of this committee.

The Chancellor appointed Doctor Angell, Senator Henderson, Doctor Bell, and the Secretary as the committee.

The Board then adjourned.

REGULAR MEETING OF MARCH 6, 1905.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; the Hon. Charles W. Fairbanks, Vice-President of the United States; the Hon. O. H. Platt, the Hon. Robert Adams, jr., the Hon. Hugh A. Dinsmore, the Hon. Andrew D. White, the Hon. John B. Henderson, Dr. A. Graham Bell, and the Secretary, Mr. S. P. Langley.

MINUTES OF PREVIOUS MEETING.

The minutes of the meeting held January 25, 1905, were read in abstract and approved.

APPOINTMENT OF ASSISTANT SECRETARY.

The Secretary, after stating the necessity for the appointment of an additional assistant secretary of the Institution, asked the Board's approval of his selection of Dr. Cyrus Adler, the present Librarian of the Institution, for the position, adding an explanatory statement as to Doctor Adler's fitness for the duties.

Senator Henderson followed with further commendatory remarks, and presented the subjoined resolution, which was adopted:

Resolved, That the appointment by the Secretary of Dr. Cyrus Adler as Assistant Secretary of the Smithsonian Institution, in charge of the Library and the Exchanges, with such additional duties as the Secretary may assign him, be approved.

FREER COLLECTION.

Senator Henderson, in the absence of Doctor Angell, Chairman, and on behalf of the committee appointed to visit Detroit and inspect the art collection of Mr. Charles L. Freer, presented a report, which was very fully discussed; and as it was deemed best that the matter should be considered at a subsequent meeting of the Board, at which a fuller attendance might be expected, Senator Platt offered the following resolution, which was adopted:

Resolved, That the Board of Regents take this occasion to express their sincere thanks to Mr. Charles L. Freer, of Detroit, for the courtesy shown to the committee of the Regents which recently visited Detroit to examine his art collection; and that further consideration of his generous offer to donate the same to this Institution or the United States be continued until the next meeting of the Board of Regents.

GIFT OF BOTANICAL COLLECTION.

The Secretary stated that Capt. John Donnell Smith, of Baltimore, had donated to the Institution his entire botanical collection, comprising 100,000 plants and nearly 1,600 books on botany. There were no conditions, except that the donor reserved the right to continue to work upon the collection.

Doctor White offered the following resolution, which was adopted:

Resolved, That the thanks of the Board of Regents be tendered to Capt. John Donnell Smith for his generosity in presenting to the Institution his large and valuable collection of plants and books on botany, which is gratefully accepted.

FINAL DISPOSITION OF SMITHSON'S REMAINS.

The Secretary reviewed the report presented to the Board at the meeting of January 25 by the committee charged with the final disposition of Smithson's remains, and said that he hoped that at some future time Congress would make an adequate appropriation for giving these remains a fitting interment; but that so far as he had been able he had given present effect to the mandate of the Board by depositing them temporarily within the building in a small room which he had had fitted up on the immediate left of the north entrance to the building.

The remains had been examined by medical experts and found to be in a remarkable state of preservation. They had now been put in a suitable casket and were ready to be transferred to the tomb, and he would ask the Regents, when the meeting had adjourned, to proceed to the room and witness the deposit of the casket.

After remarks on the condition of the work of the Institution, the Board adjourned, and the Regents repaired to the room referred to, where, in their presence, the casket was placed within the tomb, which was then sealed.

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

FOR THE YEAR ENDED JUNE 30, 1905.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Institution, the appropriations by Congress, and the receipts and expenditures for the Smithsonian Institution, the U. S. National Museum, the International Exchanges, the Bureau of Ethnology, the National Zoological Park, and the Astrophysical Observatory for the year ending June 30, 1905, and balances of former years:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1905.

The amount of the bequest of James Smithson deposited in the Treasury of the United States, according to act of Congress of August 10, 1846, was $515,169. To this was added by authority of Congress, February 8, 1867, the residuary legacy of Smithson, savings from income and other sources, to the amount of $134,831.

To this also have been added a bequest from James Hamilton, of Pennsylvania, of $1,000; a bequest of Dr. Simeon Habel, of New York, of $500; the proceeds of the sale of Virginia bonds, $51,500; a gift from Thomas G. Hodgkins, of New York, of $200,000 and $8,000, being a portion of the residuary legacy of Thomas G. Hodgkins, and $1,000, the accumulated interest on the Hamilton bequest, savings from income, $25,000, making in all, as the permanent fund, $937,000.

The Institution also holds an additional sum received upon the death of Thomas G. Hodgkins, which is invested in registered West Shore 4 per cent bonds of the par value of $42,000, and which were, by order of the committee, under date of May 18, 1894, placed in the hands of the Secretary of the Institution to be held by him subject to the conditions of said order.

Statement of receipts and expenditures from July 1, 1904, to June 30, 1905.

RECEIPTS.

Interest on fund, July 1, 1904	$28,110.00	
Interest on fund, January 1, 1905	28,110.00	
		$56,220.00
Interest to January 1, 1905, on West Shore bonds	1,680.00	
Cash from temporary loan	10,000.00	
Cash from rents, publications, repayments, freight and other sources	6,861.72	
		18,541.72
Total receipts		74,761.72

EXPENDITURES.

Buildings:			
Repairs, care, and improvements	$5,962.14		
Furniture and fixtures	477.41		
		$6,439.55	
General expenses:			
Postage and telegraph	272.90		
Stationery	986.51		
Incidentals (fuel, gas, etc.)	5,146.96		
Library (books, periodicals, etc.)	4,356.72		
Salaries [a]	27,395.56		
Gallery of Art	20.00		
Meetings	402.75		
Freight and express	431.49		
		39,012.98	
Publications and researches:			
Smithsonian contributions	4,272.89		
Miscellaneous collections	6,009.96		
Reports	1,293.35		
Explorations	1,963.05		
Researches	3,086.72		
Apparatus	7.20		
Hodgkins fund	2,549.85		
Hamilton fund	258.25		
		19,441.27	
Literary and scientific exchanges		4,351.20	
Deficiency July 1, 1904		362.80	
Balance June 30, 1905		5,153.92	
			74,761.72

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 Secretary of the Institution, and all payments are made by his checks on the Treasurer of the United States.

[a] In addition to the above $27,395.56 paid for salaries under general expenses, $13,606.05 was paid for services, viz: $4,956.06 charged to building account; $35 to furniture and fixtures; $3,003 to library; $170,38 to miscellaneous collections; $188.52 to reports; $2,200.47 to researches; $1,153.96 to Hodgkins fund, and $1,898.66 to literary and scientific exchange account.

Early in June, 1905, the Accountant of the Institution, W. W. Karr, whose duties also embraced the handling of its revenues, was found to be a defaulter. Instead of there being a credit balance of $46,648.33 on June 30, 1904, as shown by the books of the accountant, there was in fact a deficiency of $362.80.

The subject of this deficiency is dealt with in detail in a special report communicated by the Secretary to the executive committee, and which the executive committee now submits to the Board of Regents with its approval. It seems proper in this place to make a general résumé showing the items of the deficiency and in what manner it was perpetrated.

On July 13, 1891, a check was drawn for a semimonthly pay roll amounting to $494.57. After the voucher for the pay roll had been approved for this amount and the check corresponding to the voucher had been signed, Karr raised this check from $494.57 to $5,494.57, appropriating the difference, $5,000, to himself. This was the first transgression which was ascertained.

Between July, 1891, and May 31, 1905, there was received as income by the Institution $1,146,051.32, and actually deposited in the Treasury $1,087,184.19, leaving a difference of $58,867.13, which should have been to the credit of the Institution, but which represents the embezzlement by Karr from the receipts of the Institution proper.

In addition to this, Karr embezzled from the Congressional appropriation for the U. S. National Museum for the fiscal year 1904–5 the sum of $7,400, which amount has been repaid to the Government by the bonding company which had given bond to the Government for his fidelity. In further addition thereto, Karr abstracted from funds received by the Institution for the International Catalogue of Scientific Literature, at London, $4,691.48.[a]

To recapitulate, the actual losses through Karr's embezzlements were as follows:

Moneys received for the Smithsonian Institution and converted to his own purpose	$58,867.13
Moneys embezzled by him on the raised check	5,000.00
Moneys embezzled by him from funds for transmission to the International Catalogue of Scientific Literature	4,691.48
Total	68,558.61

The executive committee in 1891, when these defalcations began, consisted of James C. Welling, Henry Coppée, and Gen. M. C. Meigs.

As the deficiency, on June 30, 1904, was practically of only momentary duration, having been immediately transformed into a balance by the

[a] Mr. Karr was indicted and when arraigned pleaded guilty and was sentenced to imprisonment for five years in the penitentiary at Moundsville, W. Va.

deposit of the semiannual interest funds, the fact that there had been peculations from the Institution was not discovered until June, 1905, when the Institution was informed that its account was overdrawn. As the end of the fiscal year was drawing near, it was found necessary to borrow the sum of $10,000 to meet current obligations. The loan was paid on July 5, 1905, or as soon as collections would permit. Owing to the condition in which the books and accounts were left by the late accountant, it is impossible to state in their respective classes the amounts of the miscellaneous receipts. The total of such receipts deposited in the Treasury during the year was in the aggregate $6,861.72, as given in the foregoing statement.

Your committee also presents the following statements in regard to appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution:

Detailed statement of disbursements from appropriations committed by Congress to the care of the Smithsonian Institution for the fiscal year ending June 30, 1905, and from balances of former years.

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1905.

RECEIPTS.

Appropriated by Congress for the fiscal year ending June 30, 1905, "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" (sundry civil act April 28, 1904) $27,000.00

DISBURSEMENTS.

Salaries or compensation:

1 acting curator, at $225 per month	$2,250.00	
1 chief clerk, at $183.33 per month	2,108.29	
1 clerk, at $150 per month	1,800.00	
1 clerk, at $125 per month	1,500.00	
1 clerk, at $116.66 per month	1,283.26	
1 clerk, at $80 per month	960.00	
1 clerk, at $55 per month	660.00	
1 stenographer, at $110 per month	1,320.00	
1 workman, at $60 per month	660.00	
1 packer, at $55 per month	605.00	
1 messenger, at $40 per month	320.00	
1 messenger, at $40 per month	92.00	
1 messenger boy, at $30 per month	325.00	
1 messenger boy, at $25 per month	170.42	
1 messenger boy, at $20 per month	70.67	
1 agent, at $75 per month	450.00	
1 agent, at $66.66⅔ per month	400.00	
1 agent, at $15 per month	90.00	
Total salaries or compensation		$15,064.64

General expenses:			
Books	$38.13		
Boxes	699.60		
Freight	5,947.67		
Furniture	65.00		
Postage	400.00		
Supplies	66.51		
Stationery, etc	204.50		
		$7,421.41	
Total disbursements			$22,486.05
Balance July 1, 1905			4,513.95

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1904.

Balance July 1, 1904, as per last report	$2,674.95

DISBURSEMENTS.

Salaries or compensation:			
1 agent at $50 per month	$200.00		
1 agent at $15 per month	90.00		
1 agent at $75 per month	450.00		
Total salaries or compensation		$740.00	
General expenses:			
Books	46.70		
Boxes	448.50		
Freight	1,268.44		
Stationery	89.00		
Supplies	72.23		
		1,924.87	
Total disbursements			2,664.87
Balance July 1, 1905			10.08

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1903.

Balance July 1, 1904, as per last report	$29.44

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, forty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building" (sundry civil act April 28, 1904)	$40,000.00

DISBURSEMENTS.

Salaries or compensation:			
1 chief of bureau, at $333.33 per month	$3,999.96		
1 ethnologist, at $200 per month	2,400.00		
1 ethnologist, at $200 per month	2,400.00		
1 ethnologist, at $133.33 per month	1,599.96		
1 ethnologist, at $125 per month	1,500.00		
1 ethnologist, at $125 per month	1,500.00		
1 ethnologist, at $83.33 per month	916.65		
1 ethnologist, at $100 per month	1,200.00		
1 editor, at $225 per month	450.00		
1 editorial assistant, at $100 per month	900.00		
1 editorial clerk, at $100 per month	283.33		
1 philologist, at $250 per month	500.00		
1 head clerk, at $100 per month	1,200.00		
1 clerk, at $100 per month	1,150.00		
1 clerk, at $125 per month	375.00		
1 clerk, at $90 per month	1,080.00		
1 clerk, at $75 per month	900.00		
1 illustrator, at $166.67 per month	2,000.04		
1 stenographer and typewriter, at $60 per month	364.00		
1 typewriter, at $65 per month	390.00		
1 messenger, at $50 per month	600.00		
1 messenger, at $55 per month	660.00		
1 skilled laborer, at $60 per month	720.00		
1 laborer, at $45 per month	540.00		
1 laborer, at $30 per month	30.00		
2 laborers, at $1.50 per day	30.00		
1 cleaner, at $1.50 per day	3.00		
1 cleaner, at $1.25 per day	60.00		
1 charwoman, at $1.50 per day	45.00		
Total salaries or compensation		27,796.94	
General expenses:			
Books, binding, etc	419.21		
Drawings, maps, etc	1,813.95		
Electricity	202.54		
Freight	176.13		
Furniture	451.26		
Manuscript	1,372.64		
Miscellaneous	160.74		
Postage, telegraph, and telephone	80.60		
Rental	1,375.00		
Special services	2,532.68		
Specimens	656.60		
Stationery	535.76		
Supplies	522.50		
Travel and field expenses	1,260.19		
		11,559.80	
Total disbursements			39,356.74
Balance July 1, 1905			643.26

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1904.

Balance July 1, 1904		$1,906.94
General expenses:		
Books	$91.04	
Drawings	25.80	
Electricity	64.35	
Freight	50.87	
Furniture	85.12	
Manuscript	250.00	
Miscellaneous	40.68	
Postage, telephone, and telegraph	30.48	
Rental	125.00	
Specimens	38.00	
Special services	60.00	
Supplies	57.55	
Stationery	314.78	
Travel and field expenses	597.57	
Total disbursements		1,831.24
Balance July 1, 1905		75.70

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1903.

Balance July 1, 1904		$1,101.87
General expenses:		
Books	$73.23	
Freight	216.87	
Manuscript	110.00	
Postage, telegraph, and telephone	11.16	
Printing	123.41	
Stationery	104.33	
Supplies	11.30	
Travel	72.95	
Total disbursements		723.25
Balance		378.62

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "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, $180,000, of which sum $5,500 may be used for necessary drawings and illustrations for publications of the National Museum, and all other necessary incidental expenses" (sundry civil act of April 28, 1904) $180,000.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Salaries or compensation	$160,422.74		
Special services	2,054.58		
Total salaries and services		$162,477.32	
Miscellaneous:			
Supplies	3,985.88		
Stationery	766.63		
Freight and cartage	1,361.69		
Traveling expenses	2,105.36		
Drawings and illustrations	749.65		
Specimens	1,908.13		
Total miscellaneous		10,877.34	
Total expenditure to June 30, 1905			173,354.66
Balance July 1, 1905, to meet outstanding liabilities			6,645.34

Analysis of expenditures for salaries or compensation.

(July 1, 1904, to June 30, 1905.)

Scientific and administrative staff:	
1 assistant secretary, 12 months, at $258.33	$3,099.96
1 administrative assistant, 12 months at $291.66	3,499.92
1 head curator, 12 months, at $291.66	3,499.92
1 head curator, 12 months, at $291.66	3,499.92
1 acting head curator, 12 months, at $291.66	3,499.92
1 curator, 12 months, at $200	2,400.00
1 curator, 9 months 29 days, at $200	1,993.34
1 associate curator, 5 months, 15 days, at $200	1,100.00
1 curator, 12 months, at $100	1,200.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 12 months, at $150	1,800.00
1 curator, assistant, 6 months 15 days, at $150	975.00
1 curator, assistant, 2 months 8 days, at $150	340.00
1 curator, assistant, 12 months, at $133.33	1,599.96
1 curator, assistant, 12 months, at $133.33	1,599.96
1 curator, assistant, 12 months, at $125	1,500.00
1 curator, assistant, 8 months, at $120	960.00
1 curator, assistant, 12 months, at $116.66	1,399.92
1 curator, assistant, 12 months, at $116.66	1,399.92
1 curator, assistant, 12 months, at $100	1,200.00
1 curator, assistant, 16 days, at $100	53.33
1 curator, assistant, 1 month, at $83.33	83.33
1 curator, second assistant, 12 months, at $100	1,200.00
1 aid, 12 months, at $100	1,200.00
1 aid, 8 months 21 days, at $100	870.00
1 aid, 11 days, at $100	36.67
1 aid, 12 months, at $83.33	999.96
1 aid, 12 months, at $83.33	999.96
1 aid, 11 months, at $83.33	916.63

Scientific and administrative staff—Continued.

1 aid, 5 months 14 days, at $83.33	$455.54	
1 aid, 12 months, at $75	900.00	
1 aid, 2 months, at $75	150.00	
1 aid, 12 months, at $60	720.00	
1 aid, 5 months 15 days, at $60	330.00	
1 aid, 12 months, at $50	600.00	
1 aid, 12 months, at $50	600.00	
1 aid, 12 months, at $50	600.00	
1 aid, 12 months, at $45	540.00	
1 chief of correspondence and documents, 12 months, at $200	2,400.00	
1 registrar, 12 months, at $167	2,004.00	
1 editor, 12 months, at $167	2,004.00	
1 editorial assistant, 4 months 133 days, at $133.33	1,126.67	
1 assistant librarian, 12 months, $133.33	1,599.96	
1 disbursing clerk, 11 months, at $116.67	1,283.37	
1 disbursing agent, 15 days, at $125	62.50	
1 property clerk, 12 months, at $90	1,080.00	
		$64,783.66
Preparators:		
1 photographer, 12 months, at $175	2,100.00	
1 modeler, 12 months, at $100	1,200.00	
1 osteologist, 12 months, at $90	1,080.00	
1 preparator, 4 months 14 days, at $125	558.33	
1 preparator, 12 months, at $100	1,200.00	
1 preparator, 12 months, at $90	1,080.00	
1 preparator, 9 months 45 days, at $90	945.00	
1 preparator, 12 months, at $85	1,020.00	
1 preparator, 9 months 39 days, at $85; 208 hours at 50 cents	979.50	
1 preparator, 12 months, at $80	960.00	
1 preparator, 11 months 15 days, at $70	805.00	
1 preparator, 12 months, at $55	660.00	
1 preparator, 2 months, at $50	100.00	
1 preparator, 1 month, at $50	50.00	
1 preparator, 12 months, at $45	540.00	
1 preparator, 12 months, at $40	480.00	
1 preparator, 6 months, at $40	240.00	
1 preparator, 8 months 15 days, at $25	212.50	
1 preparator, 176 hours, at 50 cents	88.00	
1 assistant preparator, 6 months, at $40	240.00	
1 chief taxidermist, 12 months, at $125	1,500.00	
1 taxidermist, 12 months, at $100	1,200.00	
1 taxidermist, 12 months, at $60	720.00	
1 taxidermist, apprentice, 10 months, at $25	250.00	
1 collector, 2 months, at $50	100.00	
1 classifier, 2 months, at $100	200.00	
1 cataloguer, 12 months, at $60	720.00	
1 cataloguer, 25 days, at $50	41.67	
1 cataloguer, 8 months, at $55	440.00	
1 cataloguer, 2 months 25 days, at $50	141.67	
1 cataloguer, 3 months 2 days, at $50	153.33	
		$20,005.00

Clerical staff:

1 finance clerk, 12 months, at $125	$1,500.00	
1 stenographer, 12 months, at $175	2,100.00	
1 stenographer, 9 months, at $90	810.00	
1 stenographer, 3 months, at $90	270.00	
1 stenographer, 12 months, at $83.33	999.96	
1 stenographer and typewriter, 12 months, at $90	1,080.00	
1 stenographer and typewriter, 2 months 31 days, at $75	227.50	
1 stenographer and typewriter, 8 months 37 days, at $60	554.00	
1 stenographer and typewriter, 2 months 21 days, at $60	162.00	
1 stenographer and typewriter, 1 month, at $60	60.00	
1 stenographer and typewriter, 11 months, at $60; 1 month, at $83.33	743.33	
1 stenographer and typewriter, 5 months 56 days, at $50	360.00	
1 stenographer and typewriter, 6 months 13 days, at $50	321.67	
1 stenographer and typewriter, 5 months 11 days, at $50	268.33	
1 stenographer and typewriter, 3 months 13 days, at $50	171.67	
1 stenographer and typewriter, 3 months 6 days, at $50	160.00	
1 stenographer and typewriter, 2 months 13 days, at $50	121.67	
1 stenographer and typewriter, 1 month 15 days, at $50	75.00	
1 botanical clerk, 2 months, at $75	150.00	
1 botanical clerk, 9 months 28 days, at $60	596.00	
1 botanical clerk, 6 months 15 days, at $50	325.00	
1 document clerk, 12 months, at $55	660.00	
1 recorder, 1 month, at $60	60.00	
1 clerk and preparator, 12 months, at $60	720.00	
1 clerk and typewriter, 12 months, at $75	900.00	
1 clerk, 8 months 14 days, at $125	1,058.33	
1 clerk, 6 months, at $125	750.00	
1 clerk, 12 months, at $115	1,380.00	
1 clerk, 11 months 24 days, at $100	1,180.00	
1 clerk, 10 months, at $100	1,000.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 2 months, at $75	150.00	
1 clerk, 11 days, at $75	27.50	
1 clerk, 12 months, at $70	840.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 12 months, at $50	600.00	
1 clerk, 11 months, at $50	550.00	
1 clerk, 1 month 5 days, at $40	46.67	
1 clerk, 12 months, at $35	420.00	
1 typewriter, 12 months, at $85	1,020.00	
1 typewriter, 11 months 10 days, at $75	850.00	
1 typewriter, 11 months 29 days, at $60	718.00	
1 typewriter, 8 days, at $50	13.33	
1 typewriter, 11 months, at $70; 1 month at $75	845.00	
		$31,684.96

Buildings and labor:

1 captain of watch, 12 months, at $90	$1,080.00
1 lieutenant of watch, 12 months, at $70	840.00
1 lieutenant of watch, 12 months, at $70	840.00
1 watchman, 12 months, at $65	780.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
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1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 11 months 29 days, at $60	718.00
1 watchman, 10 months 55 days, at $60	710.00
1 watchman, 10 months 54 days, at $60	708.00
1 watchman, 9 months 83 days, at $60	706.00
1 watchman, 10 months, at $60	600.00
1 watchman, 6 months, at $55; 4 months, at $60	570.00
1 watchman, 6 months, at $55; 3 months, at $60	510.00
1 watchman, 3 months 4 days, at $60	188.00
1 general foreman, 12 months, at $122.50	1,470.00
1 carpenter, 19½ days, at $4.40	85.80
1 carpenter, 18 days, at $4.40	79.20
1 carpenter, 3 days, at $4.40	13.20
1 carpenter, 3 days, at $4.40	13.20
1 workman, 12 months, at $50	600.00
1 wrapper, 33 days, at $2	66.00
1 packer, 19 days, at $2.25	42.75
1 packer, 12 days, at $2.25	27.00
1 packer, 3 days, at $2.25	6.75
1 classified laborer, 12 months, at $47	564.00
1 classified laborer, 3 months, at $47	141.00
1 classified laborer, 3 months, at $40	120.00
1 classified laborer, 1 month, at $40	40.00
1 classified laborer, 13 days, at $1.50	19.50
1 skilled laborer, 10 months 39 days, at $55	621.50
1 skilled laborer, 10 months, at $55	550.00
1 skilled laborer, 12 months, at $50	600.00
1 skilled laborer, 12 months, at $50	600.00
1 skilled laborer, 11 months 11 days, at $50	568.33
1 skilled laborer, 2 months, at $40	80.00
1 skilled laborer, 2 months 25 days, at $35	99.17
1 skilled laborer, 307 days, at $1.50	460.50
1 skilled laborer, 80 hours, at $0.55	44.00
1 watchman, 3 days, at $60	6.00

Buildings and labor—Continued.

1 watchman, 3 days, at $60	$6.00
1 watchman, 1 month, at $55	55.00
1 watchman, 1 day, at $55	1.83
1 watchman, 5 months 34 days, at $40	245.34
1 watchman, 83 days, at $1.75	145.25
1 laborer, 14 days, at $60	28.00
1 laborer, 7 months 13 days, at $47	349.37
1 laborer, 1 month 34 days, at $47	100.27
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 11 months 29 days, at $40	478.67
1 laborer, 11 months 29 days, at $40	478.67
1 laborer, 10 months 56½ days, at $40	475.34
1 laborer, 10 months 48 days, at $40	464.00
1 laborer, 9 months, at $40	360.00
1 laborer, 7 months 21 days, at $40	311.50
1 laborer, 3 months, at $40	120.00
1 laborer, 8 months 10 days, at $35	291.67
1 laborer, 2 months, at $35	70.00
1 laborer, 7 days, at $2.25	15.75
1 laborer, 40 days, at $2	80.00
1 laborer, 36 days, at $2	72.00
1 laborer, 34 days, at $2	68.00
1 laborer, 29½ days, at $2	59.00
1 laborer, 26 days, at $2	52.00
1 laborer, 23 days, at $2	46.00
1 laborer, 12 days, at $2	24.00
1 laborer, 10½ days, at $2	21.00
1 laborer, 10 days, at $2	20.00
1 laborer, 6½ days, at $2	13.00
1 laborer, 6½ days, at $2	13.00
1 laborer, 3¾ days, at $2	7.50
1 laborer, 3 days, at $2	6.00
1 laborer, 3 days, at $2	6.00
1 laborer, 2 days, at $2	4.00
1 laborer, 311½ days, at $1.75	545.13
1 laborer, 205 days, at $1.50	307.50
1 laborer, 78 days, at $1.50	117.00
1 laborer, 59 days, at $1.50	88.50
1 laborer, 52 days, at $1.50	78.00
1 laborer, 48 days, at $1.50	72.00
1 laborer, 39 days, at $1.50	58.50
1 laborer, 15 days, at $1.50	22.50
1 laborer, 13 days, at $1.50	19.50

Buildings and labor—Continued.

1 laborer, 12 days, at $1.50	$18.00	
1 laborer, 9 days, at $1.50	13.50	
1 laborer, 9 days, at $1.50	13.50	
1 laborer, 40¼ days, at $1	40.25	
1 laborer, 11½ days, at $1	11.50	
1 mail carrier, 12 months, at $45	540.00	
1 messenger, 2 months, at $40	80.00	
1 messenger, 7 months 3 days, at $35	248.50	
1 messenger, 12 months, at $30	360.00	
1 messenger, 35 days, at $30	35.00	
1 messenger, 1 month, at $20; 6 months 5 days, at $25; 4 months 25 days, at $35	343.34	
1 messenger, 7 months, at $20; 4 months, at $25; 1 month, at $35	275.00	
1 messenger, 3 months 14 days, at $20; 8 months 16 days, at $25	282.66	
1 messenger, 9 months 16 days, at $20; 26 days, at $25	212.34	
1 messenger, 7 months 11 days, at $20	147.33	
1 messenger, 4 months 22 days, at $20	94.67	
1 messenger, 4 months 15 days, at $20	90.00	
1 messenger, 3 months 4 days, at $20	62.67	
1 messenger, 1 month 27 days, at $20	38.00	
1 messenger, 19 days, at $20	12.67	
1 messenger, 1½ days, at $1	1.50	
1 messenger boy, 2 months 10 days, at $20	46.67	
1 messenger boy, 9 days, at $20	6.00	
1 attendant, 12 months, at $40	480.00	
1 attendant, 12 months, at $40	480.00	
1 attendant, 182 days, at $1.25	227.50	
1 cleaner, 12 months, at $35	420.00	
1 cleaner, 12 months, at $35	420.00	
1 cleaner, 12 months, at $35	420.00	
1 cleaner, 12 months, at $35	420.00	
1 cleaner, 11 months 24 days, at $35	413.00	
1 cleaner, 5 months 23 days, at $35	201.83	
1 cleaner, 4 months 6 days, at $35	147.00	
1 cleaner, 3 months 6 days, at $35	112.00	
1 cleaner, 5 months 40 days, at $30	190.00	
		$43,949.12
Total services		160,422.74

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance as per report July 1, 1904	$6,139.[illegible]

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Special services		$1,201.45
Miscellaneous:		
Drawings and illustrations	$457.55	
Supplies	1,901.61	
Stationery	591.15	

Miscellaneous—Continued.

Travel	$1,343.88		
Freight	445.36		
Total miscellaneous		$4,739.55	
Total expenditure			$5,941.00
Balance July 1, 1905, to meet outstanding liabilities			198.99

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance as per report July 1, 1904	$400.23

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Freight	39.42
Balance July 1, 1905	360.81

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees" (sundry civil act, April 28, 1904)	$22,500.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Salaries or compensation		$12,460.29	
Special services		329.00	
Total salaries and services			$12,789.29
Miscellaneous:			
Cases, exhibition	$220.00		
Cases, storage	1,884.00		
		$2,104.00	
Drawings		35.03	
Drawers, trays, boxes		777.50	
Woodwork		277.62	
Glass		323.00	
Hardware		556.42	
Tools		16.19	
Cloth, etc		147.59	
Lumber		1,377.27	
Paints		319.33	
Office furniture		874.66	
Rubber, leather, cork		42.76	
Slate		10.50	
Flour		5.00	

Miscellaneous—Continued.			
Plumbing material	$11.08		
Paper	36.00		
Glass jars	26.77		
Total miscellaneous		$6,940.72	
Total expenditure			$19,730.01
Balance July 1, 1905, to meet outstanding liabilities			2,769.99

Analysis of expenditures for salaries or compensation.

(July 1, 1904, to June 30, 1905.)

1 superintendent, 6 months, at $166.66	$999.96
1 clerk, 12 months, at $100	1,200.00
1 shop foreman, 12 months, at $85	1,020.00
1 carpenter, 9 days, at $3	27.00
1 carpenter, 7 days, at $4.40	30.80
1 carpenter, 313 days, at $3	939.00
1 carpenter, 313 days, at $3	939.00
1 carpenter, 201 days, at $3	603.00
1 carpenter, 78 days, at $3	234.00
1 carpenter, 8 days, at $4.40	35.20
1 carpenter, 122½ days, at $3	367.50
1 carpenter, 7 days, at $4.40	30.80
1 carpenter, 312 days, at $3	936.00
1 painter, 9 months 41 days, at $70	725.66
1 painter, 9 months 54 days, at $75	810.00
1 skilled laborer, 3 months 5 days, at $65	205.83
1 skilled laborer, 6 months, at $100	600.00
1 skilled laborer, 2 months, at $55	110.00
1 skilled laborer, 1 month 82 days, at $75	280.00
1 skilled laborer, 3 days, at $4.40	13.20
1 skilled laborer, 10 months, 13 days at $65	678.17
1 skilled laborer, 1 month 98 days, at $75	320.00
1 workman, 313 days, at $2	626.00
1 laborer, 20 days, at $1.50	30.00
1 laborer, 15 days, at $1.50	22.50
1 painter's helper, 12 months, at $55	660.00
1 messenger, 20 days, at $25	16.67
Total	12,460.29

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance as per report July 1, 1904	$3,431.98

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Miscellaneous:		
Cases, exhibition	$612.00	
Cases, storage	751.00	
		$1,363.00
Drawers, trays, boxes		1,230.67
Frames, stands, miscellaneous woodwork		6.50

Miscellaneous—Continued.

Hardware	$225.16	
Tools	8.45	
Cotton, cloth, etc	118.80	
Lumber	184.82	
Paints	2.25	
Office furniture	274.25	
Rubber and leather	8.14	
Flour	3.00	
Total expenditure		$3,425.04
Balance July 1, 1905, to meet outstanding liabilities		6.94

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance per last report July 1, 1904	$12.58

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

None.

Balance July 1, 1905	12.58

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

HEATING AND LIGHTING, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum" (sundry civil act, April 28, 1904)	$18,000.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Salaries or compensation	$8,173.17		
Special services	40.00		
Total services		$8,213.17	
Miscellaneous:			
Coal and wood	$4,880.90		
Gas	527.40		
Electricity	1,369.90		
Telephones	490.25		
Electrical supplies	446.44		
Rental call boxes	90.00		
Heating supplies	449.22		
Telegrams	63.32		
Total miscellaneous		8,317.43	
Total expenditure to June 30, 1905			$16,530.60
Balance July 1, 1905, to meet outstanding liabilities			1,469.40

Analysis of expenditures for salaries or compensation.

(July 1, 1904, to June 30, 1905.)

1 engineer, 12 months, at $125	$1,500.00
1 telephone operator, 12 months, at $70	840.00
1 telephone operator, 18 days, at $1.50	27.00
1 telephone operator, 5 days, at $1.50	7.50
1 electrician, 40 days, at $4	160.00
1 blacksmith, 12 months, at $60	720.00
1 skilled laborer, 6 months, at $100	600.00
1 skilled laborer, 12 months, at $75	900.00
1 skilled laborer, 12 months, at $80	960.00
1 fireman, 12 months, at $60	720.00
1 plumber's assistant, 12 months, at $65	780.00
1 laborer, 12 months, at $40	480.00
1 laborer, 11 months 29 days, at $40	478.67
Total	8,173.17

HEATING, LIGHTING, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1904, as per report	$815.58

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Coal and wood	$6.19	
Gas	33.60	
Telephones	165.90	
Rental call boxes	10.00	
Electrical supplies	136.81	
Telegrams	10.84	
Electricity	141.51	
Heating supplies	256.25	
Total expenditure		761.10
Balance July 1, 1905, to meet outstanding liabilities		54.48

HEATING, LIGHTING, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance July 1, 1904, as per report	$11.86

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

None.

Balance July 1, 1905	11.86

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

POSTAGE, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for postage stamps and foreign postal cards for the National Museum" (sundry civil act, April 28, 1904)	$500.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

For postage stamps	500.00

PRINTING AND BINDING, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for the Smithsonian Institution, for printing labels and blanks, and for the 'Bulletins' and 'Proceedings of the National Museum,' the editions of which shall not be less than 3,000 copies, and binding in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library" (sundry civil act, April 28, 1904)	$25,000.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Bulletins of the Museum	$9,461.53	
Proceedings of the Museum	6,033.13	
Contributions to National Herbarium	5,020.13	
Reprinting publications	822.22	
Labels	400.58	
Blanks and circulars	133.88	
Public documents	74.10	
Binding	2,389.85	
Record books	466.78	
Botanical cards	22.49	
Total expenditure to June 30, 1905		24,824.69
Balance July 1, 1905, to meet outstanding liabilities		175.31

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for rent of workshops and temporary storage quarters for the National Museum" (sundry civil act, April 28, 1904)	$4,580.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Rent of workshops:		
431 Ninth street SW., 12 months, at $166.66	$1,999.92	
217 Seventh street SW., 12 months, at $105	1,260.00	
309 and 313 Tenth street SW., 12 months, at $80	960.00	
915 Virginia avenue (rear), 12 months, at $30	360.00	
Total expenditures to June 30, 1905		4,579.92
Balance July 1, 1905		.08

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance as per report July 1, 1904 .... $0.08

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

None.

Balance July 1, 1905.......... .08

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance as per report July 1, 1904 .... $0.08

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

None.

Balance July 1, 1905.......... .08

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

BUILDING REPAIRS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material" (sundry civil act, April 28, 1904)...... $15,000.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Salaries or compensation..........	$8,424.18		
Special services	290.00		
Total salaries and services..........		$8,714.18	
Miscellaneous:			
Repairs to roof (by contract)..........	$2,604.51		
Steel trusses	450.00		
Lumber	323.76		
Cement, mortar, marble, brick, sand	129.75		
Hardware, tools..........	226.51		
Paints, oil, brushes..........	269.59		
Skylights and gearing attachments	450.00		
Glass	30.80		
Total miscellaneous expenditures..........		4,484.92	
Total expenditures to June 30, 1905			13,199.10
Balance July 1, 1905, to meet outstanding liabilities			1,800.90

Analysis of expenditures for salaries or compensation.

(July 1, 1904, to June 30, 1905.)

1 superintendent, 6 months, at $166.66..........	$999.96
1 foreman, 12 months, at $85..........	1,020.00
1 carpenter, 12 days, at $3	36.00

1 carpenter, 50 days, at $3	150.00
1 carpenter, 243 days, at $3	729.00
1 carpenter, 313 days, at $3	939.00
1 carpenter, 65 days, at $3	195.00
1 painter, 7 days, at $75	17.50
1 painter, 15 days, at $75	37.50
1 painter, 15 days, at $75; 3½ days at $3	48.00
1 tinner, 2 months 29½ days, at $70	208.83
1 rigger, 3 months, at $60	180.00
1 classified laborer, 12 months, at $60	720.00
1 skilled laborer, 41½ days, at $75	103.75
1 skilled laborer, 26 days, at $75	65.00
1 skilled laborer, 18 days, at $2.50	45.00
1 skilled laborer, 7 months 132½ days, at $70	799.17
1 skilled laborer, 18 days, at $2.50	45.00
1 laborer, 15 days, at $1.50	22.50
1 laborer, 6½ days, at $1.50	9.75
1 laborer, 4 days, at $1.50	6.00
1 laborer, 10 days, at $1.50	15.00
1 laborer, 10 days, at $1.50	15.00
1 laborer, 1 day, at $1.50	1.50
1 laborer, 12 months, at $40	480.00
1 laborer, 23 days, at $1.50	34.50
1 laborer, 30 days, at $1.50	45.00
1 laborer, 5 days, at $1.50	7.50
1 laborer, 21 days, at $1.50	31.50
1 laborer, 29 days, at $1.50	43.50
1 laborer, 12 months, at $47	564.00
1 laborer, 5 days, at $1.50	7.50
1 laborer, 8 months 29½ days, at $47	422.22
1 messenger, 10 months, at $30; 2 months, at $40	380.00
Total	8,424.18

BUILDING REPAIRS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance, July 1, 1904, as per report	$2,468.32

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Total salaries and services		$956.00	
Miscellaneous:			
Repairs to roof (contract)	$846.60		
Lumber	98.56		
Mortar	2.40		
Hardware, tools, etc	117.82		
Paints, oils, chemicals, etc	28.60		
Terrazzo pavement	365.00		
Total miscellaneous expenditure		1,458.98	
Total expenditure			2,414.98
Balance July 1, 1905, to meet outstanding liabilities			53.34

BUILDING REPAIRS, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance July 1, 1904, as per report	$58.04

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

None.

Balance July 1, 1905	58.04

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

BOOKS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "for purchase of books, pamphlets, and periodicals, for reference in the National Museum" (sundry civil act, April 28, 1904)	$2,000.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Books, pamphlets, and periodicals	1,034.04
Balance July 1, 1905, to meet outstanding liabilities	965.96

BOOKS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1904, as per report	$772.40

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Books, pamphlets, and periodicals	754.08
Balance July 1, 1905, to meet outstanding liabilities	18.32

BOOKS, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance July 1, 1904, as per report	49.76

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Books, pamphlets, and periodicals	31.02
Balance July 1, 1905	18.74

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

NATIONAL MUSEUM, TRANSPORTATION OF EXHIBITS ACQUIRED FROM THE LOUISIANA PURCHASE EXPOSITION.

RECEIPTS.

Appropriation by Congress "for the transportation from the Louisiana Purchase Exposition, St. Louis, Mo., to the U. S. National Museum, Washington, D. C., of exhibits acquired by the United States Government for addition to the collections in the National Museum, including expenditures incurred prior to March 4, 1905, for packing, freight, cartage, unpacking, and all other necessary expenses incident thereto, to be immediately available" (sundry civil act, March 3, 1905)	$6,500.00

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Services		$304.92	
Miscellaneous:			
Lumber, boxes, barrels	$240.93		
Packing material	102.60		
Hardware	23.40		
Freight and cartage	497.13		
Travel	95.90		
Total miscellaneous expenditure		959.96	
Total expenditure			$1,264.88
Balance July 1, 1905, to meet outstanding liabilities			5,235.12

PURCHASE OF SPECIMENS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1904, as per report	$1,482.27

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Purchase of specimens	867.55
Balance July 1, 1905, to meet outstanding liabilities	614.72

PURCHASE OF SPECIMENS, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance July 1, 1904, as per report	$350.18

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

Purchase of specimens	71.00
Balance July 1, 1905	279.18

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

PUBLICATION CONTRIBUTIONS TO NATIONAL HERBARIUM, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance July 1, 1904, as per report	$2.71

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

None.

Balance July 1, 1905	2.71

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

PLANS FOR ADDITIONAL BUILDING, NATIONAL MUSEUM, 1903.

RECEIPTS.

Balance July 1, 1904, as per report	$43.20

EXPENDITURES.

(July 1, 1904, to June 30, 1905.)

None.

Balance July 1, 1905	43.20

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "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, printing and publishing results of researches, not exceeding 1,500 copies, repairs and alterations of buildings, and miscellaneous expenses, $15,000" (sundry civil act, April 28, 1904)	$15,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 aid, at $225 per month	$2,700.00	
1 junior assistant, at $150 per month	1,650.00	
1 clerk, at $125 per month	125.00	
1 stenographer, at $116.66 per month	1,399.92	
1 special assistant, at $100 per month	310.00	
1 bolometric assistant, at $50 per month	61.67	
1 photographic assistant, at $70 per month	140.00	
1 messenger boy, at $20 per month	60.00	
1 cataloguer, at $50 per month	50.00	
1 instrument maker, at $100 per month	1,190.00	
1 fireman, at $60 per month	714.00	
1 carpenter, at $91 per month	45.50	
1 carpenter, at $3.50 per day	17.50	
1 carpenter, at $3.50 per day	1.75	
1 carpenter, at $3.50 per day	10.50	
1 carpenter, at $3.50 per day	21.00	
1 painter, at $3 per day	18.00	
1 painter, at $3 per day	6.00	
1 laborer, at $30 per month	270.00	
1 laborer, at $1.50 per day	7.50	
1 cleaner, at $1.25 per day	163.75	
1 cleaner, at $1.25 per day	8.75	
Total salaries or compensation		$8,970.84
General expenses:		
Apparatus	264.37	
Building repairs, etc.	290.92	
Books and binding	139.04	

General expenses—Continued.

Castings	$202.93		
Drawings	92.00		
Electricity, gas, etc	187.05		
Freight	49.90		
Lumber	22.82		
Stationery	15.00		
Supplies, chemicals, etc	430.81		
Travel	145.80		
		$1,840.64	
Total disbursements			$10,811.48
Balance July 1, 1905			4,188.52

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1904.

Balance July 1, 1904, as per last report		$4,366.52
General expenses:		
Apparatus	$3,972.94	
Books and binding	43.33	
Castings	12.20	
Drawings	21.90	
Freight	30.77	
Lumber	28.87	
Postage and telegraph	2.53	
Supplies, gas, etc	220.96	
Total disbursements		4,333.50
Balance July 1, 1905		33.02

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1903.

Balance July 1, 1904, as per last report	$8.02

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

OBSERVATION OF ECLIPSE, MAY 28, 1900.

RECEIPTS.

Balance July 1, 1904, as per report	$712.29

DISBURSEMENTS.

General expenses:	
Printing, etc	575.80
Balance July 1, 1905	136.49

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

NATIONAL ZOOLOGICAL PARK, 1905.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1905, "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 and providing seats in the park; care, subsistence, purchase, and transportation of animals; including salaries or compensation of all necessary employees, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding 1,500 copies, and general incidental expenses not otherwise provided for, $95,0(0" (sundry civil act, April 28, 1904)	$95,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 superintendent, at $275 per month	$3,300.00	
1 assistant superintendent, at $166.66 per month	1,999.92	
1 clerk, at $125 per month	1,500.00	
1 clerk, at $125 per month	1,500.00	
1 stenographer, at $83.33 per month	999.96	
1 messenger boy, at $40 per month	480.00	
1 messenger boy, at $35 per month	420.00	
1 messenger boy, at $1 per day	18.00	
1 landscape gardener, at $83.33 per month	624.97	
1 photographer, at $70 per month	420.00	
1 head keeper, at $125 per month	1,500.00	
1 keeper, at $60 per month	720.00	
1 keeper, at $60 per month	638.50	
1 keeper, at $60 per month	708.00	
1 keeper, at $60 per month	720.00	
1 keeper, at $60 per month	720.00	
1 sergeant of watch, at $65 per month	429.00	
1 watchman, at $60 per month	720.00	
1 watchman, at $60 per month	660.00	
1 watchman, at $60 per month	720.00	
1 watchman, at $60 per month	60.00	
1 watchman, at $60 per month	720.00	
1 mechanician, at $3.50 per day	357.00	
1 machinist, at $100 per month	1,200.00	
1 assistant foreman, at $65 per month	780.00	
1 assistant blacksmith, at $60 per month	720.00	
1 workman, at $60 per month	720.00	
1 laborer, at $60 per month	698.00	
1 laborer, at $60 per month	699.00	
1 laborer, at $60 per month	422.00	
Total salaries or compensation		$25,174.35
Miscellaneous:		
Buildings	3,023.77	
Building material	588.34	
Fencing, cage material, etc	537.75	
Food for animals	13,959.10	

Miscellaneous—Continued.			
Freight and transportation of animals	$1,160.19		
Fuel	2,003.11		
Furniture	36.98		
Lumber	1,278.99		
Machinery, tools, etc	385.82		
Miscellaneous supplies	903.04		
Paints, oils, glass, etc	250.54		
Postage, telegraph, and telephone	195.46		
Purchase of animals	1,598.00		
Road material and grading	42.06		
Stationery, books, printing, etc	290.27		
Surveying, plans, etc	578.18		
Travel and field expenses	199.92		
Trees, plants, etc	56.95		
Water supply, sewerage, etc	42.31		
Park seats	105.30		
Total miscellaneous		$27,236.08	
Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, laying water pipes, building roads, gutters, and walks, planting trees, and otherwise improving the grounds:			
1 carpenter, at $3 per day	955.50		
1 workman, at $2 per day	726.00		
3 laborers, at $2.25 per day	1,200.80		
13 laborers, at $2 per day	9,179.01		
17 laborers, at $1.75 per day	8,063.23		
36 laborers, at $1.50 per day	8,097.77		
2 laborers, at $1.25 per day	641.59		
8 laborers, at $1 per day	556.25		
2 attendants, at $0.75 per day	288.94		
1 helper, at $0.75 per day	63.94		
4 helpers, at $0.50 per day	106.14		
1 stonebreaker, at $0.60 per cubic yard	8.40		
3 wagons and teams, at $3.50 per day	1,193.52		
5 horses and carts, at $1.75 per day	315.00		
1 horse, at $0.50 per day	35.75		
Total wages of mechanics, etc		31,431.84	
Total disbursements			$83,842.27
Balance July 1, 1905			11,157.73

NATIONAL ZOOLOGICAL PARK, 1904.

Balance July 1, 1904, as per last report		$14,434.97
General expenses:		
Buildings	$8,664.28	
Fencing, cage material, etc	15.22	
Food for animals	1,301.32	
Freight	200.77	
Fuel	452.60	

General expenses—Continued.		
Furniture	$129.50	
Lumber	47.60	
Machinery, tools, etc	57.73	
Miscellaneous supplies	275.06	
Paints, oils, glass, etc	48.40	
Postage, telegraph, and telephone	78.57	
Purchase and transportation of animals	1,010.67	
Road material, grading, etc	24.00	
Stationery, books, etc	100.74	
Surveying, plans, etc	575.00	
Travel and field expenses	29.95	
Trees, plants, etc	12.37	
Water supply, sewerage, etc	34.20	
Total disbursements		$13,057.98
Balance July 1, 1905		1,376.99

NATIONAL ZOOLOGICAL PARK, 1903.

Balance July 1, 1904, as per last report		$203.62
General expenses:		
Building material	$7.70	
Freight	20.07	
Special services, plans, etc	175.00	
Total disbursements		202.77
Balance		.85

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

ELEPHANT HOUSE, NATIONAL ZOOLOGICAL PARK, 1903.

Balance July 1, 1904, as per last report	$0.54

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1905.

RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1905, appears from the foregoing statements and account books to have been as follows:

SMITHSONIAN INSTITUTION.

From interest on Smithsonian fund for the year	$56,220.00	
From interest on West Shore bonds	1,680.00	
From sales of publications, repayments, freight, etc	6,861.72	
Cash from temporary loan	10,000.00	
		$74,761.72
Deduct deficit July 1, 1904		362.80
		74,398.92

APPROPRIATIONS COMMITTED BY CONGRESS TO THE CARE OF THE INSTITUTION.

International Exchanges, Smithsonian Institution:		
From balance of 1902–3	$29.44	
From balance of 1903–4	2,674.95	
From appropriation for 1904–5	27,000.00	
		$29,704.39
American Ethnology, Smithsonian Institution:		
From balance of 1902–3	1,101.87	
From balance of 1903–4	1,906.94	
From appropriation for 1904–5	40,000.00	
		43,008.81
Preservation of collections, National Museum:		
From balance of 1902–3	400.23	
From balance of 1903–4	6,139.99	
From appropriation for 1904–5	180,000.00	
		186,540.22
Furniture and fixtures, National Museum:		
From balance of 1902–3	12.58	
From balance of 1903–4	3,431.98	
From appropriation for 1904–5	22,500.00	
		25,944.56
Heating and lighting, National Museum:		
From balance of 1902–3	11.86	
From balance of 1903–4	815.58	
From appropriation for 1904–5	18,000.00	
		18,827.44
Postage, National Museum:		
From appropriation for 1904–5		500.00
Printing and binding, National Museum:		
From appropriation for 1904–5		25,000.00
Rent of workshops, National Museum:		
From balance of 1902–3	.08	
From balance of 1903–4	.08	
From appropriation for 1904–5	4,580.00	
		4,580.16
Building repairs, National Museum:		
From balance of 1902–3	58.04	
From balance of 1903–4	2,468.32	
From appropriation for 1904–5	15,000.00	
		17,526.36
Transportation of exhibits acquired from the Louisiana Purchase Exposition, National Museum:		
Appropriation		6,500.00
Books, National Museum:		
From balance of 1902–3	49.76	
From balance of 1903–4	772.40	
From appropriation for 1904–5	2,000.00	
		2,822.16
Purchase of specimens, National Museum:		
From balance of 1902–3	350.18	
From appropriation for 1903–4	1,482.27	
		1,832.45

Contributions to National Herbarium, National Museum:		
From balance July 1, 1904		$2.71
Plans for additional building, National Museum:		
From balance July 1, 1904		43.20
Astrophysical Observatory, Smithsonian Institution:		
From balance of 1902-3	$8.02	
From balance of 1903-4	4,366.52	
From appropriation for 1904-5	15,000.00	
		19,374.54
Observation of eclipse of May 28, 1900:		
From balance July 1, 1904		712.29
National Zoological Park:		
From balance of 1902-3	203.62	
From balance of 1903-4	14,434.97	
From appropriation for 1904-5	95,000.00	
		109,638.59
Elephant house, National Zoological Park:		
From balance July 1, 1904		.54

SUMMARY.

Smithsonian Institution	$74,761.72	
Exchanges	29,704.39	
Ethnology	43,008.81	
Preservation of collections	186,540.22	
Furniture and fixtures	25,944.56	
Heating and lighting	18,827.44	
Postage	500.00	
Printing and binding	25,000.00	
Rent of workshops	4,580.16	
Building repairs	17,526.36	
Transportation of exhibits acquired from the Louisiana Purchase Exposition, National Museum	6,500.00	
Books	2,822.00	
Purchase of specimens	1,832.45	
Contributions to National Herbarium	2.71	
Plans for additional building	43.20	
Astrophysical Observatory	19,374.54	
Observation of eclipse	712.29	
National Zoological Park	109,638.59	
National Zoological Park, elephant house	.54	
		$567,319.98

The committee has examined the vouchers for payment from the Smithsonian income during the year ending June 30, 1905, 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.

The quarterly accounts current, the vouchers, and journals have been examined and found correct.

Statement of regular income from the Smithsonian fund available for use in the year ending June 30, 1906.

Balance July 1, 1905		$5,153.92 *
Interest due and receivable July 1, 1905	$28,110.00	
Interest due and receivable January 1, 1906	28,110.00	
Interest, West Shore Railroad bonds, due July 1, 1905	840.00	
Interest, West Shore Railroad bonds, due January 1, 1906	840.00	
		57,900.00
Total available for year ending June 30, 1906		63,053.92

Respectfully submitted.

J. B. HENDERSON, *Chairman*,
ALEXANDER GRAHAM BELL,
ROBERT R. HITT,
Executive Committee.

WASHINGTON, D. C., *January 9, 1906.*

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION, ETC.

[Continued from previous reports.]

[Fifty-eighth Congress, third session.]

SMITHSONIAN INSTITUTION.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancy on the Board of Regents of the Smithsonian Institution, of the class other than members of Congress, shall be filled by the reappointment of James B. Angell, of Michigan, whose term of office expires on January twenty-fourth, nineteen hundred and five. (Approved January 23, 1905; Statutes, XXXIII, 1279.)

SMITHSONIAN DEPOSIT [LIBRARY OF CONGRESS].—For custodian, one thousand five hundred dollars; assistant, one thousand two hundred dollars; messenger, seven hundred and twenty dollars; messenger boy, three hundred and sixty dollars; in all, three thousand seven hundred and eighty dollars. (Approved February 3, 1905; Statutes XXXIII, 640.)

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, twenty-eight thousand eight hundred dollars. (Approved March 3, 1905; Statutes, XXXIII, 1165.)

NAVAL OBSERVATORY.—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, two thousand five hundred dollars. (Approved February 3, 1905; Statutes, XXXIII, 666.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, forty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building. (Approved March 3, 1905; Statutes, XXXIII, 1165.)

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, printing and publishing results of researches, not exceeding one thousand five hundred copies, repairs and alterations of buildings and miscellaneous expenses, fifteen thousand dollars. (Approved March 3, 1905; Statutes, XXXIII, 1165.)

NATIONAL MUSEUM.

For continuing the construction of the building for the National Museum, and for each and every purpose connected with the same, one million five hundred thousand dollars.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twenty-two thousand five hundred dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, eighteen 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, one hundred and eighty 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 the transportation from the Louisiana Purchase Exposition, Saint Louis, Missouri, to the United States National Museum, Washington, District of Columbia, of exhibits acquired by the United States Government for addition to the collections in the National Museum, including expenditures incurred prior to March fourth, nineteen hundred and five, for packing, freight, cartage, unpacking, and all other necessary expenses incident thereto, to be immediately available, six thousand five hundred dollars.

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 rent of workshops and temporary storage quarters for the National Museum, four thousand five hundred and eighty dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars. (Approved March 3, 1905; Statutes, XXXIII, 1165, 1166.)

For the Smithsonian Institution, for printing labels and blanks, and for the "Bulletins" and "Proceedings" of the National Museum, the editions of which shall not be less than three 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, twenty-five thousand dollars. (Approved March 3, 1905; Statutes, XXXIII, 1212.)

For books, National Museum, four dollars and thirty-four cents. (Approved March 3, 1905; Statutes, XXXIII, 1257.)

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, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding one thousand five hundred copies, and general incidental expenses not otherwise provided for, including purchase, maintenance, and driving of horses and vehicles required for official purposes, 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 3, 1905; Statutes, XXXIII, 1166.)

To pay amounts found due by the accounting officers of the Treasury on account of the appropriation "National Zoological Park," for the fiscal year nineteen hundred and three, seven hundred and fifty dollars. (Approved March 3, 1905; Statutes, XXXIII, 1219.)

PROVISION AGAINST DEFICIENCIES.

That section thirty-six hundred and seventy-nine of the Revised Statutes of the United States is hereby amended to read as follows:

"SEC. 3679. No Department of the Government shall expend, in any one fiscal year, any sum in excess of appropriations made by Congress for that fiscal year, or involve the Government in any contract

or obligation for the future payment of money in excess of such appropriations unless such contract or obligation is authorized by law. Nor shall any Department or officer of the Government accept voluntary service for the Government or employ personal service in excess of that authorized by law, except in cases of sudden emergency involving the loss of human life or the destruction of property. All appropriations made for contingent expenses or other general purposes, except appropriations made for the fulfilment of contract obligations expressly authorized by law, or for objects required or authorized by law without reference to the amounts annually appropriated therefor, shall, on or before the beginning of each fiscal year, be so apportioned by monthly or other allotments as to prevent undue expenditures in one portion of the year that may require deficiency or additional appropriations to complete the service of the fiscal year; and all such apportionments shall be adhered to except when waived or modified in specific cases by the written order of the head of the Executive Department or other Government establishment having control of the expenditure, but this provision shall not apply to the contingent appropriations of the Senate or House of Representatives; and all such waivers or modifications, together with the reasons therefor, shall be communicated to Congress in connection with estimates for any additional appropriations required on account thereof. Any person violating any provision of this section shall be summarily removed from office and may also be punished by a fine of not less than one hundred dollars or by imprisonment for not less than one month." (Approved March 3, 1905; Statutes, XXXIII, 1257.)

RESTRICTIONS ON PRINTING, BINDING, AND ILLUSTRATIONS.

And no more than an allotment of one-half of the sum hereby appropriated shall be expended in the first two quarters of the fiscal year, and no more than one-fourth thereof may be expended in either of the last two quarters of the fiscal year, except that, in addition thereto, in either of said last quarters, the unexpended balances of allotments for preceding quarters may be expended: * * * *Provided further*, That hereafter no part of the appropriations made for printing and binding shall be used for any illustration, engraving, or photograph in any document or report ordered printed by Congress unless the order to print expressly authorizes the same, nor in any document or report of any Executive Department or other Government establishment until the head of the Executive Department or Government establishment shall certify in a letter transmitting such report that the illustration is necessary and relates entirely to the transaction of public business. (Approved March 3, 1905; Statutes, XXXIII, 1213.)

REPORT

OF

S. P. LANGLEY,

SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR THE

YEAR ENDING JUNE 30, 1905.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to present herewith my report, showing the operations of the Institution during the year ending June 30, 1905, 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, and the Astrophysical Observatory.

Following the precedent of several years, there is given, in the body of this report, a general account of the affairs of the Institution and its bureaus, while the Appendix presents more detailed statements by the persons in direct charge of the different branches of the work. Independently of this, the operations of the National Museum are fully treated in a separate volume of the Smithsonian Report, and the Report of the Bureau of American Ethnology constitutes a volume prepared under the supervision of the Chief of that Bureau. The scientific work of the Astrophysical Observatory is recorded in occasional publications.

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 of the United States, and the heads of the Executive Departments. The prerogative of the Establishment is "the supervision of the affairs of the

Institution and the advice and the instruction of the Board of Regents."

As organized on June 30, 1905, the Establishment consisted of the following ex officio members:

THEODORE ROOSEVELT, *President of the United States.*
CHARLES W. FAIRBANKS, *Vice-President of the United States.*
MELVILLE W. FULLER, *Chief Justice of the United States.*
JOHN HAY, *Secretary of State.*
LESLIE M. SHAW, *Secretary of Treasury.*
WILLIAM H. TAFT, *Secretary of War.*
WILLIAM H. MOODY, *Attorney-General.*
GEORGE B. CORTELYOU, *Postmaster-General.*
PAUL MORTON, *Secretary of Navy.*
ETHAN ALLEN HITCHCOCK, *Secretary of the Interior.*
JAMES WILSON, *Secretary of Agriculture.*
VICTOR H. METCALF, *Secretary of Commerce and Labor.*

ORGANIZATION OF 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 residents of the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State."

As organized at the end of the fiscal year, the Board consisted of the following members:

The Hon. M. W. Fuller, Chief Justice of the United States, Chancellor; the Hon. C. W. Fairbanks, Vice-President of the United States; Senator S. M. Cullom, Representative R. R. Hitt, Representative Robert Adams, jr., Representative Hugh A. Dinsmore, Dr. James B. Angell, of Michigan; Dr. Andrew D. White, of New York; the Hon. J. B. Henderson, of Washington City; Prof. A. Graham Bell, of Washington City; the Hon. Richard Olney, of Massachusetts, and the Hon. George Gray, of Delaware.

There are two vacancies on the Board, caused by the death of Senator O. H. Platt and the retirement of Senator Francis M. Cockrell.

MEETINGS OF THE BOARD OF REGENTS.

At a meeting of the Board of Regents held March 12, 1903, the following resolution was adopted:

"*Resolved*, That in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted."

In accordance with the above resolution the Board met on December 6, 1904, January 25, 1905, and March 6, 1905.

The following is an abstract of its proceedings, which latter will be found in the annual report of the Board to Congress:

REGULAR MEETING OF DECEMBER 6, 1904.

A statement concerning the disposition of the remains of James Smithson, and the report of the special committee having in charge the final disposition of the remains, was presented to the Board, which adopted the following resolution:

"*Resolved*, That the special committee having in charge the matter of the final disposition of the remains of James Smithson be authorized to receive the original tomb, and to place it, suitably inscribed, with the remains, in some proper position that they may select in the grounds of the Institution; the expenses involved in the matter to be met from the funds of the Institution."

The Secretary made a statement to the Board concerning the progress on the new building for the National Museum. The excavation for the building was begun on June 15, 1904, and the laying of the foundations in concrete was finished November 9, 1904. The contracts for the granite had been entered into.

The Secretary recalled to the Board the various bills introduced for the preservation of antiquities on the national domain. He had learned in the meantime that the Secretary of the Interior had in contemplation a bill which would meet the needs of the Department and be satisfactory to the Institution, which had prepared for the Secretary of the Interior the requisite maps giving the location of antiquities on the public lands. The Secretary of the Interior had also taken preliminary steps for the appointment of guardians for important ruins.

ANNUAL MEETING, JANUARY 25, 1905.

The Secretary announced the reappointment of Dr. J. B. Angell as a Regent for six years, by joint resolution approved by the President January 19, 1905.

The usual resolution relative to income and expenditure was adopted, and the annual reports of the Secretary, the executive committee, and the permanent committee were submitted.

The special committee on the disposition of the remains of James Smithson reported the arrival of the original tomb, and their decision, under the authority given at the previous meeting, to place it and the remains within the Smithsonian building. A statement of the reinterment of the remains will be found on a subsequent page.

The Secretary informed the Board of the proposal of Mr. Charles L. Freer, of Detroit, to bequeath or to make a deed of gift, to take effect upon his death, of a collection of paintings and etchings, largely

those of Whistler and his school, and of American and oriental pottery and other objects of art; and of erecting a building to be used solely for the purpose of exhibiting these objects, on condition that the Regents should providé for the maintenance of the building and collections. The Secretary had laid this matter before the executive committee under date of December 16, which adopted the following report:

"The executive committee, having heard with interest and appreciation the statement by Secretary Langley of the proposition and views of Mr. Charles L. Freer, of Detroit, to intrust to the Smithsonian Institution a collection of works of art, now in his possession, which has already cost $600,000, and to which he proposes to add almost as much more, and to construct for housing it a hall costing $500,000, upon condition that all the expense and responsibility for its care and maintenance shall be provided, are of opinion that it would be well for the Board of Regents to consider such a proposition in sympathy with the broad and cultivated spirit in which it is made; but as it is presented only as a statement of a conversation with Mr. Freer, it is requested by the committee that Secretary Langley communicate with Mr. Freer, and suggest to him that he put in more precise form his views and his wishes, so that the action which the committee may recommend to the Board shall be such as will exactly set forth Mr. Freer's purposes and be given the careful consideration appropriate to such an enduring benefaction.

"It is further requested by the committee that Mr. Freer be communicated with in such time that his reply may be received and be considered by the committee before the meeting of the Board, which occurs on January 25, 1905."

After reading several communications from Mr. Freer on the subject, and the correspondence between him and the Secretary, the following resolution was adopted:

"*Resolved*, That the Chancellor appoint a committee of three Regents, whose duty it shall be to make personal examination of the collection of art objects which Mr. Charles L. Freer has proposed to give or bequeath to the Smithsonian Institution, and make report to the Board of its value and merits; and said committee is further instructed to ascertain from Mr. Freer what alterations, if any, can be made in the conditions of his very generous proposal; and the Secretary of this Institution is hereby added as an additional member of this committee."

The following committee was then appointed: Doctor Angell, Senator Henderson, Doctor Bell, and the Secretary.

REGULAR MEETING OF MARCH 6, 1905.

The Secretary asked the Board's approval of his appointment of Dr. Cyrus Adler as Assistant Secretary of the Institution, and the following resolution was adopted:

"*Resolved*, That the appointment by the Secretary of Dr. Cyrus Adler as Assistant Secretary of the Smithsonian Institution, in

charge of the Library and the Exchanges, with such additional duties as the Secretary may assign him, be approved."

In the absence of Doctor Angell, chairman of the special committee, Senator Henderson presented a report giving an account of the visit of the committee to Detroit and their conference with Mr. Freer. The report was fully discussed, and the following resolution was adopted:

"*Resolved*, That the Board of Regents take this occasion to express their sincere thanks to Mr. Charles L. Freer, of Detroit, for the courtesy shown to the committee of the Regents which recently visited Detroit to examine his art collection; and that further consideration of his generous offer to donate the same to this Institution or the United States be continued until the next meeting of the Board of Regents."

The Secretary stated that Capt. John Donnell Smith, of Baltimore, had donated to the Institution his entire botanical collection, and the Board adopted the following resolution:

"*Resolved*, That the thanks of the Board of Regents be tendered to Capt. John Donnell Smith for his generosity in presenting to the Institution his large and valuable collection of plants and books on botany, which is gratefully accepted."

The Secretary stated that a room in the Smithsonian building had been fitted up as a temporary resting place for the remains of Smithson, and asked the Regents to be present at their transfer.

After adjournment, the Regents repaired to the room referred to, where, in their presence, the remains were placed within the tomb, which was then sealed.

GENERAL CONSIDERATIONS.

Sixty years ago, when Joseph Henry became the first Secretary of the Smithsonian Institution, the scope of the work he assumed was practically unlimited; Smithson's direction being that his bequest was to be used for the "increase and diffusion of knowledge among men." After considering many suggestions as to how this might best be done, Professor Henry decided that the proper function of the Smithsonian Institution was "to assist men of science in making original researches, to publish them in a series of volumes, and to give a copy of them to every first-class library on the face of the earth." This has remained the policy of the Institution; and although its operations have, of necessity, been modified from time to time, its original breadth of scope has never been narrowed.

The methods of assisting in original research have been various. Numerous grants have been made to qualified investigators, and expeditions have been sent out in many directions. Several enterprises undertaken by the Institution on a small scale outgrew the original intention and, in accordance with the policy of the Institution

not to carry on work that could be done elsewhere, have been allowed to establish themselves independently, chief among which are the United States Weather Bureau, the Geological Survey, and the Fish Commission. Other establishments, as the National Museum, the Bureau of American Ethnology, the International Exchanges, and the National Zoological Park, have continued under the direction of the Institution. It led the way in the organization of library work in the United States; it took the initial steps and continues to support schemes for international cataloguing, and it maintains a benevolent relation with the American Historical Association and the National Society of the Daughters of the American Revolution.

The results of all important investigations and the operations of the Institution and its dependencies are reported upon constantly. Its publications, which include more than 250 volumes, are to be found in all the important libraries of the world, and some of them on the work table of every scientific student. Through the agency of the International Exchange System, these works, together with other public documents and learned treatises, are distributed throughout the civilized world, and the foreign works received in exchange are invaluable in American scientific libraries.

Thus the Smithsonian Institution is in constant association with the Government and all the public institutions of the United States. To them the Institution holds out a friendly cooperation, its aim being, while continuing its own work upon its accepted lines and adapting them to new needs as occasion arises, to continue along the established policy of preventing rivalries, promoting wise cooperation, diminishing waste, and furthering the search for knowledge, the recording of discovered truth, and its dissemination among the people.

In this great work the individual is not lost sight of; the publications of the Institution are widely distributed, its library constitutes an important part of the Library of Congress, and its museum is the rarest in existence in many branches of the natural history and ethnology of the New World. Less imposing than these methods of serving the public, but no less important, is the satisfaction of a constant stream of inquirers, whose letters from every corner of the country bring questions bearing on every branch of knowledge.

BUILDINGS.

The only important building operation carried on during the past year, of course excepting the work on the new Museum building, was the construction of a mortuary chapel to contain the tomb of James Smithson, brought from Italy.

INTERIOR OF SMITHSON MORTUARY CHAPEL.

DOOR TO SMITHSON MORTUARY CHAPEL, SHOWING IRON GATEWAY MADE FROM RAILING AROUND THE TOMB IN THE SAN BENIGNO CEMETERY, GENOA.

When the San Benigno Cemetery at Genoa was expropriated for municipal purposes by the Italian Government in 1903, the Regents determined to bring the remains of James Smithson to Washington. Dr. Alexander Graham Bell, the committee appointed for this purpose, was successful in his mission, and on January 25, 1904, formally gave the remains into the hands of the Regents. Doctor Bell's report and an account of the ceremonies incident to the removal and reception of the remains were published in the Annual Report for 1904.

The body, upon its arrival in Washington, was placed temporarily in a room in the Smithsonian building containing the relics of Smithson. While resting there, the remains were examined by medical experts and found to be in a remarkable state of preservation. Meanwhile, a small mortuary chapel was prepared for them on the immediate left of the north entrance of the Smithsonian building, and on March 6, 1905, the remains were carried to this chapel and, in the presence of the Regents, replaced in the original tomb, recently brought from Genoa (plates I, II), where they will rest until Congress makes adequate provision for their interment.

Work on the reconstruction on the large archeological hall in the main Smithsonian building has continued throughout the year, as has the process of repairing various portions of the roof of the Museum, including the re-covering of the central rotunda. Some time has also been spent in going through the subcellar of the Museum building removing dead wires, whitewashing, and otherwise improving its condition.

FINANCES.

The permanent funds of the Institution are as follows:

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
Portion of residuary legacy of Thomas G. Hodgkins, 1894		8, 000. 00
Deposit from savings of income, 1903		25, 000. 00
Total permanent fund		937, 000. 00

The above fund is deposited in the Treasury of the United States and bears interest at 6 per cent per annum under the provisions of the act organizing the Institution and act of Congress approved March 12, 1894. In addition to the permanent fund, the Regents hold cer-

tain approved railroad bonds which form part of the fund established by Mr. Hodgkins.

At the beginning of the fiscal year July 1, 1904, there was a deficit of $362.80 instead of a credit balance of $46,648.33, as stated in my report for the year ended June 30, 1904. On June 2, 1905, it was discovered that the accountant of the Institution was a defaulter, and that by the aid of false entries and erasures he had been able to conceal his misdeeds from detection. He was immediately placed in the custody of the law and an examination of the books and accounts was commenced, but the total amount of the defalcation had not been determined at the close of the fiscal year, and a more complete statement will be submitted in a special report.

During the year the total receipts deposited in the Treasury of the United States in behalf of the Institution were $74,761.72. Of this sum $57,060 were derived from interest, $10,000 from a temporary loan, and the balance of $7,701.72 from miscellaneous sources. The disbursements during the year amounted to $69,245, the details of which are given in the report of the executive committee. The balance remaining to the credit of the Secretary on June 30, 1905, for the expenses of the Institution, was $5,153.92.

During the fiscal year 1905 the Institution was charged by Congress with the disbursement of the following appropriations:

International Exchanges	$27,000
American Ethnology	40,000
Astrophysical Observatory	15,000
United States National Museum:	
Furniture and fixtures	22,500
Heating and lighting	18,000
Preservation of collections	180,000
Postage	500
Books	2,000
Rent of workshops	4,580
Repairs to buildings	15,000
National Zoological Park	95,000
Total	419,580

The following estimates were forwarded as usual to the Secretary of the Treasury for carrying on the Government's interests under the charge of the Institution for the fiscal year ending June 30, 1906. This table shows the estimates and sums respectively appropriated:

	Estimates.	Appropriations.
International Exchanges	$34,600	$28,800
American Ethnology	50,000	40,000
Astrophysical Observatory	15,000	15,000
National Museum:		
Furniture and fixtures	22,500	22,500
Heating and lighting	18,000	18,000
Preservation of collections	210,000	180,000
Purchase of specimens	10,000	....
Books	5,000	2,000
Postage	500	500
Building repairs	15,000	15,000
Rent of workshops	4,580	4,580
Sunday and night opening	11,616	....
Transportation of exhibits	6,500	6,500
Building for National Museum	1,500,000	1,500,000
National Zoological Park	135,000	95,000
Readjustment of boundaries, Zoological Park	60,000	....
Total	2,098,296	1,927,880

RESEARCHES.

In accordance with the original plan of the Institution that its Secretary should devote his time to scientific matters as well as administrative,[a] research work in various fields has been continued under my direction by the Institution and its dependencies.

In the Astrophysical Observatory I have continued work believed to be important, and inaugurated some experiments of novel interest, which are referred to later.

Through the Museum and the Bureau of American Ethnology the Institution has been enabled to carry on various biological, geological, and ethnological researches, which will be found fully described elsewhere in this report.

HODGKINS FUND.

Frequent applications for grants from the Hodgkins fund are received; and while, as noted in previous reports, the conditions establishing the foundation are such as to measurably restrict the scope of its activities, all requests for aid are carefully considered and acted on. In addition to the researches here mentioned, reports on several interesting investigations, already noted as in progress, are still awaited and will be published later.

A grant has been approved on behalf of Mr. A. L. Rotch, of Blue Hill Meteorological Observatory, whose investigations of the upper

[a] *Resolved*, That the Secretary continue his researches in physical science, and present such facts and principles as may be developed for publication in the Smithsonian contributions. (Adopted at meeting of the Board of Regents, January 26, 1847.)

air currents by means of kites have been aided by the Hodgkins fund. Mr. Rotch conducted a series of experiments at the St. Louis Exposition with ballons-sondes, which carry instruments only, these recording automatically the temperature and pressure of the air, the duration of flight and the place of landing, indicating also the velocity and direction of the air currents traversed. The success of these first experiments in America with recording balloons was such as to warrant their continuance under the same direction, and on their termination the results will be embodied in a report by Mr. Rotch for publication by the Institution.

A paper on the Construction of a Vowel Organ, by Dr. E. W. Scripture, has been recently published by the Institution. This article gives the details of work under a Hodgkins grant approved for the purpose and mentioned in my last report.

In extending his researches in connection with speech or phonetics Doctor Scripture has been fortunate in securing individual gramophone voice records of much historical interest. A voice record of the Emperor of Germany was transmitted by Doctor Scripture in January, 1905, for preservation in the United States National Museum. This record gives, in about two hundred words, the Emperor's conception of the aims and beauty of true manhood and of man's duty to his fellow, and recognizes the wisdom of the Almighty and Omniscient Creator. At present only one other record of His Majesty's voice exists, namely, one made at the same time for preservation in the library of Harvard University.

The experiments conducted by Mr. Alexander Larsen, of Chicago, in connection with the photography of lightning flashes, with a special effort to measure their duration, mentioned in my last report as having been aided by a limited grant from the Hodgkins fund, have been continued during the year and the results carefully reported. An interesting research on the fluorescence of minerals has also been carried on by Mr. Larsen, more than 100 specimens, sent for the purpose by the Institution, having been examined and reported on. During these experiments many interesting facts have been noted, which may prove the basis of further investigation.

A moderate additional grant has been approved during the year on behalf of Doctor von Lendenfeld, of the K. K. Zoologisches Institute, Prague, to assist in defraying the cost of the construction of an improved apparatus for taking the serial instantaneous photographs required for studies of the flight organs of animals. Doctor von Lendenfeld has given serious and protracted attention to this subject, in connection with which numerous articles prepared by him, or under his direction, have been published. A paper by Doctor Mascha, supervised by Doctor von Lendenfeld, on "The Structure of Wing-Feathers," has recently been printed in the Smithsonian Miscella-

neous Collections, and the translation of an article by Doctor von Lendenfeld on the "Relation of Wing Surface to Weight of Body," published originally in the Naturwissenschaftliche Wochenschrift, appeared in the Smithsonian Report for 1904.

In May, 1905, a grant was approved on behalf of Prof. W. P. Bradley, of Wesleyan University, for an experimental investigation of the expansion of air through a nozzle. As all practical forms of apparatus for the production of liquid air depend, so far, upon this type of expansion, the research is deemed an important one, the more so from the fact that the theory of the nozzle expansion of gases is in dispute and must apparently remain so until more complete data are secured.

The results of previous experiments in the liquefaction of air, carried on by Professor Bradley at Wesleyan University, show conclusively that he is in an exceptionally favorable position for the direction of an extended inquiry into the factors which make for efficiency in such a research, and as it is expected that further investigation will materially aid a decision as to certain questions concerning which experimentalists are not fully agreed, the report to be submitted by Professor Bradley is awaited with interest.

Early in the year 1904 a third grant was approved on behalf of Dr. Carl Barus to aid in preparing the completed report of his recent research for publication. This memoir, "A Continuous Record of Atmospheric Nucleation," is in press, as one of the Smithsonian Contributions to Knowledge, and will be the third and last volume of the series giving a detailed account of the investigation of Doctor Barus. A request that a summary of the work should be prepared by the author for presentation before the first international congress on ionization and radioactivity at Liège in September, 1905, was approved, thus enabling an investigation on a subject of much immediate interest, prosecuted under the auspices of the Institution, to be brought to the attention of this notable gathering.

The subscription to the Journal of Terrestrial Magnetism and Atmospheric Electricity has been renewed for the present year, with the understanding that the publication will be maintained in the future without such aid, a stipulated number of copies being forwarded this year, as heretofore, to addresses designated by the Institution.

Among the miscellaneous investigations aided by the Institution during the year I may mention that Dr. Edward L. Greene, associate in botany, United States National Museum, has undertaken to prepare for publication by the Smithsonian Institution a monograph to be entitled "Landmarks of Botanical History." Doctor Greene expects to complete this work in two years. Dr. Albert M. Reese, of Syracuse University, received a small grant to assist him in his

work of collecting in Florida the materials for the study of the embryology of the alligator, and in subsequent investigations. Mr. W. A. Bentley, of Jericho, Vt., has from time to time made numerous photographs of snow crystals and has recently turned over to the Institution 500 glass positives of his best and most interesting photographs, together with a descriptive paper relating to them.

NAPLES TABLE.

The Smithsonian seat in the Naples Zoological Station has been continuously occupied for the greater part of the present year and, as heretofore, the reports submitted at the close of appointments mention the exceptional opportunities for special research afforded at Naples.

To avoid the confusion and inconvenience likely to result from the duplication of appointments, Doctor Dohrn has recently made a request that two students should not be assigned to Naples at the same period without previous consultation with the management of the station. In order, therefore, to meet the wishes of the always courteous and accommodating director, it is desirable that those wishing to occupy the Smithsonian seat should enter their applications as long a time as possible in advance of the period decided on. This will permit the necessary correspondence in regard to each appointment, when, as is not infrequently the case, there are more applicants than can be readily provided for, and will perhaps also at times afford the opportunity for the extra occupation of an unassigned seat.

It may be added that appointments covering twelve months of the year—June 30, 1905, to June 30, 1906—have already been approved, but as two students are to be received during the same period for one limited appointment, it may be possible to approve additional brief sessions during the year. As before announced, applications for the ensuing year may be taken up for consideration at any time within six months of the period desired.

The appointment of Prof. J. B. Johnston, of the University of West Virginia, terminated March 1, 1905. While at Naples Doctor Johnston obtained and prepared a large amount of material for future experiment and study. Being an experienced teacher, he hopes to embody the results so far secured in a more complete and exact account of the brain, which will be incorporated in a text-book on The Nervous System of Vertebrates, now in course of preparation.

In April Doctor Johnston was succeeded at the station by Dr. Stewart Paton, a former member of the teaching staff of Johns Hopkins University, on whose behalf a second appointment of six months from November 1, 1905, has since been approved. A previous investigation to determine the time when the first spontaneous movements and definite reactions to external stimulation occur in the embryo

will be continued by Doctor Paton, who will investigate also the correlative structural changes in the central nervous system that accompany these functional developments, and will endeavor to determine the elements which conduct the nervous impulses.

I am glad to state that the advisory committee continues the same, and to record my appreciation of the helpful action of the members in recommendations as to appointments to the Smithsonian seat.

EXPLORATIONS.

ARCHEOLOGY OF GULF STATES OF MEXICO.

Dr. J. Walter Fewkes, a member of the Bureau of American Ethnology, has carried on an extended archeological reconnoissance for the Smithsonian Institution in the Gulf States of Mexico. His trip was successful, adding information to what is known of the prehistoric inhabitants of this rich but only partially explored region. While the main object of this visit was the increase of our knowledge of Mexican archeology, attention was incidentally given to the striking likeness of many prehistoric objects observed to those from the United States and its bearing on the question of culture migrations. An area was shown in each of the States of Vera Cruz and Tamaulipas, as typical of the prehistoric culture of this region, one of these extending from Xalapa, capital of Vera Cruz, to the Gulf coast, the other being near the city of Tampico, on the banks of the Panuco and Tamese rivers.

The numerous ruins or mounds that occur in these areas, rarely visited by archæologists, are supposed to be typical of the former culture of two great allied peoples, the Totonacs and Huaxtecs, who in prehistoric times inhabited the greater part of Vera Cruz and what is now southern Tamaulipas.

On account of its historical as well as archeological importance, a visit was made to the little-known ruin of Cempoalan, a Totonac metropolis visited by Cortés, the conqueror of Mexico. Archeological literature pertaining to this city is very scanty; there is not a single description in English of the still well-preserved temples of this remarkable capital. On his visit to the site of Cempoalan Doctor Fewkes obtained many fine photographs of the four stately pyramids and gathered much data regarding their construction. He also studied and took photographs of the many small objects found in the neighborhood of the mounds that will later be published. An attempt to determine the site of another flourishing Totonac city revealed, near the ancient Villa Rica de la Vera Cruz, an important cluster of earth mounds of considerable size. These were also photographed and their relics studied.

Doctor Fewkes visited several large ruins in the neighborhood of Xalapa, one of which, near Xicochimalco, he has identified as the remains of the pueblo of Sochimatl, mentioned by Bernal Diaz del Castillo, historian of the conquest. By this identification new light is shed on the hitherto obscurely known route of the conquerors from Cempoalan over the mountains to the plateau of Mexico.

The extensive group of large earth mounds, some of which are remains of pyramidal temples, situated at Texolo, near Xico, were also visited, and important material was gathered from them bearing on their prehistoric inhabitants. The numerous ruins in the vicinity of Tampico were found to be extensive, and objects from them revealed evidences of a high development of culture. Of the large Huaxtec pueblo called Chila, subdued by Cortés, nothing now remains but a group of mounds in an almost impenetrable forest a few miles from Tamos. Many sites of prehistoric pueblos were found on the banks of the Panuco; some of these were once temples, others mortuary hillocks containing pottery offerings and bones of the dead. Numerous shell heaps occur in this region, some of which were visited and examined. About a mile from Tampico, Doctor Fewkes reports, he found a cluster of large earth mounds of considerable extent, up to within a few years concealed by a dense jungle. The most notable ruins in this region lie on the banks of the Champayan lagoon, at the Rancho de San Francisco and Cebadella. In the Sierra de Palma there is a pyramid having a cut-stone facing and stairways similar to those in the Totonac region.

THE SMITHSONIAN ALASKAN EXPEDITION.

An expedition to Alaska and adjacent territory was made during the summer of 1904 by Mr. A. G. Maddren, under the direction of the Smithsonian Institution, for an examination of the Pleistocene deposits of northern Alaska, in which most of the mammoth and other vertebrate remains occur. His report treats of these formations and the criteria by which they are to be distinguished from the more recent ice and alluvial deposits which have been variously noticed and discussed by travelers and writers. He says:

> The problems of geographic distribution of the animal and vegetable life of North America in Pleistocene time with the disturbance of faunas and floras caused by the widespread glaciation during that period and their subsequent readjustment over the glaciated area all combine to form a complex arrangement, to solve which will require large collections of specimens from the Pleistocene deposits of the unglaciated area of Alaska and the adjacent Canadian territory. At present our knowledge of this fauna and flora is very limited. As far as we know, only one species of elephant (*Elephas primigenius*), the mammoth, inhabited Alaska and Siberia during Pleistocene time.
>
> The longest mammoth tusk so far reported from Alaska is one 12 feet 10 inches long, measured on the outside of the curve. Remains of the rhinoceros

have not been reported with those of the mammoth in Alaska, as in Siberia, and it also appears that the remains of the mammoth in Alaska are not in as fresh a state of preservation as those found in Siberia, which points to the surmise that the mammoth became extinct in Alaska before the last of the species succumbed in Siberia. Associated with the mammoth were herds of large bison and horses. This species of horse may have been the last native to North America, the rear guard of the last migration of these animals across the region of Bering Straits to Asia before the land connection disappeared. There was a species of musk-ox, together with sheep and bear. Descendants of these last three forms have by adaptive changes survived in these northern regions down to the present time.

The relation that the fauna and flora north of the area occupied by glaciers bore to that region in the United States before, during, and after separation by the snow and ice fields; also the relation of forms in Alaska to those of Siberia, with the time and duration of the land connection across Bering Straits and their subsequent separation, form a complex problem, the solution of which will require the accumulation of much material.

Mr. Maddren summarizes his conclusions as follows:

I. That while remnants of the large Pleistocene mammal herds may have survived down to the Recent period and in some cases their direct descendants, as the musk-ox, to the present, most of them became extinct in Alaska with the close of Pleistocene.

II. The most rational way of explaining this extinction of animal life is by a gradual changing of the climate from more temperate conditions, permitting of a forest vegetation much farther north than now, to the more severe climate of to-day, which, subduing the vegetation and thus reducing the food supply, besides directly discomforting the animals themselves, has left only those forms capable of adapting themselves to the Recent conditions surviving in these regions to the present.

III. There are no facts to support the contention that the climate of the Arctic and sub-Arctic regions ever has been colder than it is at present. There are no phenomena presented in those regions that require a more severe climate than that now existing to account for them. There are no ice deposits in Alaska, except those of large glaciers, that may be considered of Pleistocene age. There are no ice beds interstratified with the Pleistocene deposits of Alaska.

IV. That the various forms of land ice, together with the deposits of peat, now existing through the Arctic and sub-Arctic regions of Alaska belong to the Recent period, and these deposits may be most conveniently and logically classified by their position with reference to the Pleistocene and Recent formations and the ice deposits, can not be differentiated satisfactorily into deposits of snow or of water origin by their physical structure and character alone.

THE SMITHSONIAN GLACIER EXPEDITION.

The expedition dispatched by the Smithsonian Institution to the Canadian Rockies and Selkirks, under the immediate direction of Prof. William H. Sherzer, of the Michigan State Normal School, had a successful season's work on the glaciers along the line of the Canadian Pacific Railway. A selection was made of those five glaciers which are at the present time most readily accessible to the tourist or the student of glacial geology, and these were found to exhibit, more or less strikingly, the characteristics of glaciers throughout

the world. It may be a matter of surprise to many to learn that four or five days of comfortable railway travel places one in the midst of snow fields rivaling in size and grandeur those of Switzerland, that the ice bodies descending from these fields may be studied from modern hotels as a base, and that of those to be reported upon one may safely ride a horse to the very nose of each. For trips on the ice to the passes and neighboring peaks experienced Swiss guides are available during the summer months. So far as is known, there is here the most magnificent development of glaciers of the Alpine type on the American continent, and the purpose of the survey was to gather as much information concerning them as the time and facilities rendered possible. Many photographs with which to illustrate the details of glacial structure were obtained, a number of which accompany a preliminary report of the expedition printed in the Smithsonian Miscellaneous Collections. Professor Sherzer reviews his work as follows:

Field work began July 1, 1904, with two assistants, and continued until the middle of September, camps being made at Lake Louise, Moraine Lake, and in Yoho, Asulkan, and Illecillewaet valleys, in each case as close as practicable to the glaciers under study. Quite in contrast with the two preceding summers, that of 1904 proved exceptionally propitious for field studies. The unusual number of bright days and the reduced precipitation, however, reacted unfavorably in that they permitted forest fires to spread in several of the valleys, and during much of the summer the atmosphere was more or less charged with smoke, rendering distant photography unsatisfactory or quite impossible.

Covered with a veneering of rock débris over its lower third, the Victoria glacier, at Lake Louise, is not the most interesting of the series to the casual observer, who is liable to carry home the idea that it is simply a stone heap, and a rather uninteresting pile at that. Geologically, however, this glacier is the most active and varied of any of those that can be conveniently reached in the entire region, and nearly six weeks were devoted to the study of it and its tributary, the Lefroy. In spite of the many visits which a camp alongside the glacier for this length of time permitted, as well as numerous visits during two previous seasons, not one failed to reveal some new feature or to shed important light on one previously observed. This longer stay at the Victoria permitted measurements of the forward flow of ice under variable conditions of temperature, the construction of an accurate cross section, the determination of the amount of surface melting, and the varying amounts of drainage and sediment discharged—work which was not feasible on the other glaciers, to each of which but seven or ten days could be devoted. A detailed survey was made of each of the five glaciers, from the nose around each way to the nevé field, by means of plane table or compass and steel tape, and full data for a map of the ice and moraines and for a general description were procured. Especial attention was given to the structure of the ice itself, with the hope of shedding more light on some of the points still under discussion.

Only the most general statements concerning those results of the field studies in which the scientific public may be interested will now be noted. The glaciers generally were found to be still in retreat, the Wapta, at the head of Yoho Valley, having exceeded its average of the last three years by a few feet, while the Illecillewaet, at Glacier House, receded but one-third of the average which it

has maintaind during the last seventeen years. The Asulkan, in an adjoining valley, which had been advancing for about two years, has remained practically stationary during the last year. The Victoria presents an oblique front of nearly half a mile, and its lower 800 feet, completely veneered with rock as above stated, has pushed out into the forest at a comparatively recent date. This part has remained quiet apparently for a number of years, but accurate measurements to stones embedded in the face show that a very gradual wastage occurred during the summer, with a small stream of clear, ice-cold water as confirmatory evidence.

Farther up, for a distance of about 1,600 feet, there is a steep ice front which is so nearly parallel with the main axis of the glacier that there is a question as to whether it is not its side. Here the front of the ice is receding, the amount for the last year being about the same as the average maintained for the last five or six years, and this in spite of an actual forward flowing movement of the ice of 2 to 3 inches daily in summer and perhaps half this amount in winter. The Wenckchemna glacier, in the Valley of the Ten Peaks, proved of exceptional interest because of its almost unique character, only one other of the type—the Malaspina in Alaska—having been described. The Wenckchemna consists of a sluggish ice mass, relatively short, but broad, formed by the lateral coalescence of about a dozen short ice streams, each of which retains its identity more or less perfectly entirely across the glacier, and maintains its own nose and motion independently of its neighbors. Accurate measurements to stones embedded in the frontal slope showed that some of these ice streams are stationary, some receding, and others advancing, the most rapid advance being near the center, where freshly cut trees were observed. To those who do not fully appreciate all the factors of the problem it is frequently a matter of surprise that a glacier in one valley may be in retreat while that in an adjacent valley may be advancing, as has just been the case in the Asulkan and Illecillewaet valleys; but in the case of the Wenckchemna there is still more varied behavior in streams that are actually side by side almost throughout their length.

PUBLICATIONS.

It is largely through its publications that the Institution carries out that vital principle of its foundation, "the diffusion of knowledge among men." Each year adds something of importance to the long series of published works comprised in the Smithsonian Contributions to Knowledge, the Smithsonian Miscellaneous Collections, and its Annual Reports. All these are published by the parent Institution, but the series is augmented by the Proceedings and Bulletins of the National Museum, the Reports and Bulletins of the Bureau of American Ethnology, and the Annals of the Astrophysical Observatory, which bring before the public specialized matter no less important.

The details of the work of the past year are given in the Editor's report, the subjects treated in that time including practically every branch of human knowledge.

To the series of Contributions there has been added a third memoir by Dr. Carl Barus, entitled "A Continuous Record of Atmospheric Nucleation," in which the author further discusses his researches on

the nucleus, as published in "Experiments with Ionized Air" (Smithsonian Contributions to Knowledge, vol. XXIX, 1901) and in "Structure of the Nucleus," issued as part of the same volume in 1903. The investigation was carried on with the aid of a grant from the Hodgkins fund. Doctor Barus describes the nucleus as a dust particle small enough to float in the air but larger than the order of molecular size, and shows that such a particle precipitates condensation in an atmosphere saturated with water in its immediate vicinity. He uses the term "nucleation" to denote the number of nuclei per cubic centimeter regardless of their source—which may be from mechanical, thermal, chemical, high potential, or radio-active processes—or their special properties. By far the greater number are initially ionized, or at least carry an electric charge, and where they occur in thousands and millions of approximately uniform size they give rise to condensational phenomena of transcendent beauty and importance.

The articles printed in the Miscellaneous Collections are, as the name of the series would indicate, miscellaneous in character. The past year has added 38 numbers to this series of papers, including several relating to the bibliography of chemistry; an exhaustive catalogue of Diptera, or two-winged flies, showing the geographical distribution of several species known to spread disease; accounts of explorations in Alaska and among the Canadian glaciers; some interesting popular papers by Doctor Gill on the sculpin, the tarpon, the ladyfish, and the carp, and a lecture by Dr. Andrew D. White on the diplomatic service of the United States, the first of the series of lectures under the Hamilton bequest.

The Contributions and Miscellaneous Collections just spoken of are published at the expense of the Institution fund in editions of 1,500 copies, and are intended solely for distribution to the large libraries and institutions of learning throughout the world.

The Annual Report, on the other hand, is published by a Government appropriation in an edition of some 12,000, and is intended for a more general distribution. Primarily, this volume is a report to Congress on the operations of the Institution during the year, but its popular interest lies largely in its General Appendix, containing a number of papers showing the recent progress of the world's scientific work. To the selection of appropriate papers for this Appendix I have given much personal attention for several years past.

The manuscript of the work of the late Dr. G. Brown Goode, on some contributions of America to the progress of science, which during the past year has been worked over by Mr. Kenneth M. Goode, editorial assistant, is now almost in its final shape, and will, I hope, appear as a Smithsonian publication during the coming year.

The Institution proper distributed during the year a total of 60,063 volumes or parts of volumes of the series of Smithsonian Contributions, Miscellaneous Collections, Reports, and publications not included in the regular series,[a] making an increase of 13,455 over the number sent out during the previous year.

THE LIBRARY.

The library of the Smithsonian Institution is, first of all, a library of science, and, secondly, a collection of catalogues and bibliographical apparatus. The general aim, as stated in the original plan, has been "to procure a complete collection of the memoirs and transactions of learned societies throughout the world, and an entire set of the most important scientific and literary periodicals." In 1866 the main portion of the Smithsonian library was for administrative purposes transferred to the custody of the Library of Congress, and became one of the important elements of that great National Library. This collection continues as the Smithsonian Deposit. It has annually increased in size and importance, and at present aggregates nearly half a million entries.

There is retained at the Institution such books as are of immediate importance to investigators carrying on their researches in the Smithsonian building. This reference collection, together with the special libraries of the National Museum, the Astrophysical Observatory, the National Zoological Park, and the Bureau of American Ethnology, numbers about 55,000 volumes.

Besides the accessions of books from customary sources, during the past year there has been received a valuable library relating to civil engineering bequeathed to the Institution by the late Dr. J. Elfreth Watkins; also a collection of about 1,600 books on the flora of tropical America, presented by Capt. John Donnell Smith, and a large number of additions to the Watts de Peyster Collection Napoleon Bounaparte.

The International Catalogue of Scientific Literature established three years ago, with administrative headquarters in London, now contains over half a million reference cards, 50,000 of which are references made for the United States by the Smithsonian Institution. The entire work of preparing cards for this country is done in connection with the library of the Institution, the cost of the work thus far having been borne out of an allotment made by the Institution.

[a] Contributions to Knowledge, 4,540; Miscellaneous Collections, 27,558; Reports, 25,425; publications not in regular series, 1,905; publications not Smithsonian yet distributed by the Institution, 635.

CORRESPONDENCE.

From its correspondence it appears that the Institution is generally considered by the public as an establishment to which requests may be addressed for information on all branches of knowledge, for the solution of various scientific problems, for the examination and indorsement both of scientific investigations and crude, unscientific speculations, for supplying answers to questions in prize contests, and the like. It seems well, therefore, to state that while responses are cheerfully given, as far as practicable, to all legitimate requests for scientific information, the Institution does not undertake to maintain a general question bureau. The communications received cover every conceivable subject, from new theories of the physical phenomena of the universe to a request for information as to the value of some supposedly rare book, and the preparation of the data desired entails the expenditure of a considerable amount of time and labor by the members of the Institution's staff. Many of these correspondents are men of considerable culture and of much general reading, but are wanting in that special training which is necessary for successful scientific investigation, and correspondence with this class is especially difficult to manage, since the rejection of the propositions made is generally attributed to prejudice and is resented by the writers, who array themselves as martyrs to science.

During the year many letters have been received from inventors who desire either grants of money with which to develop their various devices or an expression of the Institution's opinion as to the merits of their inventions. As the Institution has no funds from which such aid can be given, and as the Secretary is prohibited by a decision of the Board of Regents from expressing an opinion of this character, he is obliged to refuse all such requests. It would seem proper to state also that the Institution does not supply information of a commercial nature, such as is customarily furnished for a fee by engineers or other professional advisers, or which is designed to benefit some individual rather than the public.

In spite of these restrictions, however, the conduct of this correspondence is an important agency for the diffusion of knowledge among men.

NATIONAL GALLERY OF ART.

In the message of President Roosevelt communicated to the two Houses of Congress at the beginning of the third session of the Fifty-eighth Congress (dated December 6, 1904) he says:

> The collection of art contemplated in section 5586 of the Revised Statutes should be designated and established as a national gallery of art, and the Smithsonian Institution should be authorized to accept any additions to said collection that may be received by gift, bequest, or devise.

The section of the Revised Statutes cited by the President is the act of foundation of the Smithsonian Institution, which declares that "whenever suitable arrangements can be made from time to time for their reception, all objects of art and of foreign and curious research, all objects of natural history, plants, and geological and mineralogical specimens belonging to the United States * * * shall be delivered to such persons as may be authorized by the Board of Regents to receive them, and shall be so arranged and classified in the building erected for the Institution as best to facilitate the examination and study of them;" so that the first object of the Institution, in the eyes of its founders, appears to have been to give it the curatorship of the Art collections of the nation.

During its early years this object was promoted in various ways; among others, by the acquisition of a very valuable collection of prints and engravings belonging to the Hon. George P. Marsh. After the fire in the Institution in 1865 these prints were deposited for temporary safe-keeping in the Library of Congress and (with other works of art) in the Corcoran Gallery.

Subsequently an appropriation was granted by Congress for making a fireproof room in which these could be kept, but it was not until 1896 that the Regents provided for their recall to the Institution. In the journal of the proceedings of the Board for 1896 (Smithsonian Report, 1896, pp. xiii and xiv) will be found the action taken by the Board providing for their restoration to their own immediate control. The following resolution offered then by Senator Gray was adopted:

> *Resolved*, That the question of the propriety of bringing the works of art belonging to the Institution under the more immediate control of the Board of Regents be referred to the executive committee and the Secretary, with power to act.

In pursuance of this the Institution brought back to its own keeping a number of prints of value, both from the Library of Congress and the Corcoran Gallery, leaving, by an amicable understanding with the latter establishment, as a loan, a few of the works of art, notably a large picture by Healy.

The old name of the collections was the "Gallery of Art," a title which seems almost too ambitious for the present collections of the Institution, though it is to be hoped that this designation will be justified by their future increase. These have been placed by me in a room specially fitted up for that purpose (the Art Room), under the temporary charge of the librarian.

There is now in the courts awaiting legal interpretation a will containing a bequest of a valuable collection of art objects.

On January 3, 1905, Mr. Charles L. Freer, of Detroit, offered under certain contingencies to bequeath to the Smithsonian Institution his valuable art collection, proposing at the same time to provide after

his death for a building of appropriate design and proportion, provided the Institution would undertake its maintenance. The objects include a remarkable collection of the works of the late J. A. McNeil Whistler and a number of oriental art objects. The proposal of Mr. Freer is still under consideration by the Board of Regents.

HAMILTON LECTURE.

A number of years ago Mr. James Hamilton left a small bequest to the Smithsonian Institution, the income of which was to be appropriated biennially by the Secretary, either in money or a medal, for such contribution, paper, or lecture on any scientific or useful subject as the Secretary might approve.

The Regents of the Institution decided to let this small sum accumulate, and it is only recently that the Secretary has found himself able to commence to employ the income as a lecture fund. The first address under the auspices of this fund was delivered by Dr. Andrew D. White, LL. D., D. C. L., in the lecture hall of the National Museum on March 9, 1905, and was entitled "The Diplomatic Service of the United States with some Hints toward its Reform."

This lecture was printed by the Smithsonian Institution as a pamphlet of some twenty pages and was distributed to members of Congress, officers of the Department of State, various members of the diplomatic corps, the libraries of the larger universities, presidents of colleges, and others likely to be interested in the important question discussed.

SMITHSONIAN DELEGATES AT INTERNATIONAL CONGRESSES.

Congress on Zoology.—Messrs. Leonhard Stejneger and Gerrit S. Miller, jr., of the United States National Museum, represented the Institution and Museum at the Sixth International Congress on Zoology held at Berne, Switzerland, August 14–19, 1904.

Congress of Americanists.—Mr. William H. Holmes, Chief of the Bureau of American Ethnology, represented the Institution at the Fourteenth International Congress of Americanists held at Stuttgart, August 18–23, 1904. He delivered an address on the "Contributions of American Archeology to Human History" and presented to the congress a set of 75 bound volumes relating mainly to American archeology and ethnology, published by the Smithsonian Institution and its two Bureaus—the National Museum and the Bureau of American Ethnology.

Congress of Orientalists.—Prof. Paul Haupt, honorary curator of the Division of Historical Archeology, United States National Museum, represented the Smithsonian Institution and the Museum at the Fourteenth International Congress of Orientalists held at Algiers in April, 1905.

Congress of Psychology.—Dr. William James, professor of philosophy at Harvard University, was designated to represent the Smithsonian Institution at the Fifth International Congress of Psychology at Rome, April 26–30, 1905.

Botanical Congress.—Mr. F. V. Coville, curator of the Division of Plants in the National Museum, represented the Smithsonian Institution and the Museum at the Second International Botanical Congress at Vienna, June 11–18, 1905.

Ornithological Congress.—Dr. Leonhard Stejneger, curator of the Division of Reptiles and Batrachians in the National Museum, represented the Smithsonian Institution and the Museum at the Fourth International Ornithological Congress at London, June 12–17, 1905.

International Convention of the International Catalogue of Scientific Literature.—Dr. Leonhard Stejneger represented the Institution at the meeting of this body held in London, July 25–30, 1905.

NATIONAL MUSEUM.

A great museum, in the modern usage of the word, has been defined as "an institution for the preservation of those objects which best illustrate the phenomena of nature and the works of man, and the utilization of these for the increase of knowledge and for the culture and enlightenment of the people." This thought is that of one very especially conversant with the subject, and implies both a collection for the student and an exhibition for the visitor. It is this second part of the museum's work, the exhibition collection, which was probably in the minds of those who originally described the future Smithsonian museum as containing "objects of art and of foreign and curious research," although even at that early date they added "and all objects of natural history, plants, and zoological and mineralogical specimens belonging to the United States." Under the impulse of Congressional legislation the Museum has obtained a signal advantage over the national museums of other countries, since by law all collections made by the surveys of the Government of the United States must be deposited here, thus providing for the systematic preservation of collections of great extent and vast importance.

From the foundation of the Institution to about 1857 its specimens were collected solely to serve as materials for research, and the exhibition collections belonging to the United States were maintained at the Patent Office. At the date mentioned Congress made an appropriation to the Smithsonian Institution for the building of cases to receive these collections, which were known as the "National Cabinet of Curiosities," and from that time on the Institution's

museum besides aiding students served to instruct and entertain the public. The great growth of the Museum dates from the close of the Centennial Exhibition in 1876, since which time collections have been actively gathered and exhibited because of their educational value. Neither purpose has been lost sight of because of the other, and the instruction of the public has been secured not only by dignified exhibition of interesting objects, but by adding to them series of instructive labels based upon the maxim that a good educational museum consists in a series of carefully prepared labels with well selected specimens attached. With these two great purposes in mind the Museum has now succeeded in bringing together catalogued objects amounting to over 6,000,000 in number, the exhibition series being so installed that the individual objects or groups would not stand as inert curiosities by themselves, but are arranged in such manner as to show their relation either to the orderly development of nature or to the varied manifestations of human thought and activity.

It can not but be realized that the Museum's main attainment from this point of view consists not only of the collections or of the building which houses them, but to an ever increasing degree in the possession of the experts who have the custody of these collections and the knowledge to classify them and to make them available for public instruction. I regret to say that the enormous growth of the collections in the Museum has not been accompanied by any proportionate increase in its administrative and scientific staff. The greatest efficiency can hardly make up for the numerical inability to cope with the increasing work, and it becomes each year more painfully apparent that the personnel of the establishment must be materially augmented if the present standards are to be maintained.

Despite this paucity of workers and the congested halls, the past year has been as successful as any in the history of the National Museum. During this time more additions to its collections have been recorded than in any previous year save the period immediately following the Centennial Exhibition of 1876. From the Louisiana Purchase Exposition alone over thirty carloads were received, including many valuable ethnological and technological exhibits. Besides this there were the usual accessions from the Government surveys and from donations and exchanges. Altogether, nearly 250,000 specimens have been entered during the year, while a mass of material is yet to be sorted out, these recent additions bringing the total number of specimens now preserved in the Museum collections well over 6,000,000.

That only a very small fraction of these specimens can ever be on public exhibition is evident, yet those stored away are by no means the least important. The scientific staff is constantly engaged in re-

search in connection with the work of classification, and students from kindred institutions frequently visit Washington or have collections sent to them for investigation.

Duplicate material is used, when not actually needed for study, for the purpose of exchange with other museums, and to a limited extent, by authority given by Congress to the Regents of the Institution, for distribution among American schools. Fourteen thousand specimens were distributed during the past year to schools and colleges throughout the land for the general purpose of promoting education.

The present crowded condition of the building has rendered it difficult to place any more collections there, and such as come in from one source or another are in the main temporarily stored in rented buildings. While it has been found impossible to increase the amount of material on exhibition, the standard of the objects exhibited is being constantly improved, and the methods of installation represent the most modern practice in this regard.

In the division of ethnology a place has been made for a Malaysian collection contributed by Dr. W. L. Abbott and an interesting Philippipe exhibit gathered by Dr. E. A. Mearns. Over the hall of mammals has been hung the cast of a great sulphur-bottom whale, about 80 feet in length. Another noteworthy addition during the past year is the reconstructed skeleton of a gigantic Triceratops, measuring almost 20 feet.

During the course of the year some 235,000 persons, an average of 753 visitors a day, have viewed these collections. This number would unquestionably be greatly increased should it become feasible to open the building at night or on Sundays.

Work on the new building, for the continuation of which Congress at its last session appropriated $1,500,000, is progressing satisfactorily. The excavation was completed and the heavy concrete foundation laid last autumn. The erection of the outer walls of granite is now well under way.

The completion of this structure will, it is hoped, mark the beginning of a new era in the activities of the National Museum. No longer cramped for space, it can suitably care for the splendid collections intrusted to its care; by exhibiting these, and by labels, publications, and lectures, it will still further endeavor to impart definite instruction along definite lines to all who care to learn. Then, as now, the first great lesson it will try to enforce is that a museum is in nowise a cabinet of curios to while away an idle moment, but an active instrument for the diffusion of knowledge among men.

THE BUREAU OF AMERICAN ETHNOLOGY.

The energies of the Bureau during the past year have been devoted chiefly to preparing for publication the proposed Handbook of Indians, which will include not only descriptions of the tribes and their settlements, but also popular articles covering the whole range of ethnological and archæological research relating to them. No work of its kind so comprehensive in scope has ever been attempted, and the effort to combine popular treatment with scientific accuracy has involved an extra amount of time and labor. Almost all the prominent ethnologists of the country have written special articles for the Handbook, and all the staff of the Bureau and ethnologists resident in the city have aided in criticism and revision.

Though somewhat curtailed through the necessity of retaining several ethnologists for work on the Handbook, the field work of the Bureau has been continued in Maryland, Virginia, Oklahoma, Indian Territory, Arizona, New Mexico, Oregon, and Mexico. Dr. J. Walter Fewkes, under a grant from the Smithsonian Institution, made an extended archæological trip through Mexico; Dr. Ales Hrdlicka, of the National Museum, made a visit to Arizona in behalf of the Bureau; and Mr. E. L. Hewett was commissioned to visit New Mexico for the purpose of making researches among the ancient ruins of the so-called Pajarito Park district.

The systematic study of visiting Indian delegations has been continued with success. During the year 22 delegations consented to be photographed, and in some cases allowed themselves to be measured and even to have plaster casts of their faces taken.

The work of compiling an archæological map of the United States, which had received some attention in previous years, was carried forward with all possible dispatch during the past year.

INTERNATIONAL EXCHANGES.

The International Exchange Service of the Smithsonian Institution has for more than fifty years been the medium of exchange of documents and scientific publications between the Government and learned institutions of the United States and those of foreign countries. Through its operations the Library of Congress has secured a large collection of public documents, and an unequaled collection of scientific serials has been acquired by the Institution for its deposit in the Library of Congress. Each year the service grows in size and importance. The weight of packages handled by it in 1899 was 317,883 pounds; in 1905 it was 474,871 pounds, an increase of 40 per cent in six years.

The number of exchange correspondents now aggregates 51,880, or nearly 4,000 more than the number ten years ago. These are scattered throughout every corner of the civilized world, and new centers of scientific activity are opening up every year. It is largely through the system of International Exchanges that the Institution realizes the catholicity of its founder's bequest, which contemplated the diffusion of knowledge among all men. Moreover, this constant exchange of courtesies among the learned institutions of the world has not only served to enrich the universities, libraries, museums, and learned societies of our country and those with whom we exchange, but has at the same time done much to promote friendly relations among the nations themselves.

NATIONAL ZOOLOGICAL PARK.

The annual appropriation made for the service of the National Zoological Park was in the following terms:

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 and providing seats in the park; care, subsistence, purchase, and transportation of animals, including salaries or compensation of all necessary employees; the purchase of necessary books and periodicals; the printing and publishing of operations, not exceeding one thousand five hundred copies, and general incidental expenses not otherwise provided for, ninety-five thousand dollars.

The collection of animals exhibited has increased, and comprised at the end of the year over 1,300 individuals of all species. A considerable number of these were born at the park, and 128 birds were received from the exhibit made at the Louisiana Purchase Exposition.

The new house for mammals, mentioned in last year's report, is now approaching completion and will constitute one of the most attractive features of the park. As this structure is necessarily built from the general appropriation for the park, its progress is limited by the amount of funds available for use. As the care of the animals, the maintenance of the collection, the improvement and care of the grounds, including the roads and walks, the repair of all structures, fences, and inclosures must also be defrayed from this appropriation, it is obvious that considerable economy must be exercised in order to have any funds for the erection of buildings.

The park exists, in the words of the act of Congress, "for the advancement of science and the instruction and recreation of the people." The first and primary object is never to be lost sight of, but in pursuance of the second much is done to facilitate the visits of those who seek the pleasant influences of rural scenery and open air. For this reason it is thought that attempts should be made to enhance the

park features by greater care of the indigenous trees and the planting of copses where such are required, by the establishment of seats, and by perfecting the roads and walks as far as practicable. The park is now the nearest to the city of any large stretch of open, picturesque country, and this would seem to be almost a duty owed to the public.

This again brings to mind a project often urged upon Congress, but never realized by an actual appropriation for the work. I refer to the plan for extending the park to the nearest boundary road on the southeast and the west. This has often been referred to in previous annual reports, and it would seem that the present time is particularly favorable for the accomplishment of this object, since roads have recently been established by act of Congress quite near to the present boundaries.

Among the more pressing needs of the park is a small building with outlying yards, which can be used as a hospital and quarantine for sick animals and, incidentally, as a pathological and anatomical laboratory. In this connection, in view of the fact that the primary object of the park is for "the advancement of science," it must be considered how much our knowledge has been increased by such establishments as the Jardin des Plantes, of Paris, under Buffon, Cuvier, or Milne-Edwards; the gardens of the Zoological Society in London, by Huxley and others, and those at Berlin and elsewhere. I approve the recommendation of the superintendent that a modest laboratory for pathological research be added to the park equipment.

During the last year the number of visitors to the park has further increased, and it is not too much to say that no equal expenditure by Congress has brought so much of instruction and rational enjoyment to the people.

ASTROPHYSICAL OBSERVATORY.

As for several years past, the operations of the Astrophysical Observatory have been almost wholly directed toward measuring the amount of the solar radiation, and its loss in transmission through the sun's envelope and through our own atmosphere.

I do not yet regard the evidence of solar variability as conclusive, but still as rendering this conclusion more probable, and I am glad to state that two lines of investigation have this year become very prominent in the work of the Observatory, which will almost certainly lead to a conclusion regarding this important question.

The first of these is the almost daily bolometric examination of the large solar image formed by the great horizontal telescope, for the purpose of detecting changes in the transparency of the solar absorbing envelope. This work depends so little on the transparency of our

own atmosphere that it can be done almost as well in Washington as at a station more favored as regards atmospheric transparency and freedom from clouds. The past year has not given evidence of very marked variations either in the transparency of the sun's envelope or in the supposedly dependent mean temperature of the earth, but on the contrary the observations have continued most of the time near the mean in both respects. Such changes as have been noted are not, however, contradictory to the view that alterations of the transparency of the sun's envelope do occur, and cause changes in the amount of solar radiation received by the earth, which in turn cause departures of the earth's temperature from its mean.

The second line of investigation to which I have referred above is the determination of the total solar radiation outside our atmosphere, by observations with the bolometer and pyrheliometer at a station located in a relatively clear and cloudless region and at a considerable altitude above sea level. As long ago as February, 1902, at the request of the Hon. C. D. Walcott, and for the consideration of the Carnegie Institution, I urged in a letter to him the great utility of an observatory for solar research to be located at a high altitude and charged with the determination of the question of the amount of solar radiation and the limits of its variability. An observatory for solar research has now, in fact, been established by the Carnegie Institution on Mount Wilson, in southern California, after extensive tests of different proposed sites. By invitation of the director, Prof. George E. Hale, and in accord with the authorization of Congress for the undertaking of observations at high altitudes by the Astrophysical Observatory, I have sent to Mount Wilson an expedition in charge of Mr. C. G. Abbot, for the purpose of determining the conditions for studying the variability of the sun.

The expedition is equipped with spectro-bolometric and pyrheliometric apparatus of the highest quality, and wholly adequate to making the most accurate possible determinations of solar radiation and its transmission through our atmosphere. As I have elsewhere remarked, I am not convinced that it is possible to estimate exactly the loss of radiation in our atmosphere by any observations whatever, but it does seem that the estimates which can be made from the observations of the Mount Wilson expedition will be so close an approximation to the truth that if a notable variation of solar radiation outside our atmosphere occurs the results will show it. Furthermore, similar observations are being continued as usual in Washington. Mr. Abbot reports that the sky above Mount Wilson is of great clearness and uniformity, and that weeks and even months pass there without a cloud appearing above the horizon, so that observations may be made almost every day with good prospects

of success. It is expected that the expedition will remain on Mount Wilson until late in the autumn.

I take this opportunity to express my obligation to the Carnegie Institution and to Professor Hale and his coworkers for the aid and counsel they have so generously extended in furthering the objects of the expedition.

Additional details of the work of the Astrophysical Observatory will be found in the report of the aid acting in charge.

NECROLOGY.

ORVILLE HITCHCOCK PLATT.

It is with a keen personal regret that I have to record the death on April 22, 1905, of Senator Orville H. Platt, of Connecticut, who for six years had served on the Board of Regents, and who at all times took much personal interest in the welfare of the Institution.

Senator Platt was born in Washington, Conn., July 19, 1827. After an academic education he undertook the study of law at Litchfield. He was admitted to the bar in 1849, and practiced at Meriden. He became secretary of state of Connecticut in 1857. In 1861–62 he was a State senator; later he served as a member of the State house of representatives and as speaker of that body. From 1879 until the time of his death he was United States Senator from his native State, and his public life belongs to his country. I shall not add here my poor testimony to that of the history which will record his contribution to the national good. He was a man honored by all and best loved by those who best knew him.

Respectfully submitted.

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

APPENDIX TO THE SECRETARY'S REPORT.

Appendix I.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

Sir: I have the honor to submit the following report upon the condition and operations of the National Museum during the year ending June 30, 1905.

At the beginning of the year the excavation for the new building on the northern side of the Mall was actively under way and in the autumn the heavy concrete foundations were completed. In October, 1904, the contracts were executed for the granite required for the outer walls and for the trimmings of the two courts. Contracts for other materials were also entered into at intervals during the remainder of the year, all at prices which insure the putting up of the structure within the limit of $3,500,000 fixed by Congress. It was hoped that work upon the basement might begin by February or March, but unfortunately the winter was severe, with much snow, which interfered with quarrying, and up to the close of the fiscal year not enough stone had been received to warrant the commencement of building operations. The date at which this report is written, however, permits it to be said that the first basement stone was laid on August 21, 1905, and no further delays are anticipated.

In respect to the increase of collections, the year's record has never been exceeded, except during the period immediately following the Centennial Exhibition of 1876. There were the usual accessions from the Government surveys and through donation and exchange, but the Louisiana Purchase Exposition, held at St. Louis, furnished an opportunity probably not soon again to be presented for securing a very large amount of valuable material, especially in ethnology, mineral technology, and other branches of the useful arts, which was accepted to the extent of over thirty carloads. Only a small proportion of these objects could, however, be directly added to the classified and exhibition collections, owing to lack of space, and the greater part have been placed in storage to await the completion of the new building.

Among the additions from other sources was one of special moment consisting of the large and important private herbarium and botanical library of Capt. John Donnell Smith, of Baltimore, which the owner has most generously presented. The former comprises over 100,000 mounted plants, and the latter above 1,500 volumes.

The number of accessions, including only that small part of the material from the exposition which it was possible to place on record, was 1,692, and of specimens 245,384.

Except for the crowded state of the buildings, the Museum is now in as good condition as at any time in its history. The standard of the exhibition collections was materially improved, though their expansion practically ceased some years ago. The reserve, or study, collections were extensively utilized

in the promotion of knowledge, and duplicate specimens to the number of over 14,000 were distributed to educational establishments throughout the country.

Buildings and equipment.—The roofs of the Museum building have, as usual, demanded most attention in the matter of repairs. The temporary strengthening a few years ago of the supporting iron framework over the main halls has continued to be effective, but most of the slate covering had so far deteriorated that in 1904 the roof above the east hall was coated experimentally with asphalt, burlap, and slag. Having answered its purpose through one season, the roofs of the other halls and of the rotunda and one pavilion were similarly treated during last year. The metal work upon the roofs also required extensive overhauling, and several skylights were added. The 20 large windows in archeological hall, which have been approaching a condition bordering upon collapse, were completely repaired and made practically as strong as ever.

In view of the crowded condition of all the public halls, the building of only a few exhibition cases was called for. To provide, however, for the care and arrangement of the very extensive accessions received during the year, mainly from the Louisiana Purchase Exposition, the Government surveys, and a few large private donations, a considerable amount of storage furniture was demanded. The number of permanent cases of this character constructed was 213, and of drawers 1,032, in addition to which much shelving was put up and many boxes made for the storage of material in bulk and the distribution of duplicates.

The heating plant, with the addition of a few radiators, has given good service. Steam was maintained from October 8, 1904, to May 2, 1905, on an average of sixteen hours a day, the expenditure of coal amounting to 830 tons. A new arrangement of telephones was effected at the beginning of the year whereby the cost was materially reduced, and as a special fire precaution six standard alarm boxes of the pattern used by the District of Columbia have been installed in different parts of the Museum building.

Organization and staff.—The organization of the Museum remains the same as heretofore, except that a Department of Mineral Technology, with Dr. Charles D. Walcott, Director of the United States Geological Survey, as curator, was established in the autumn of 1904, to permit of proper direction in the selection of objects relating to this subject at the Louisiana Purchase Exposition.

Dr. Cyrus Adler was made curator, and Dr. I. M. Casanowicz assistant curator of the Division of Historic Archeology. In the Division of Plants Dr. J. N. Rose was advanced to associate curator and Mr. W. R. Maxon to assistant curator, the position of aid being filled by the appointment of Mr. J. H. Painter. Dr. James E. Benedict, assistant curator of the Division of Marine Invertebrates, has supervised the exhibits in biology and had charge of the collections of comparative anatomy. Mr. Herbert S. Barber was appointed aid in the Division of Insects, and Mr. B. H. Ransom, of the Bureau of Animal Industry, assistant custodian of the Helminthological collections.

Mr. Charles Schuchert, for some years assistant curator of Stratigraphic Paleontology, who resigned to accept the professorship of paleontology in Yale University, has been succeeded by Dr. Ray S. Bassler. Vacancies in the Section of Vertebrate Paleontology were filled by the selection of Mr. James W. Gidley and Mr. Charles W. Gilmore as preparators, and of Mr. Norman H. Boss as assistant preparator.

The following gentlemen, to whom the Museum has become indebted for distinguished services or noteworthy contributions, were designated as honorary associates: In historic archeology, Dr. Paul Haupt, of Johns Hopkins University;

in zoology, Dr. W. L. Abbott, of Philadephia; in botany, Capt. John Donnell Smith, of Baltimore; in mineralogy, Rev. L. T. Chamberlain, of New York City; in paleobotany, Prof. Lester F. Ward, of Washington.

Additions to the collections.—The principal source of accessions during the past year was the Louisiana Purchase Exposition. The exhibition made in that connection by the Museum itself contained many important objects acquired through the Government appropriation for the exposition, which, excepting such as were sent to the Lewis and Clark Exposition, were subsequently incorporated in the public series here. Much more extensive and noteworthy, however, were the gifts made to the national collections by several foreign governments, by many States of the Union, and by a large number of individuals having exhibits at St. Louis. So extensive, in fact, were these contributions that they amounted in bulk to about 30 carloads of specimens, besides five of exhibition cases. Of this number 25 cars were filled with collections illustrative of mineral technology alone, comprising examples of the natural and finished products and of the appliances of manufacture in many branches of mineral industry. Unfortunately the arrangement and display of this instructive material must be deferred until more space becomes available through the completion of the new building. The Department of Geology also received many important additions, especially in the way of large masses and pieces appropriate for exhibition. The contributions in ethnology, next in extent to those in mineral technology, were exceedingly varied and interesting, since they relate to the customs and industries of several peoples, and will richly supplement the existing collections.

Through the accessions already noted, the total number of specimens in the Museum has been increased to about 6,141,900, classified as follows: Anthropology, 986,964; biology, 4,409,135; geology, 745,801.

The most noteworthy additions in ethnology, besides those obtained at St. Louis, were from the several islands between Sumatra and Borneo, the Mergui Archipelago, and the island of Mindanao of the Philippine group; from pueblos, cliff houses, and caves in western Socorro County, New Mexico; and from the Apache and Pima Indians of Arizona, and the pueblo of Zuni. To the collections in physical anthropology was added a large amount of material bearing upon the natural history of several races of man, especially the American Indians, Negroes, Slavs, and Filipinos.

The most important acquisitions in historic archeology consisted of Arabic manuscripts and prints from the Moros of Mindanao, and of coins, pottery lamps, and jars from the Orient. The Division of Prehistoric Archeology obtained two valuable collections of implements from Japan; many interesting specimens from Australia and Tasmania, Cape Colony, Thuringia (Germany), and Belmonti, Italy; and a large number of stone implements and pottery from the United States, Mexico, and South America.

The collection of timekeeping devices was increased by several gifts and loans, and acknowledgments are due to the War Department for depositing numerous pieces of ordnance, among them being many of considerable historic interest.

The Division of Graphic Arts received many contributions from foreign exhibitors at the Louisiana Purchase Exposition, and two pictures taken by Daguerre. Among the accessions in ceramics were an extensive and very beautiful collection of glassware from the Union Glass Works; examples of Teco ware and Van Briggle pottery, and a collection of typical Japanese and Chinese porcelains and pottery and of Japanese lacquer work.

To the collection of American history were added 768 objects, mostly loans.

including many personal military relics and examples of the wearing apparel and other articles of the colonial period in Maryland and New York.

Mention may here be made of the large oil portrait of the Empress Dowager of China, painted by Miss Katherine A. Carl and presented to the United States by the Government of China, with appropriate ceremonies at the White House. The picture, encased in its heavy and elaborately carved frame of camphor wood, was transferred directly to the custody of the Museum and temporarily installed in the lecture hall.

About 217,538 specimens were acquired by the Department of Biology, the principal increases as regards number of specimens being in the divisions of Plants, Insects, and Mollusks, though in other branches the additions were not less important. The Division of Mammals received large collections containing many novelties from Malaysia and the Philippine Islands, besides many interesting specimens from southern Europe, Brazil, and Japan, the Kamerun district of West Africa, and Bewean Island in the Java Sea. The most important additions to the Division of Birds were from the Philippine Islands, Malaysia, and Costa Rica. Of reptiles, collections were obtained from Japan, Formosa, the Philippine Islands, Malaysia, China, France, Switzerland, Jamaica, Guatemala, and several parts of the United States. The Division of Fishes received by transfer from the United States Bureau of Fisheries type collections from Samoan waters and Hawaii, and a very large number of specimens from the Pacific and Atlantic coasts of North America.

The Bureau of Fisheries was also the largest single contributor to the Division of Mollusks, having transferred some 5,000 specimens from recent dredgings of the steamer *Albatross* on the coast of California. Other important accessions comprised land and fresh-water shells from Texas, California, and Montana; about 1,500 identified specimens of Philippine shells from the collection of the late Herr Mollendorff, and many marine mollusks from Alaska. While no single large collection was received by the Division of Insects, yet as a whole the additions were of average importance, aggregating over 34,000 specimens from many parts of the world.

The Division of Marine Invertebrates obtained from the Bureau of Fisheries 300 lots of foraminifera from the region about the Hawaiian Islands and a large collection of crustaceans and samples of ocean bottom from the *Albatross* cruise of the winter of 1904–5 in the eastern part of the Central Pacific. The most important additions to the Helminthological Collection was a series of parasites from Egypt.

The past year has been especially noteworthy as regards the increase of the collection in the Division of Plants, the additions having been very much greater than in any previous year in the history of the Museum, embracing 750 accessions and 143,690 specimens. This was chiefly owing to the generous gift by Capt. John Donnell Smith, of Baltimore, of his entire private herbarium, which alone contained 100,889 specimens from different regions, but mainly from tropical America. This large and valuable donation, the work of many years in assembling, was accompanied by a choice botanical library of over 1,500 volumes. The next important contribution was by transfer from the United States Department of Agriculture of 13,965 specimens from many parts of the United States, and from Alaska, Greenland, Canada, Mexico, Guatemala, Europe, and India.

The Department of Geology acquired by gift at the Louisiana Purchase Exposition important series of ores, minerals, and economic products from Brazil, Siam, Ceylon, Greece, and several of the States, and through other sources, many interesting minerals and cut gems.

The collections in Stratigraphic Paleontology were mainly increased through transfers from the Geological Survey, of which the principal ones consisted of large numbers of Niagaran fossils from Tennessee, of Ordovician fossils from the slates at Arvonia, Va., and of Devonian and Carboniferous fossils from Colorado. A very valuable acquisition was the gift by Mr. E. O. Ulrich and Dr. R. S. Bassler of the type and figured specimens of 65 species. The Section of Vertebrate Paleontology received two large collections from the Geological Survey, one made in the Wasatch Eocene of the Big Horn basin, Wyoming, the other from the Oligocene of Oelrichs, S. Dak. In Paleobotany, the most important additions were about 400 specimens from the coal fields of São Paulo and Santa Catharina, Brazil, and about the same number from the higher beds of the anthracite series in the vicinity of Pottsville, Pa.

Explorations.—As custodian of the national collections, the Museum depends chiefly for its increment upon the Government explorations conducted by such establishments as the Geological Survey, the Bureau of Fisheries, several of the bureaus of the Department of Agriculture charged with biological research, and the Bureau of American Ethnology, though in the history of the Museum both the Army and Navy have figured conspicuously. The very limited means available for the purpose prevents any extended amount of field work by members of the Museum staff.

From October, 1904, to March, 1905, the steamer *Albatross*, of the Bureau of Fisheries, made extensive explorations in the eastern part of the Central Pacific Ocean, under the scientific direction of Dr. Alexander Agassiz. For the Bureau of American Ethnology Dr. J. Walter Fewkes investigated the sites of ancient Totonac semicivilization in southern Mexico, and Mrs. Matilda Coxe Stevenson continued her studies among the Zuni Indians of New Mexico, both of these expeditions being productive of important collections. Mr. E. A. Schwarz, who visited Cuba for the Department of Agriculture, brought back a large collection of insects which is especially rich in Coleoptera. Mr. A. G. Maddren, under a grant from the Smithsonian Institution, made a reconnoissance of a part of the Yukon River basin of Alaska, during which he secured fragmentary remains of several interesting Pleistocene mammals.

Reference should also be made to the movements of two of the most generous benefactors of the Museum, Dr. W. L. Abbott and Maj. Edgar A. Mearns, surgeon, U. S. Army, from both of whom important contributions were received during the year. The former, with headquarters at Singapore, has recently been working in the Mergui Archipelago and on the islands of Banka, Billiton, and Karimata, where his detailed and painstaking inquiries have furnished most important results in both zoology and ethnology; the latter, who was with the army of Maj. Gen. Leonard Wood on the island of Mindanao, has collected in the same lines and with the same care.

Of field work conducted by assistants of the Museum, the following may be mentioned: Dr. Alés Hrdlička, during his investigations among the Apaches and Pimas of Arizona in the spring of 1905, obtained an important series of ethnological specimens, and Dr. Frederick W. True made several short trips to near-by places in Maryland and Virginia for the purpose of securing remains of the cetaceans which occurred in this region during the Cretaceous period. Dr. Leonhard Stejneger and Mr. Gerrit S. Miller, jr., collected animals and plants in Switzerland, France, and Italy during the summer of 1904. Mr. Robert Ridgway, who was in Costa Rica from November, 1904, to June, 1905, obtained a large series of the birds of that country, and was instrumental in securing a most important donation from the national museum at San José. Dr. W. L. Ralph visited the Dismal Swamp, Virginia, and the Adirondack region of New York, while Mr. Barton A. Bean collected in Carroll County, western Maryland.

Dr. F. V. Coville, while engaged in field work for the Department of Agriculture in Texas, Arizona, and New Mexico, obtained many plants which have since been transferred to the Museum, and Prof. O. F. Cook made botanical collections in Guatemala. Mr. W. R. Maxon was in Jamaica during the first part of the year, and later, accompanied by Mr. Robert Hay, in Guatemala under detail to the Department of Agriculture. In June, 1905, Dr. J. N. Rose, with Mr. Joseph H. Painter, left on a collecting trip to Mexico, which will be continued during the summer.

The Department of Geology was enriched from several localities through cooperative work with the United States Geological Survey, participated in by Dr. George P. Merrill, and Dr. R. S. Bassler; and in June Mr. Charles W. Gilmore accompanied one of the field parties of the Survey to New Mexico, where he obtained a small but interesting series of fossil vertebrates.

Researches.—The classified arrangement of the collections prescribed by law calls for a large amount of research work in the study and naming of specimens, although a greater or less proportion of the material received has already been identified. A full compliance with this requirement has at no time been possible, since the attention of the scientific staff on its past and present basis has been mainly absorbed in the mere care and preservation of the collections, and the maintenance of the exhibition features. Much help is obtained, however, from the scientific men of other institutions, many of whom are interested in one or other of the subjects represented in the Museum, and they may visit Washington or have collections sent to them for the purposes of investigation. The results of most of the inquiries conducted in the Museum laboratories are only indicated in the manuscript records, which are virtually a descriptive history of the national collections, constantly in progress, but the working up of a collection from any particular locality or region, or of a group of objects, large or small, may lead to a positive contribution to knowledge, meriting dissemination through the medium of publication. Some of the more important investigations of the past year, both by assistants of the Museum and by others, have been as follows:

In the Department of Anthropology, Dr. Walter Hough began a detailed study of the very extensive Pueblo collections, continued his observations upon the primitive uses of fire, and nearly completed a report on the Hopi Indians of Arizona. The collections in archeology were utilized by Mr. W. H. Holmes in preparing subjects and illustrations for the Handbook of North American Indians and by Dr. J. W. Fewkes in working up the results of his recent archeological explorations in the Antillian region. Several lines of research in physical anthropology occupied the attention of Dr. Alés Hrdlička, and a paper descriptive of the Howland loan collection of Buddhist religious art was written by Dr. I. M. Casanowicz.

In the Department of Biology, Dr. F. W. True prepared a diagnosis of the fossil skull of a new genus and species of sea lion from Oregon and began a report on the collection of ziphioid whales in the Museum. Mr. Gerrit S. Miller, jr., spent several months at the natural history museums of London, Paris, Berlin, and Leiden in completing his studies and identifications of the very extensive East Indian collection of mammals belonging to the National Museum and of material from other regions. Dr. E. A. Mearns, while in Washington during the winter, studied and described the unique collection of mammals and birds which he brought from the Philippines and completed the first part of his report on the mammals obtained in connection with the Mexican boundary survey.

Mr. Robert Ridgway continued the preparation of his monograph on the birds of North and Middle America. The birds obtained by Dr. W. L. Abbott

on the islands off the west coast of Sumatra were the subject of study by Dr. Charles H. Richmond, and those secured by the same explorer in Kilimanjaro and the China Sea by Mr. H. C. Oberholser, of the Biological Survey. Mr. J. H. Riley reported on a collection from the islands of Antigua and Barbuda. Mr. Barton A. Bean, in conjunction with Dr. C. H. Eigenmann, of Indiana University, worked up the specimens of fishes brought from the Amazon River by Prof. J. B. Steere in 1901. The Characinidæ have been referred to Doctor Eigenmann, and the Pacific deep-sea fishes are being studied by Dr. C. H. Gilbert, of Leland Stanford Junior University.

Dr. W. H. Dall completed a revision of the land and fresh-water mollusks of North America north of latitude 49°, a review of the classification of the American Cyclostomatidæ, and papers on land and fresh-water shells from the Bahamas and Central America. He also has in progress reports on the Pyramidellidæ, in joint authorship with Dr. Paul Bartsch; and on recent collections from the Bureau of Fisheries. Dr. William H. Ashmead has about completed his work on the superfamily Formicoidea or ants, and Mr. D. W. Coquillett has been engaged upon a monograph of the North American mosquitoes. Miss M. J. Rathbun prepared for the Bureau of Fisheries two reports on Brachyura and Macrura, collected at the Hawaiian Islands and in Alaska, and continued her studies on the fresh-water crabs. Dr. Harriet Richardson completed a comprehensive monograph of the North American Isopods, and Dr. T. Wayland Vaughan gave much time to the madreporarian corals.

Dr. J. N. Rose reports satisfactory progress with his researches on the flora of Mexico and on the Crassulaceæ and Cactaceæ of North America. Mr. William R. Maxon prepared several papers on ferns, and Mr. J. H. Painter studied the Mexican species of Meibomia. Capt. John Donnell Smith, associate in botany, continued his investigations and the printing of his extensive work, and Dr. E. L. Greene, under a grant from the Smithsonian Institution, began upon an important paper to be entitled "Landmarks of Botanical History."

Dr. George P. Merrill completed a contribution to a history of American geology and conducted observations on the origin of asbestiform serpentine and the weathering of building stones. Research work in mineralogy was mainly confined to the study of the structure of meteorites by Mr. Wirt Tassin. Dr. R. S. Bassler submitted a paper on the Bryozoa of the Rochester Shales. The report of Dr. Anton Handlirsch, of Vienna, on the Paleozoic insects represented in the Museum collection was received during the year and will soon be published. An important work, sent to press before the close of the year, was a catalogue of the type specimens of fossil invertebrates contained in the collections of the Museum.

In Paleobotany, Prof. Lester F. Ward completed the second part of his monograph on the status of the Mesozoic floras of the United States. Mr. David White has made extensive use of the Lacoe collection in the preparation of a report on the stratigraphic succession of the Pottsville floras in the basins of the Appalachian trough, while Dr. F. H. Knowlton has been engaged upon the flora of the Laramie group and in the study of material from Alaska.

Distribution and exchange of duplicate specimens.—Duplicate invertebrate fossils to the number of some 60,000 specimens, gradually segregated from the reserve series during the progress of researches, were prepared for the use of educational institutions, being made up into several hundred sets. There also remained on hand for the same purpose a few sets of fishes, marine invertebrate animals, and geological specimens illustrating rock weathering and soil formation. Of these several collections, which are recognized as very helpful

in connection with science teaching in the higher schools and colleges, 121, aggregating over 14,000 specimens, were distributed during the year. In making exchanges with scientific establishments and individuals about the same number of duplicate specimens were utilized, but as an equivalent is obtained in these transactions they directly benefit the collections.

Exhibition halls.—The crowded state of the exhibition halls prevents any extensive additions to the public collections, but specimens are frequently received which are deemed of sufficient importance to replace others that have been for some time on display, and the installations in all branches are being constantly improved. In ethnology the interesting Malaysian collection of Dr. W. L. Abbott and Philippine collection of Dr. E. A. Mearns were substituted for some of the older material from Polynesia; the basketry collection was rearranged and several conspicuous examples of the handiwork of the Indians of southern Alaska were installed. To the exhibition in historic archeology were added a series of biblical gems, coins of the Bible, oriental manuscripts, etc. The entire collection of prehistoric archeology, occupying the large upper hall of the Smithsonian building, recently renovated, is being thoroughly revised and will soon again be opened to the public. The exhibits in technology received some interesting accessions, especially in the lines of electrical apparatus, firearms, and railroad appliances. In the gallery of ceramics the collection of purely artistic ware in porcelain, glass, lacquer, and metal work was arranged by countries in a series of separate cases.

The most important additions in biology consisted of objects which had been obtained and prepared for the Museum display at the Louisiana Purchase Exposition, including a number of large exotic mammals, the skeleton and cast of the exterior of a sulphur-bottom whale about 80 feet long, accurately colored casts of several large snakes, and a fine set of models of deep-sea fishes. The American faunal exhibit of insects was nearly completed, and the synoptic series of marine invertebrates was enlarged. A number of large examples of important rocks and ores, besides several minerals and gems, were added to the collections in geology, but the most noteworthy feature was a skeleton of the great fossil Dinosaurian reptile, *Triceratops prorsus*, consisting chiefly of the actual bones of this Cretaceous monster, the few missing parts being reproduced in plaster. It stands 8 feet 2 inches high and measures 19 feet 8 inches long.

Visitors.—The Museum building was visited during the year by 235,921 persons, and the Smithsonian building by 149,380 persons, making an average daily attendance of 753 at the former and of 477 at the latter.

Meetings and lectures.—The lecture hall was used during the last half of the year for several important functions. On March 9, 1905, the Hon. Andrew D. White delivered, before a distinguished audience, the first lecture under the Hamilton fund of the Smithsonian Institution, his subject being "The diplomatic service of the United States, with some hints toward its reform." On March 25 occurred the commencement exercises of the United States Naval Medical School, the President of the United States being present and delivering the diplomas to the graduates. Saturday afternoon lectures on zoological and botanical subjects were given there from March 18 to April 22, under the auspices of the Biological Society of Washington, the speakers being Dr. Albert Mann, Dr. L. O. Howard, Dr. A. D. Hopkins, Dr. George T. Moore, Mr. William L. Underwood, and Dr. F. W. True.

The regular annual session of the National Academy of Sciences was held from April 18 to 20, the lecture hall being used for the public meetings and the office of the Assistant Secretary for business purposes, and on May 3 the hall

was occupied, for one of its daily sessions, by the American Institute of Mining Engineers, then holding its annual meeting in Washington.

Publications.—The publications issued during the past year comprised the Annual Report of the National Museum for 1903; volume 3 of Bulletin No. 50, forming the third part of Mr. Robert Ridgway's monograph of the "Birds of North and Middle America;" part 4 of volume 8 of "Contributions from the National Herbarium," entitled "Studies of Mexican and Central American Plants, No. 4," by Dr. J. N. Rose; volume 9 of the same series, composed of a single paper on "The Useful Plants of the Island of Guam," by Mr. William E. Safford; and the greater part of volume 28 of the Proceedings of the Museum. The General Appendix to the Report for 1903 comprised two papers, one by the Assistant Secretary, entitled "The United States National Museum: An Account of the Buildings Occupied by the National Collections," the other by Dr. A. B. Meyer, of Dresden, entitled "Studies of the Museums and Kindred Institutions of New York City, Albany, Buffalo, and Chicago, with Notes on some European Institutions."

Library.—The working library of the Museum now contains about 24,170 bound volumes and 38,643 unbound papers, the additions during the past year having comprised 3,573 books, 3,048 pamphlets, and 563 parts of volumes. It is chiefly dependent on exchanges for its increases, but a large share of the books required for the classification of the collections are not to be obtained in this way, and the $2,000 annually appropriated by Congress is entirely inadequate to supply even the most important demands in this respect.

Expositions.—The exhibit made by the Museum, in conjunction with the other bureaus of the Institution, formed one of the especially noteworthy features of the Louisiana Purchase Exposition, at St. Louis, Mo., which closed on December 2, 1904. Arrangements were then begun for the Lewis and Clark Exposition, at Portland, Oreg., which opened on June 1, and is to continue until October 15, 1905. Dr. Frederick W. True was designated as the representative of the Institution and Museum, and Dr. Marcus W. Lyon, jr., as chief special agent. The exhibit for Portland, which had necessarily to be planned upon a much smaller scale than the one at St. Louis, was made up almost entirely of selections from the latter, though a few novelties were added.

Respectfully submitted.

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

MR. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

APPENDIX II.

REPORT OF THE CHIEF OF THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: I have the honor to submit the following report of the operations of the Bureau of American Ethnology, for the fiscal year ending June 30, 1905, in accordance with the act of Congress making provision "for continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution," approved April 28, 1904.

The work of the Bureau has been conducted in accordance with the plan of operations approved by the Secretary June 17, 1904. The systematic researches have been carried forward by the seven members of the Bureau's scientific staff, assisted by a large number of associates and collaborators who have been called on to prepare papers on special subjects or to conduct investigations for which their qualifications especially fitted them. During the year seven members and associates of the Bureau have made researches in the field, the regions visited including Maryland, Virginia, Oklahoma, Indian Territory, Arizona, New Mexico, Oregon, and Mexico.

The amount of field work has been somewhat curtailed by the necessity of detaining a number of the ethnologists in the office to assist in the completion of the Handbook of the Indians (hitherto referred to as the Cyclopedia or Dictionary of the Indian Tribes), which was designed to be submitted to the Secretary at the close of the year. The enlargement of the scope of the work to include not only descriptions of the tribes and their settlements, but also popular articles covering the whole range of ethnological and archeological research relating to them, greatly increased the amount of investigation required, but the value of the Handbook as a work of reference has been more than proportionately increased. With the view of revising and unifying the great number of articles designed for introduction into the Handbook a committee of revision was organized, consisting of members of the Bureau and all available resident anthropologists, fourteen in all, who met three times each week to discuss the papers presented. The meetings of this committee proved both interesting and profitable, and suggested the advisability of holding similar meetings hereafter for the discussion of current researches of the Bureau.

As a result of the preparation of the papers for the Handbook, covering, as they do, the entire range of Indian ethnology and administration, the researches conducted in the office during the year have been exceptionally comprehensive; every branch of anthropologic research, including somatology, psychology, linguistics, sociology, religion, technology, and æsthetics, has received such consideration as the comprehensive though necessarily brief articles for the Handbook required. Besides the articles treating of these primary departments of research, many others have been prepared, on the various phases of the history, archeology, biography, and education of the Indians and the administration of their affairs. With the exception of the bibliography and index, which were retained for reference in proof reading, the manuscript for the Handbook, accompanied with about 800 illustrations, was submitted to the Secretary July 1.

Under the auspices of the Smithsonian Institution the Chief visited Europe for the purpose of attending the International Congress of Americanists, held at Stuttgart, Germany, beginning August 18, 1904. In addition to representing the Smithsonian Institution, he served as delegate of two other scientific organizations, and was also designated by the Department of State as the official representative at the congress of the United States Government. As a member of the scientific staff of the National Museum he was intrusted with the additional commission of visiting a number of the principal museums of Europe for the purpose of acquiring information to be utilized in the erection and furnishing of the new National Museum building. On July 26 the Chief sailed from New York in company with Mr. J. R. Marshall, of the firm of Hornblower & Marshall, architects of the new building, and reached Plymouth, England, August 1. Nine days were spent in visiting the museums of London, Oxford, and Cambridge, and eight days in similar observations in Paris, and on August 18 Stuttgart was reached. The opening session of the Congress of Americanists was held in the forenoon of that day and was attended by a large number of members and other prominent persons, including His Majesty, King William II, of Wurttemberg, who, in response to the address of the president of the congress, Prof. Karl von den Steinen, expressed at length his appreciation of the aims and work of the congress, and his pleasure at having the session held in his capital city.

A report of the last meeting of the congress, held at New York City in 1902, was presented by Dr. Franz Boas, honorary philologist of the Bureau, and other routine business was transacted. Members of the congress were invited to take luncheon with the King at his suburban palace, which was followed by a reception in the palace gardens. The King's interest was highly appreciated and contributed much to the success of the congress. During the presence of the Americanists receptions were also held by Count von Linden, vice-president of the congress, and by Mr. Edward N. Ozmun, United States consul at Stuttgart. Sessions were held on August 19, 20, 22, 23, and 24, and a large number of papers, dealing in the main with questions of American history, ethnology, and archeology, were read. On the 20th the Chief of the Bureau of American Ethnology delivered an address on "Contributions of American Archeology to Human History," and at its close he presented to the congress a set of 75 bound volumes, relating chiefly to American archeology and ethnology, published by the Smithsonian Institution and two of its bureaus—the National Museum and the Bureau of American Ethnology—for which the president extended the thanks of the congress. The Chief also presented a series of 66 photographs of American Indians, representing delegations which visited Washington during the winter of 1903–4, the series having been taken cojointly by the Bureau of American Ethnology and the National Museum. Various excursions were made to points of interest, the principal being to Schaffhausen, Switzerland, to visit the sites of Dr. J. Nuesch's recent explorations of the famous lake-dwelling stations at Schweizerbild and Koenigsbau.

After the adjournment of the congress, the Chief proceeded to Dresden, where, under the guidance of Dr. A. B. Meyer, director of the Royal Zoological and Anthropological Museum of Saxony, the various museums of that city were examined. After leaving Dresden, a number of cities in Germany, Holland, and Belgium were visited with a view to museum study, and on August 12 he returned to Paris, and on the 25th sailed from Cherbourg, en route for New York. Between the date of his arrival in Plymouth, August 1, and his departure from Paris, September 25, the Chief of the Bureau visited and made studies of upward of 50 museums. These observations are embodied in a separate report submitted to the Secretary of the Smithsonian Institution.

RESEARCH WORK.

Shortly after his return from Europe in September, the Chief found it necessary to undertake the preparation of a number of articles relating to aboriginal art and archeology for the Handbook of the Indians. Among the subjects treated at some length are archeology, architecture, art, antiquity, Bureau of American Ethnology, bonework, catlinite, cliff-dwellings, copper, engraving, graphic art, mines and quarries, metal work, ornament, pottery, sculpture, shell-heaps, shellwork, and stonework. The only field work undertaken by the Chief during the year was a brief visit to Cavetown, Md., for the purpose of observing the exploration there being conducted by Dr. Charles Peabody and Mr. W. K. Moorehead in the well-known cave near that village. Mr. J. D. McGuire had begun the exploration of this cave for the Carnegie Institution in 1903 and had obtained valuable evidence of its former occupancy by Indians. The present work, which consisted of extensive excavations within the outer chamber of the cavern, yielded much additional material of the same general character.

During the first few weeks of the year Mr. James Mooney, ethnologist, was at St. Louis supervising the final installation of the Kiowa heraldry exhibit in the Smithsonian section of the Government building, Louisiana Purchase Exposition. This exhibit comprised about 120 articles, filling 50 feet of wall case, together with one floor case, and consisted of 90 small shield models, 4 original shields, 5 tipi models, 6 paintings on buckskin, with several ceremonial lances and smaller objects. On the completion of this work, after a brief leave of absence, Mr. Mooney returned to Mount Scott, in the Kiowa country, Oklahoma, where he continued his researches, including the preparation of models and the collection of ethnological material. A number of Cheyenne tipi models were also made for the Field Columbian Museum, of Chicago, with funds provided by that institution, as authorized by joint arrangement with the Bureau. At the end of October Mr. Mooney returned to Washington and was engaged in writing a preliminary paper on Kiowa heraldry until about the end of the calendar year, when he was called on to cooperate in the preparation of the Handbook of the Indians, for which work the following articles were furnished: Arawakan colony, Calusa tribe, Cheyenne tribe, Kiowa tribe, military societies, peyote, population, shields, skin-dressing, signals, sign language, Timucua tribe. Besides these about 100 minor articles were prepared, treating of tribes, biographies of noted Indians, and other subjects. In connection with this work the available information relating to the ancient tribes of Florida and the Gulf States generally was found to be so deficient and confused that Mr. Mooney undertook an investigation of the subject from original sources. A part of the results has been embodied in the Handbook of the Indians, and the foundation has been laid for an extended paper on the ethnology of this region to form a complement to his previous studies of the Siouan tribes of the east and the Cherokee. In the meantime he also supervised the photographing of the large series of shield models and other parts of the heraldry collection made by him during previous years, and prepared catalogues and labels for such portions of this material as were required for the Bureau exhibit at the Lewis and Clark Exposition.

Dr. J. Walter Fewkes, ethnologist, spent the first six months of the year in the completion of the text of his monograph on the Aborigines of Porto Rico. He left Washington on January 7, 1905, for an extended archeological trip to the Republic of Mexico, under a grant from the Smithsonian Institution, and returned on the 15th of May. About three weeks were spent by Doctor Fewkes in the City of Mexico making arrangements with officials for letters

to those who could aid him in the prosecution of his studies. While not thus engaged at the capital his time was profitably employed in studying the collections in the Museo Nacional and one or two private collections, and in making several excursions to places of archeological interest in the neighborhood of the city, including several of the ruins near Lake Tezcoco, as well as those at Iztapalapa and at San Juan Teotihuacan. While awaiting letters of introduction from the President to the governors of Veracruz and Tamaulipas, Doctor Fewkes visited Cuernavaca, where he made photographs of the so-called "Victory stone," or chimalli, the pictograph of the eagle, and the famous stone lizard, and made a trip also to the ruins of Xochicalco and Tepotzlan. From the ruin known as Casa del Tepozteco he obtained copies of inscriptions on the raised seat in the inner room.

After receiving the necessary letters through the courtesy of President Diaz, Doctor Fewkes proceeded to Xalapa, in the State of Vera Cruz, which he made the base of operations during February, March, and a part of April. While in that city considerable time was devoted to an examination of the magnificent collection of Governor Dehesa, as well as the collection of Señora Estafania and others. The vicinity of Xalapa was found to be particularly rich in ruins and mounds, among which are those at Coatepec, Bandarilla, and Xalapa Viejo. An excursion was made also to Texolo, where there are thirteen or more large mounds, some of which are evidently the remains of temples of an old Totonac city. Xico Viejo, an undescribed ruin of a Nahuatl garrison town mentioned by Bernal Diaz and Gomara, was also visited in the mountains near the trail taken by Cortés from the coast to the City of Mexico in 1519. Instructive photographs of this ruin were taken, and notes made on the idols and pottery found in the neighborhood.

Doctor Fewkes made two visits to the ruins of Cempoala, about 20 miles from the city of Vera Cruz. On the first visit he was accompanied by an official representative of Governor Dehesa, by the alcalde of San Carlos, a neighboring town, and by the inspector and owner of the ruins. On the second trip, when he spent a week at the ruins, Governor Dehesa kindly permitted him to employ the services of the State photographer, Señor Ximines.

At the close of March Doctor Fewkes visited the old city of Villa Rica de la Vera Cruz, now called Antigua, founded by Cortés. In the neighborhood of this city but on the opposite side of the river he found many mounds indicating the site of a large prehistoric city. Other ruins were observed at Santa Fe.

Doctor Fewkes examined some of the antiquities about Cordova and Orizaba; he also visited the pyramid of Cholula near Puebla, and about the middle of April proceeded to the State of Tamaulipas, spending about three weeks at Tampico in a study of the numerous ruins along the Panuco and Tamise rivers and on the adjacent lagoons, and in visiting the extensive shell heaps and temple mounds a mile east of Tampico and others not far from the site of the old town, Tampico Viejo. Doctor Fewkes found numerous antiquities at Altamira and mounds on the banks of the Champayan lagoon. Many other evidences of former occupancy, as idols, pottery, stone weapons, and ornaments, were seen in this region. The old city of Chila, destroyed by Cortés, situated about 10 miles west of Tampico, was found to be hidden in a forest. Evidences of temples and burial mounds also occur abundantly in this locality. About 50 photographs of bowls, jars, and idols found in the neighborhood of Panuco, Tampico, and the lagoons along the banks of the Tamise River, were made. Of more than usual interest are those of large stone idols at Altamira and in the courtyard of a house in Tampico.

On his return to Washington Doctor Fewkes continued the study from his notes and photographs, and prepared a general account of his visit to Cempoala

and Xicochimalco, which was transmitted for publication by the Smithsonian Institution. The illustrative material brought back includes about 200 large photographic negatives, numerous smaller views, tracings of pictographs, and many drawings, plans, and maps.

Dr. Cyrus Thomas, ethnologist, was engaged during the year largely on the Handbook of the Indians, assisting Mr. Hodge in the laborious task of preparing the manuscripts for publication. Among the articles written by Doctor Thomas during the year for this work are agriculture, calendar, counting, Five Civilized Tribes, fortifications, habitations, maize, migrations, mortuary customs, mounds and mound builders, population, reservations, treaties, besides a number of biographical sketches and archeological articles of a more special character. The work of reading the proofs of Bulletin 28, which required especial acquaintance with archeology and glyphic systems of the ancient Mexicans, was also intrusted to Doctor Thomas. This reading was completed before the end of the year. Doctor Thomas was also frequently called on for data required in official correspondence relating to his special branches of research.

Mr. J. N. B. Hewitt, ethnologist, at the beginning of the year began the preparation of various articles for the Handbook of the Indians, and continued the correction and elaboration of the material pertaining to the Iroquoian stock for the same work. Among the articles furnished are those on adoption, clans and gentes, confederations, chiefs, government, mythology, religion, scalping, wampum, and women. The work of cataloguing the collection of linguistic manuscripts, of which Mr. Hewitt is custodian, was completed as far as copying the old cards in duplicate, when the work was laid aside for that of the Handbook. Mr. Hewitt also gave material assistance in furnishing data required in the correspondence of the Bureau relating to tribes and languages.

Mrs. M. C. Stevenson, ethnologist, spent the month of July in New Mexico, where she had been for some months making a study of the arts, industries, religion, and social customs of the Zuñi tribe. It was observed that the Zuñi pantheon is largely similar to that of the Hopi and the Rio Grande pueblos. Although the Zuñi worship numerous deities which take both human and bestial form, they believe also in a supreme power without form, yet embracing all form, the breath of life—life itself. These beliefs indicate that the Zuñi have reached a higher stage of culture than has previously been supposed, although it can not yet be said to what extent this may be attributed to the Spanish influence to which the tribe was more or less subjected for three centuries. Various details relating to Zuñi life were investigated, and valuable information regarding mortuary customs was obtained through the death and burial of Naiuchi, a celebrated priest-chief, whose demise occurred during Mrs. Stevenson's stay in Zuñi pueblo. Native plants entering into the medicine and dietary of the Zuñi were also studied; the arts of preparing and dyeing wool, which have not been practiced for many years, were observed, and specimens of the native materials and devices employed in the process, as well as of the dyed wool, were collected. Studies of symbolism as embodied in Zuñi textile and ceramic art, and investigations into the everyday life, and especially the child-life, of the pueblo were likewise made.

Early in August a day was spent by Mrs. Stevenson with the Santa Clara Indians in making a series of photographs of their annual fiesta. The month was occupied principally, however, in a study of the Sia Indians, a few days being given to the neighboring Jemez pueblo. On the 27th Mrs. Stevenson reached Cochiti, whence a visit was made to the great stone carving of cougars on the mesa 10 miles distant. In Mrs. Stevenson's comparative studies

these sculptures are of special interest, as they are referred to in some of the most sacred myths of the Zuñi. The first of September was employed in a visit to the cavate and mesa ruins about 12 miles from Santa Clara and in making observations among the Tewa people of San Ildefonso, Santa Clara, and San Juan pueblos. The religious beliefs, rituals, and daily customs of these people were found to be closely allied to those of Zuñi, difference in language alone indicating that distinct peoples are involved. In October Mrs. Stevenson returned to Washington, where she has since been engaged in the revision of proofs of her memoir on the Zuñi Indians, in the Twenty-third Annual Report, and, as opportunity afforded, in the elaboration of her several studies on Zuñi religious beliefs, on the edible and medicinal plants of Zuñi, on symbolism as embodied in the textile and ceramic arts, and on the dyeing of textile fabrics.

Dr. J. R. Swanton, ethnologist, was engaged during the year in copying and preparing for the press material obtained by him among the Tlingit Indians of Alaska during the winter of 1903–4. This work, as completed, consists of 137 pages treating of the general ethnology of the Tlingit peoples, 20 native texts with interlinear and free translations, the words of about 100 songs, with translations, together with English versions of 88 stories obtained at Sitka and Wrangell—altogether forming 900 typewritten pages. Doctor Swanton has also prepared grammatical accounts of the Dakota, Haida, and Tlingit languages for introduction into the Handbook of Indian Languages now in course of preparation under the direction of Dr. Franz Boas, honorary philologist of the Bureau; and he has also been called on to contribute several articles for the Handbook of the Indians, including kinship, names and naming, priests and priesthood, thunderbird, totem poles, secret societies, and social organization.

Dr. A. S. Gatschet, ethnologist, continued his work on certain unfinished linguistic studies which it was hoped could be completed for publication before his failing health made further progress impossible, but in January he was compelled to practically relinquish his efforts, and on March 13 was placed on furlough.

Early in the year arrangements were made with the United States National Museum to have Dr. Ales Hrdlicka, curator of physical anthropology in the Museum, visit Arizona and New Mexico on behalf of the Bureau for the purpose of making physical, physiological, and medical observations among the Apache and Pima Indians. Leaving Washington on January 20, Doctor Hrdlicka began his studies, five days later, on the San Carlos Apache Reservation, where he remained until February 8, when he visited a group of Apache residing near what is known as the Sawmill, in the Black River Region. From this point he returned to San Carlos, and on February 13 reached the Rice Station Apache School and district, situated farther northeast on the reservation. On February 26, Doctor Hrdlicka endeavored to reach the White Mountain branch of the Apache, but was prevented from doing so by exceptionally heavy rains. On March 1 he was able to proceed to Sacaton, Ariz.,where studies of the Pima tribe were made. From March 12 to 16 he was at Casa Blanca. On the latter date he returned to Casa Grande, and thence proceeded to El Paso, Tex., reaching the reservation of the Mescalero Apache in New Mexico on the 19th. After remaining six days with the Mescaleros, Doctor Hrdlicka began his return journey, reaching Washington March 31.

Doctor Hrdlicka's researches were conducted with the object of supplementing his former investigations among the same tribes. As much attention as possible was devoted to the children, from birth onward, the number examined

being nearly 1,000. Other important subjects to which study was especially devoted were fecundity, mortality, native foods, hygiene, disease, and curative means and methods. These studies were greatly facilitated by the officials of the Indian Office, and met with little objection on the part of the Indians.

In addition to his direct anthropologic investigations, Doctor Hrdlicka succeeded in gathering specimens of about 150 medicinal and food plants and a number of ethnological objects. He procured one Apache skull and five complete Apache skeletons, and in addition to making observations of value among the ancient ruins of the general region, obtained many archeological specimens from hitherto unexplored ruins in the San Carlos Valley.

In April, Mr. E. L. Hewett, who was engaged during the winter months in preparing for the Bureau an archeological map of Colorado and New Mexico, was commissioned to proceed to New Mexico for the purpose of making extended researches among the ancient ruins of the so-called Pajarito Plateau district. His first work was the investigation of numerous deserted and ruined pueblos of the Tewa tribes. This was followed by excavations of ancient mounds in Otowi Canyon, which yielded results of exceptional interest. Upward of 175 burials were uncovered, and the osseous remains of more than 100 individuals were collected and forwarded for study in the National Museum. The art remains comprise numerous entire earthenware vessels and many fragments, with a fair complement of implements of bone and stone. Mr. Hewett was fortunate in reaching this arid spot in an exceptionally wet season, as he found water within easy reach. At the close of the year he had completed his studies within the boundaries of Pajarito Plateau and was preparing to explore explore the plateaus and mountains to the west and the Jemez Valley beyond.

In June a report reaching the Bureau that important finds of prehistoric remains of man and art had been made on the site of the forthcoming Jamestown Exposition, near Norfolk, Va., Mr. J. D. McGuire was commissioned to visit the locality and report on the character of the discoveries made. Mr. McGuire spent one day on the exposition grounds collecting such information as was available, and later reported that although traces of human remains had been exposed in the excavations of the exposition company, the reports had been greatly exaggerated, the discoveries being meager and uniform in character with the relics of countless other sites in the Chesapeake-Potomac region.

The work of Dr. Franz Boas, honorary philologist, was confined to the preparation of the Handbook of American Languages which has been under way for several years. The main part of the field work for the first part of the Handbook was closed during the present year and some field work designed to be embodied in the second part was taken up. Doctor Boas also furnished the article on languages for the Handbook of the Indians.

In the course of the fiscal year the following manuscripts for the Handbook of American Languages have been submitted.

1. Dr. P. E. Goddard: Grammatical notes on the Hupa (Athapascan stock).
2. Dr. A. L. Kroeber: Grammatical notes on the Yuki (Yukian stock).
3. Dr. Roland B. Dixon: Grammatical notes on the Maidu (Pujunan stock).
4. Dr. William Jones: Grammatical notes on the Sauk and Fox (Algonquian stock).
5. Dr. John R. Swanton: Grammatical notes on the Dakota (Siouan stock).
6. Dr. John R. Swanton: Grammatical notes on the Haida (Skittagetan stock).
7. Dr. John R. Swanton: Grammatical notes on the Tlingit (Koluschan stock).
8. Dr. Franz Boas: Grammatical notes on the Kwakiutl (Wakashan stock).
9. Dr. Franz Boas: Grammatical notes on the Chinook (Chinookan stock).

The following manuscripts are still outstanding:

1. J. N. B. Hewitt: Grammatical notes on the Iroquois (Iroquoian stock).
2. Dr. Franz Boas: Grammatical notes on the Eskimo (Eskimauan stock).
3. Dr. Franz Boas: Grammatical notes on the Tsimshian (Chimmesyan stock).

During the year the grammatical notes on the Shoshoni by Mr. H. H. St. Clair, 2d, have been revised.

The general plan of the Handbook of Languages has undergone no material change, except in so far as it was deemed advisable to add briefer articles on the grammar of the remaining languages of the northern part of the continent. These are the Tlingit, the Salish, the Kutenai, and the Chemakum. It is also deemed advisable to add a sketch of one of the coast languages of Oregon which was collected during the year 1904–5 by Mr. St. Clair, who submitted his material on the Coosa and Takilma of Oregon during the present year.

It also seemed desirable to add some data relating to the formation of the noun in Chinook, which seemed of importance in order to clear up some questions relating to the fundamental traits of that family of languages. Since all our information on this stock is derived from one informant, it seemed essential to obtain additional material from other sources and from another dialect. For this reason preparations were made to send Mr. E. Sapir to the upper Columbia River to make a study of the Wasco. In the preparation of this work the Kathlamet Dictionary, based on Bulletin 26, was arranged and copied.

The work on the southern group of languages will require long and energetic field work. So far only one of the languages of the Gulf States, the Yuchi, has been taken up, this tribe being selected because it seems most likely to furnish material that will be not only of linguistic value but will afford knowledege of the early history and customs of the Southeast. This work has been intrusted to Mr. Frank G. Speck, who spent the summer of 1904 among the Yuchi tribe and who returned to this field at the close of the fiscal year.

HANDBOOK OF THE INDIANS.

Work on the Handbook of the Indians North of Mexico, hitherto frequently referred to as the "Dictionary of Indian Tribes," has been vigorously prosecuted during the year under the immediate supervision of Mr. F. W. Hodge, of the Smithsonian Institution, who, with the approval of the Secretary, has devoted most of his time thereto. Mr. Hodge has had the almost undivided assistance of Dr. Cyrus Thomas; and, as occasion required, nearly the entire scientific staff of the Bureau has aided both in the preparation of the anthropologic and kindred articles and in the revision and elaboration of the tribal descriptions found to be necessary by reason of recently acquired knowledge. So far as the funds of the Bureau afforded, the aid of ethnologists not officially connected with the Bureau was also enlisted. The services generously rendered by these, either gratuitously or for merely a nominal consideration, are highly appreciated.

As outlined in former reports it was originally the plan of Major Powell to classify the linguistic families, tribes, and settlements north of Mexico and to identify the various names by which these had been known in the vast literature of the subject, with a brief description of each such group. This material, recorded on many thousands of cards, became known as the "Cyclopedia of Tribes, with Synonymy."

In 1903 the Secretary altered the scope of the work by directing the incorporation of brief separate articles pertaining to the habits, customs, arts, and industries of the Indians, and of their dealings with the Government, together with biographies of noted individuals and a list of words of northern Indian

origin that have been incorporated into the English language. No work so comprehensive in its scope had hitherto been attempted, consequently in making plans for the new departure it became necessary to begin at the foundation. The popular style of treatment was ever kept in mind, and considerable time was consumed in correspondence with experts best qualified for the preparation of many of the special articles called for by the enlarged plan. For these reasons it has not been possible to complete the work at an earlier date. Owing to the fact that many of the specialists do not reside in Washington, it was difficult, within a limited time, to arrange for entire consistency in treatment and to prevent repetition through encroachment of one subject on another when written by many hands. On this account, and for the purpose of obtaining the views and criticisms of as many experts as possible, conferences were held, as already mentioned, three times each week, which were faithfully attended by the ethnologic staffs of the Bureau and the National Museum, as well as by other resident ethnologists; and ethnologists from elsewhere, while visiting Washington, often gave this committee of revision the benefit of their criticism.

As the articles prepared both by the regular attendants and by others were read at the conferences, and thus were accorded opportunity for criticsim, the value of the meetings in promoting the authoritativeness of the forthcoming Handbook is inestimable. New subjects were constantly suggested, and in some instances much new light was shed on others, after having been written, by reason of the personal knowledge of one or another of the critics present.

In addition to the special articles elsewhere mentioned in this report as prepared by members of the Bureau, the following are among the more important of those that have been furnished by specialists not officially connected with it:

By Dr. Franz Boas: Languages.

By Dr. A. F. Chamberlain: Armor, Basque influence, Chinook jargon, Dutch influence, Eliot's bible, English influence, fur trade, German influence, God (words for), Hawaiian influence, Kutenai, linguistic families, "Lost Ten Tribes," maple sugar, Melungeons, Negro and Indian, Scandinavian influence, Spanish influence, white man (names for), wild rice, and many articles pertaining to words of Indian origin incorporated into the English language.

By Mr. Stewart Culin: Games.

By Dr. William H. Dall: Russian influence.

By Miss Anna Dawes: Commission to the Five Civilized Tribes.

By Dr. G. A. Dorsey: Ceremony, Sun Dance.

By Mr. Wilberforce Eames: Bible translations, dictionaries, periodicals.

By Dr. Livingston Farrand: Marriage and divorce, and many articles descriptive of some of the linguistic families of the Northwest.

By Miss Alice C. Fletcher: Adornment, agency system, buffalo, camping and camp circles, civilization, dramatic representation, dreams and visions, earth lodge, etiquette, fasting, feasts, furniture, governmental policy, grass lodge, land tenure, masks, music and musical instruments, oratory, orientation, poetry, property and property right, quillwork, soldiers, tatooing, totems, trading posts, war and war discipline and articles descriptive of the Caddoan tribes.

By Mr. Gerard Fowke: "Lansing man," and many articles on technological subjects.

By Mr. H. W. Henshaw: Atlantis, exchange, pictography, popular fallacies, slavery, sweating and sweat houses.

By Dr. George Bird Grinnell: Horse.

By Mr. F. W. Hodge: Adobe, irrigation, kiva and many tribal articles, especially those pertaining to the Southwestern Indians.

By Dr. Walter Hough: Altar, clothing, collecting and excavating, dyes and pigments, fire making, food, illumination, preserving and mending, snake dance, in addition to a large number of brief articles on various implements, utensils, materials used in manufacturing processes, etc.

By Dr. Ales Hrdlicka: Anatomy, artificial head deformation, cannibalism, mixed bloods, health and disease, physiology.

By Dr. Otis T. Mason: Arrows, bows, and quivers; arts and industries, basketry, beadwork, boats, commerce, domestication of animals, education, environment, featherwork, hunting implements, invention, needlework, traps, travel and transportation, weapons, weaving.

By Dr. Washington Matthews: Color symbolism, culture heroes, dry-painting, ethics, family, magic, measurements, medicine, mourning.

By Mr. J. D. McGuire: Drilling, fishing, pipes, smoking, storage and caches, tobacco, trails and trade routes.

The Bureau was also fortunate enough to have the services of Dr. A. L. Kroeber, of the University of California, who generously revised the accumulated material pertaining to many of the linguistic families of California, and in addition gave much valuable information respecting the Shoshonean and Yuman families and the Mission Indians. The remaining Californian stocks were reviewed by Dr. P. E. Goddard, also of the University of California, and by Dr. Roland B. Dixon, of Harvard University.

With the exception of a few articles that had not been quite finished by those to whom the subjects were assigned, the manuscript of the body of the Handbook, recorded on more than 40,000 cards, together with about 800 illustrations, was submitted to the Secretary for transmittal to the Public Printer on July 1, 1905, for publication in two octavo volumes as Bulletin 30 of the Bureau. These cards do not include about 37,000 cross-references to the tribal synonyms, nor the bibliography, which are retained for use in reading the proofs of the text. After serving this purpose they will be ready to be put in type to appear at the close of the work.

ARCHEOLOGICAL MAP.

The work of compiling an archeological map of the United States, which had received some attention in previous years, was carried forward with all possible dispatch during the last year. The departments of the Government having control of the public lands have undertaken to protect from despoliation by commercial relic hunters and unskilled and unauthorized explorers the archeological remains of these lands, and excellent progress in this direction has been made, especially by the Department of the Interior. For years the Bureau has been collecting data relating to these remains, and whenever called on has furnished all available information for the use of the departments in carrying out this laudable enterprise. During the winter months Mr. J. D. McGuire was engaged in collecting and collating data relating to the antiquities of Arizona and Utah, and in platting these on topographical maps furnished by the United States Geological Survey; and Mr. E. L. Hewett has carried forward to practical completion a corresponding work in Colorado and New Mexico. The several maps have been completed so far as the data is at hand. Accompanying the maps is a card catalogue of the various sites, giving information regarding location, character of remains, and explorations previously carried on. These maps and catalogues are at the disposal of the departments when called for.

In New Mexico the following sheets embrace 512 sites of sufficient interest to be catalogued: Santa Fe, Santa Clara, San Pedro, Pajarito Park, Bernal,

Las Vegas, Chaco Canyon, Mount Taylor, Largo, Lamy, Wingate, Jemez, Taos, Tierra Amarilla, Quemado, Acoma, Manzano, Pinos Wells, Tularosa, Chloride, San Marcial, Fort Stanton, Big Hatchet, Chama, El Paso, Fort Bayard, Las Cruces, San Juan, Albuquerque, and Tres Hermanos. In Colorado the Mesa Verde sheet alone includes 54 sites. On the 21 Arizona sheets (Tusayan, Fort Defiance, San Francisco Mountain, Echo Cliff, St. Johns, Prescott, Verde, Florence, Holbrook, Canyon de Chelly, Solomonsville, Globe, Phoenix, Casa Grande, Fort Apache, Diamond Creek, Chino, Marsh Pass, Tombstone, and Tucson) 270 sites are recorded, and on the Utah sheets (Ashley, Beaver, Escalante, Fish Lake, Henry Mountain, Kanab, Manti, Salt Lake, San Rafael, St. George, Price River, Uinta, La Salle, Abajo, and Utah) are noted 122 sites. The 1,008 archeological sites thus catalogued are scattered over an immense territory and come under the jurisdiction of the Interior, Agricultural, and War departments.

EXPOSITION WORK.

The exhibit of the Bureau installed in the Smithsonian section of the Government building of the Louisiana Purchase Exposition at St. Louis during 1904, and described in the report for that year, was dismantled at the close of the exposition and a large part of it transferred to Portland, where it has been installed as a part of the Institution's exhibit at the Lewis and Clark Exposition. The remainder of the material has been returned to Washington and deposited in the National Museum.

STUDY OF INDIAN DELEGATIONS.

The systematic study of visiting Indian delegations has been continued with success. During the year 23 delegations, representing 21 tribes, have been conducted, through the agency of Mr. Andrew John, to the Bureau and National Museum laboratories. Upward of 280 portrait negatives have been made, and casts and measurements of a number of individuals have been obtained. Few Indians of the higher type, however, are willing to submit to the experience of having the face encased in plaster. The tribes represented are as follow:

	Photo.	Cast.	Measurement.		Photo.	Cast.	Measurement.
Apache	3			Oneida	1		
Catawba	1	1	1	Onondaga	1		
Cherokee	1			Osage	5	1	2
Choctaw	1			Pawnee	4		4
Cayuga	5			Pueblo	11		11
Colville	3			Seneca	3	2	1
Creek	3		3	Stockbridge	1		1
Flathead	2			Sioux	11		11
Menominee	4	1	2	Wyandot	2		
Mission	1			Total	68	6	37
Modoc	4						
Omaha	1	1	1				

COLLECTIONS.

The ethnological collections obtained during the year fall considerably short of those of previous years, owing to the reduced amount of field work undertaken. This condition was due, as already explained, to the necessity of keeping most

of the scientific staff in Washington to aid in the completion of the Handbook of Indians. The accessions are a valuable collection, made by Mrs. M. C. Stevenson at Zuñi, a series of archeological objects obtained by Doctor Hrdlicka in Arizona and New Mexico, and several minor collections, all of which have been deposited in the National Museum.

PUBLICATIONS.

The distribution of publications has continued as in former years. The great increase in the number of libraries in the country and the multiplication of demands from the public generally have resulted in an almost immediate exhaustion of the quota of volumes allotted to the Bureau, few copies of any of the reports remaining six months after the date of issue. Part II of the Twenty-second Annual Report was issued in January. During the year 1,591 copies of the Twenty-first and Twenty-second Reports were sent to regular recipients, and 2,000 volumes and pamphlets were transmitted in response to special requests, presented largely by members of Congress. The proof reading of the Twenty-third Annual and of Bulletin 28 was practically completed at the close of the year, and it is expected that the press work of these publications will shortly be begun. The Twenty-fourth Report was in the hands of the printer before the close of the year, and Bulletins 29 and 30, the latter being the Handbook of the Indians, were ready to be submitted to the Secretary on June 30, 1905, while the Twenty-fifth Annual Report was completed, with the exception of a small number of illustrations.

EDITORIAL WORK.

The editorial work of the year has presented features of exceptional difficulty, on account of the large number of papers dealing with linguistics and technical subjects. The Bureau has had the services of Mr. Frank Huntington for the greater part of the year, and Mr. J. P. Sanborn, jr., received a probational appointment as editor in May. The reading of the proofs of Mrs. Stevenson's monograph on the Zuñi Indians for the Twenty-third Annual Report, a work of much technical difficulty, was intrusted mainly to Mr. E. G. Farrell.

ILLUSTRATIONS.

The work of preparing illustrations has continued in charge of Mr. De-Lancey Gill, who has been assisted, as heretofore, by Mr. Henry Walther. The photographic work has included the making of portraits of members of 21 Indian delegations which visited the capital during the year. Three views of each individual were taken, besides several group views, the negatives numbering 208. In preparing illustrations for the publications of the Bureau upward of 200 negatives were made, and 156 films exposed in the field by members of the Bureau were developed in the laboratory. During the year about 2,350 prints were made, mainly for immediate use in illustrating the Bureau publications. Illustrations prepared for the Twenty-fourth Annual Report number 45; for the Twenty-fifth Annual Report, 128; for Bulletin 30, 800. Illustrations transmitted with reports submitted to the Secretary for publication are: For the Twenty-fourth Annual Report, 1,103; for Bulletin 30, 871. Illustrations edited for the Twenty-third Annual Report number 25; for the Twenty-fourth Annual Report, 1,102. The printed editions of 48 colored plates submitted by the engravers for the Twenty-third and Twenty-fourth Annual Reports, numbering about 450,000 prints, were individually examined and approved or rejected.

LIBRARY.

The library has been in immediate charge of Miss Ella Leary, who has had the assistance of Mrs. Ella Slaughter. The accessioning and cataloguing of the books, pamphlets, and periodicals received during the year have been kept up to date, and the cataloguing of the publications of scientific societies has been commenced. Owing to the crowded condition of the library and their questionable place in an ethnological library, about 400 publications relating to natural history, received through exchange, have been transferred to the National Museum. During the year there have been received and recorded 398 volumes, 500 pamphlets, and the current issues of upward of 500 periodicals; 120 volumes have been bound at the Government Printing Office. The library now contains about 12,563 bound volumes, 7,000 pamphlets, and a large number of periodicals bearing on ethnology and kindred topics. Purchase of books for the library has been restricted to those that bear on the subject of anthropology, with special reference to the American Indians, and only indispensable works have been obtained by this means.

CLERICAL WORK.

The clerical force of the Bureau consists of four regular employees—Mr. J. B. Clayton, head clerk; Miss Emilie R. Smedes and Miss May S. Clark, stenographers; and Miss Ella Leary, clerk and acting librarian. During the year the compilation of the Handbook of the Indians necessitated the employment of additional clerks with special training in dealing with cyclopedic material and in bibliographic work. In this the services of Mrs. F. S. Nichols, Mrs. Gertrude L. Rogers, and Miss Laura W. Steever have proved invaluable.

PROPERTY.

The property of the Bureau is comprised in seven classes, as follow: Office furniture and appliances; field outfits; linguistic and ethnological manuscripts and other documents; photographs, drawings, paintings, and engravings; a working library; collections held temporarily by collaborators for use in research, and undistributed residue of the editions of Bureau publications.

The additions to the property of the Bureau for the year include a typewriter and a few necessary articles of furniture. The only improvement made in the offices was the changing of the electric-light wiring, which was done under the direction of the District authorities at a cost of $116.55

Respectfully submitted.

W. H. HOLMES,
Chief of Bureau.

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

Appendix III.

REPORT ON INTERNATIONAL EXCHANGES.

Sir: I have the honor to submit the following report of the operations of the International Exchange Service during the year ending June 30, 1905:

The system for the interchange of publications between learned institutions and individuals in the United States and those in other countries was inaugurated by the Smithsonian Institution almost at the very beginning, and was maintained at the expense of the private fund of the Institution exclusively from 1850 to 1881, when Congress made a small appropriation to assist in the work. Since that time Congressional appropriations have been made annually, but at no time have they been large enough to provide for the entire expense of the service, the Institution having supplied all other necessary means from its private fund, with the aid of United States departments and bureaus and State institutions, which have been asked to reimburse the Institution, at the uniform rate of 5 cents per pound, for a part of the expense of preparing, boxing, and transporting contributions.

The number of packages dispatched during the year was greater than ever before, and, as a record of every package is required, the work has been considerably augmented, but there has been no increase in the clerical force.

The offices occupied by the Exchange Service, consisting of five rooms, are in the southeast basement of the Smithsonian building, and are equipped with the necessary folding and sorting tables, bins, file cases, desks, etc. In addition to the customary supplies for general clerical employment, the service requires large quantities of cards, labels, and printed forms. The supplies for packing and shipping are considerable, and so far as practicable are obtained under annual contract.

On May 1, 1905, the Institution was informed that the steamship *Buteshire*, which sailed from New York on November 26, 1904, was subject to general average adjustment on account of fire in the hold of the vessel during the voyage. Twelve cases of international exchanges destined for Australian ports formed a part of the cargo, and in the event that the contents of any of these cases prove to be irreparably damaged they will be replaced by duplicate volumes, if practicable.

The following tabular statement shows the weight and number of packages transmitted each month during the year, and also the increase over the previous twelve months in each class of correspondents. The second table is a statement of exchange transmissions during each year since 1898.

Tabular statement of the work of the International Exchange Service during the fiscal year 1904–5.

Date.	Number of packages handled.	Weight of packages handled.	Number of correspondents June 30, 1905.				Packages sent to domestic addresses.	Cases shipped abroad.
			Foreign societies.	Domestic societies.	Foreign individuals.	Domestic individuals.		
1904.								
July	11,232	29,131						
August	10,191	27,175						
September	11,047	21,690						
October	17,131	52,511						
November	9,347	24,743						
December	18,389	57,919						
1905.								
January	14,518	38,149						
February	18,028	50,599						
March	11,964	39,636						
April	20,297	64,631						
May	11,024	26,967						
June	12,587	41,730						
Total	165,753	[a]474,871	14,018	3,574	27,263	7,025	44,898	2,027
Increase over 1903-4	6,770	[a]6,539	761	110	2,362	575	6,196	40

[a] Decrease.

The following table shows the number of packages of exchanges handled and the increase in the number of correspondents each year from 1898 to 1905:

	1898-99.	1899-1900.	1900-1.	1901-2.	1902-3.	1903-4.	1904-5.
Number of packages received	97,835	113,563	121,060	125,796	150,217	158,983	165,753
Weight of packages received .... pounds.	317,883	409,991	414,277	386,418	559,718	481,410	474,871
Correspondents:							
Foreign societies	10,322	10,845	11,296	11,760	13,121	13,257	14,018
Foreign individuals	13,378	15,385	16,261	17,701	21,322	24,901	27,263
Domestic societies	2,596	2,721	2,996	3,182	3,319	3,464	3,574
Domestic individuals	4,673	5,000	5,153	5,557	6,240	6,450	7,025
Packages to domestic addresses	30,645	28,625	31,367	33,961	33,980	38,702	44,898
Cases shipped abroad	1,500	1,768	1,757	1,847	2,461	1,987	2,027

The total number of correspondents has increased from year to year until the aggregate is now 51,880, or 3,808 more than at the conclusion of the fiscal year 1903–4. The correspondents in the United States number 10,599, and those in all other countries 41,281. Of the latter number organized bodies maintaining libraries number 14,018, and those classified as individuals aggregate 27,263.

Number of correspondents of the International Exchange Service in each country on June 30, 1905.

Country.	Correspondents. Libraries.	Individuals.	Total.
AFRICA.			
Algeria	26	44	70
Angola	1	....	1
Ashantee	....	1	1
Azores	7	16	23
Beira	....	1	1
British Central Africa	1	3	4
British East Africa	....	3	3
Canary Islands	2	9	11
Cape Colony	58	107	165
Cape Verde Islands	....	5	5
Egypt	43	95	138
French Kongo	....	2	2
Gambia	....	2	2
German East Africa	5	....	5
Gold Coast	1	4	5
Kongo	....	5	5
Lagos	2	5	7
Liberia	3	10	13
Lourenço Marquez	....	5	5
Madagascar	6	9	15
Madeira	3	4	7
Mauritius	12	11	23
Morocco	....	14	14
Mozambique	....	1	1
Natal	22	29	51
Orange River Colony	3	6	9
Reunion	4	2	6
Rhodesia	8	14	22
St. Helena	3	2	5
Senegal	1	5	6
Sierra Leone	2	3	5
Sudan	1	....	1
Transvaal	32	41	73
Tunis	7	8	15
Zanzibar	2	5	7
AMERICA (NORTH).			
Canada	364	625	989
Central America:			
British Honduras	6	12	18
Costa Rica	27	47	74
Guatemala	44	72	116
Honduras	14	41	55
Nicaragua	20	55	75
Salvador	21	15	36
Greenland	2	....	2
Mexico	177	233	410
Newfoundland	17	33	50
St. Pierre-Miquelon	2	2	4
United States	3,574	7,025	10,599
AMERICA (NORTH)—continued.			
West Indies:			
Anguilla	....	1	1
Antigua	8	6	14
Bahamas	4	11	15
Barbados	10	27	37
Bermuda	6	24	30
Bonaire	....	1	1
Cuba	70	139	209
Curaçao	3	6	9
Dominica	2	7	9
Green Turtle Cay	....	1	1
Grenada	3	6	9
Guadeloupe	2	6	8
Haiti	38	18	56
Jamaica	21	50	71
Martinique	....	3	3
Montserrat	....	2	2
Nevis	....	1	1
Porto Rico	9	36	45
St. Bartholomew	....	2	2
St. Christopher	2	7	9
St. Croix	1	4	5
St. Eustatius	....	1	1
St. Lucia	2	5	7
St. Martin	....	2	2
St. Thomas	2	8	10
St. Vincent	1	2	3
Santo Domingo	3	14	17
Tobago	....	2	2
Trinidad	16	16	32
Turks Islands	3	6	9
AMERICA (SOUTH).			
Argentina	161	243	404
Bolivia	22	21	43
Brazil	156	199	355
British Guiana	19	15	34
Chile	98	115	213
Colombia	39	61	100
Dutch Guiana	5	4	9
Ecuador	24	28	52
Falkland Islands	....	6	6
French Guiana	1	2	3
Panama	3	17	20
Paraguay	21	15	36
Peru	47	86	133
Uruguay	54	41	95
Venezuela	43	51	94

Number of correspondents of the International Exchange Service in each country on June 30, 1905—Continued.

Country.	Correspondents.		
	Libraries.	Individuals.	Total.
ASIA.			
Arabia		7	7
Beloochistan		1	1
Burma	14	9	23
Ceylon	30	18	48
China	50	136	186
Cyprus	3	4	7
Formosa		3	3
French India	1	1	2
Hongkong	11	29	40
India	258	309	567
Indo-China	10	11	21
Japan	190	492	682
Korea	4	18	22
Macao	1	1	2
Malaysia:			
Borneo		1	1
British New Guinea		1	1
British North Borneo	1	2	3
Celebes		4	4
Java	22	39	61
New Guinea		1	1
Philippine Islands	24	32	56
Sarawak	1		1
Sumatra	1	2	3
Persia	3	10	13
Portuguese India	1		1
Siam	7	24	31
Straits Settlements	19	23	42
AUSTRALASIA.			
New South Wales	89	188	277
New Zealand	92	147	239
Queensland	54	72	126
South Australia	45	80	125
Tasmania	25	35	60
Victoria	120	184	304
Western Australia	33	45	78
EUROPE.			
Austria-Hungary	793	1,445	2,238
Belgium	390	549	939
EUROPE—continued.			
Bulgaria	15	22	37
Denmark	121	241	362
France	1,861	3,375	5,236
Germany	2,621	5,124	7,745
Gibralter	1	7	8
Great Britain	2,233	6,590	8,823
Greece	42	60	102
Iceland	17	11	28
Italy	900	1,265	2,165
Luxemburg	13	10	23
Malta	13	16	29
Montenegro	2	1	3
Netherlands	226	416	642
Norway	145	211	356
Portugal	111	92	203
Roumania	52	74	126
Russia	564	1,145	1,709
Servia	22	16	38
Spain	217	313	530
Sweden	196	425	621
Switzerland	393	788	1,181
Turkey	43	103	146
POLYNESIA.			
Fiji Islands	1	9	10
German New Guinea	1		1
Guam		1	1
Hawaiian Islands	30	77	107
Marshall Islands		5	5
New Caledonia		2	2
New Hebrides	1		1
Samoa		5	5
Seychelles Islands		1	1
Tahiti		8	8
Tonga		3	3
International	37		37
Total	17,592	34,288	51,880

EXCHANGE OF GOVERNMENT DOCUMENTS.

All Government publications gratuitously presented to other governments through the International Exchange Service during the year, and similar publications received by the departments and bureaus, are enumerated in the following table. The receipts from abroad show an increase of 4,166 packages, or 25.66 per cent, over the fiscal year 1903–4, while the contributions to other

countries diminished to the extent of 9,643, or 12.89 per cent, during the same period. The increase in receipts is particularly gratifying, and is due principally to earnest demands, both by personal solicitation and by letter, for more adequate reciprocal returns; while the diminution in the contributions of United States official publications is attributable largely to the elimination of many correspondents who have not sent an equivalent in their own publications.

Statement of United States Government exchanges during the year 1904–5.

Name of Bureau.	Packages. Received for—	Packages. Sent by—
American Historical Association	16	64
Astrophysical Observatory	16	
Auditor for the State and other Departments		648
Board on Geographic Names	1	
Bureau of American Ethnology	246	678
Bureau of American Republics	17	6
Bureau of Animal Industry		68
Bureau of the Census	45	1,965
Bureau of Education	118	2
Bureau of Fisheries	100	558
Bureau of Foreign Commerce	3	
Bureau of Insular Affairs		11
Bureau of Labor	55	53
Bureau of the Mint	11	196
Bureau of Navigation, Navy Department	3	
Bureau of Navigation, Department of Commerce and Labor		11
Bureau of Public Health and Marine-Hospital Service	8	548
Bureau of Statistics, Department of Commerce and Labor	303	15,495
Bureau of Steam Engineering, Navy Department		1
Chief of Staff, U. S. Army		149
Civil Service Commission	2	12
Coast and Geodetic Survey	513	314
Commissioner of Internal Revenue		8
Commissioners of the District of Columbia	6	50
Comptroller of the Currency	35	180
Department of Agriculture	494	192
Department of Commerce and Labor	3	1
Department of the Interior	21	266
Department of Justice		44
Department of State	14	2
Engineer School of Application	4	
Entomological Commission	3	
General Land Office	6	
Geological Survey	742	2,414
Health Department of the District of Columbia	10	
Hydrographic Office	94	141
Interstate Commerce Commission	24	92
Isthmian Canal Commission		1
Library of Congress	12,498	29,765
Life-Saving Service		69
Light-House Board	3	181
Military Secretary's Office		268
National Academy of Sciences	103	46
National Botanic Garden	1	
National Bureau of Standards	10	
National Museum	316	3,622
National Zoological Park	3	
Nautical Almanac Office	30	71
Naval Observatory	154	609
Navy Department	14	
Office of the Chief of Engineers	31	83
Office of the Chief of Staff, U. S. Army		8
Office of Indian Affairs	3	
Ordnance Office, War Department	2	
Patent Office	296	1,818
President of the United States	1	
Senate of the United States	3	
Smithsonian Institution	3,720	12,217
Superintendent of Documents	1	41
Surgeon-General's Office	151	326
Treasury Department	9	9
War Department	31	6
Weather Bureau	137	911
Total	20,400	65,229

RELATIVE INTERCHANGE OF PUBLICATIONS BETWEEN THE UNITED STATES AND OTHER COUNTRIES.

Following is a comparative statement of exchange transmissions between the United States and other countries during the years 1904 and 1905, respectively. Exchanges were conducted with 153 countries during the year ended June 30, 1905, or two more than during the preceding year:

Comparative statement of packages received for transmission through the International Exchange Service during the fiscal years ending June 30, 1904, and June 30, 1905.

Country.	1904.		1905.	
	Packages.		Packages.	
	For—	From—	For—	From—
Algeria	131	65	136	35
Angola	3		2	
Antigua	67		42	
Arabia	39		39	
Argentina	2,936	638	2,296	1,210
Austria-Hungary	5,349	2,969	5,136	2,743
Azores	46		35	
Bahamas	43		45	
Barbados	103		103	
Beira			17	
Beled-es-Sudan			1	
Belgium	2,848	2,459	2,894	2,871
Beloochistan	1			
Bermudas	52		54	
Bismarck Archipelago	1		1	
Bolivia	127	32	279	4
Bonaire	1			
Borneo	13		10	
Brazil	2,228	847	2,122	1,062
British America	3,943	919	3,804	762
British Burma	13		27	
British East Africa	9		11	
British Central Africa	3		4	
British Guiana	112		97	
British Honduras	53		26	
British West Africa	4		1	
Bulgaria	168		121	
Canary Islands	27		31	
Cape Colony	542	228	808	153
Cape Verde Islands	6		2	
Celebes	4		5	
Ceylon	123		271	
Chile	1,736	54	1,851	160
China	540	221	559	24
Colombia	872		671	
Kongo			1	
Costa Rica	1,255		1,167	
Cuba	1,012	97	690	214
Curaçao	22		29	
Cyprus	5		11	
Denmark	1,319	766	1,186	318
Dominica	75		71	

Comparative statement of packages, received for transmission through the International Exchange Service, etc.—Continued.

Country.	1904. Packages.		1905. Packages.	
	For—	From—	For—	From—
Dutch Guiana	49		33	
Dutch West Indies	1			
Ecuador	165		161	
Egypt	252	2	385	
Falkland Islands	13		19	
Fiji Islands	21		22	
France	9,764	5,032	10,630	6,338
French Cochin China			43	
French West Africa	2			
Gambia	2			
German East Africa	8		2	
Germany	17,621	6,928	18,280	8,464
Gibraltar	16		21	
Gold Coast	3		12	
Goree Dakar	16		18	
Grenada	8		12	
Great Britain and Ireland	17,696	8,383	18,024	13,271
Greece	811	4	720	38
Greenland	4		5	
Guadeloupe	19		20	
Guam	1			
Guatemala	230		194	
Guinea			2	
Haiti	635		438	
Hawaiian Islands	96		88	
Honduras	302		219	
Hongkong	135		136	
Iceland	48		47	
India	1,844	182	1,773	319
Italy	5,700	1,405	6,739	1,412
Jamaica	296		233	
Japan	2,463	18	2,439	84
Java	248	48	259	127
Korea	67		69	
Lagos	2		2	
Leeward Islands	4		2	
Liberia	63		83	
Lourenço Marquez	19		15	
Luxemburg	88	1	78	
Madagascar	24		30	
Madeira	22		22	
Malta	50		205	
Marshall Islands	6			
Martinique	9		19	
Mauritius	75	47	61	49
Mexico	2,279	1,619	2,002	1,385
Montenegro	1		2	
Montserrat	4			
Morocco	25		20	1
Natal	133	95	177	
Netherlands	2,495	778	2,687	1,038
New Caledonia	7		10	

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued.

Country.	1904.		1905.	
	Packages.		Packages.	
	For—	From—	For—	From—
Newfoundland	133		98	6
New South Wales	2,109	375	2,655	782
New Zealand	975	4	1,456	2
Nicaragua	239		399	
Norfolk Islands			13	
Norway	1,495	663	1,372	647
Orange River Colony	11		201	
Panama	24		107	
Paraguay	178		127	
Persia	51		72	
Peru	962	224	896	259
Philippine Islands	86	2	111	633
Porto Rico	18		19	
Portugal	1,058	337	901	455
Queensland	979	260	852	8
Reunion	14		13	
Rhodesia	20	20	21	1
Roumania	335	1,233	424	102
Russia	4,699	2,346	4,442	2,577
St. Bartholomew	6			
St. Croix	11		2	
St. Eustatius	4		1	
St. Helena	22		21	
St. Kitts	21		19	
St Lucia			3	
St. Martin	16		17	
St. Pierre and Miquelon	17		21	
St. Thomas	14		23	
St. Vincent	5		2	
Samoa	25		32	
Samos	2			
San Salvador	152	8	292	
Santa Lucia	13			
Santo Domingo	3		6	
Servia	78		86	2
Siam	195	110	101	
Sierra Leone	18		22	
Society Islands	20		21	
South Australia	2,376	4	2,035	5
Spain	1,655	110	1,647	65
Straits Settlements	202		151	
Sumatra	5		1	
Sweden	2,123	928	2,039	117
Switzerland	2,762	1,359	2,943	1,155
Syria	115		28	
Tasmania	790	24	579	3
Tonga	1			
Transvaal	703		604	1
Trinidad	83		92	
Tunis	38		35	12
Turkey	825		820	
Turks Islands	25		23	

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued

Country.	1904.		1905.	
	Packages.		Packages.	
	For—	From—	For—	From—
United States	38,702	116,087	44,902	116,044
Uruguay	1,304	21	916	307
Venezuela	846		690	
Victoria	1,920	816	1,683	484
Western Australia	813	214	639	4
Windward Islands	3			
Zanzibar	21		25	

With few exceptions the same arrangements exist for distributing exchanges in other countries as those mentioned in the previous report, and, although it is a source of regret that every country does not maintain an official exchange bureau—among the most important being England, Germany, and Austria-Hungary—the Institution has been successful in enlisting the services of some institution of learning or prominent individual in nearly all countries not officially represented, with the result that means have been found for forwarding exchanges to every part of the world. On account of the extent of the work, and various disturbances which are liable to occur, interruptions and delays are sometimes unavoidable.

China is still considering the proposal to establish an official exchange bureau, and efforts were recently renewed through the diplomatic service with that end in view, but, pending more satisfactory arrangements, facilities have been added to the somewhat limited method of distribution. Packages for Shanghai are now forwarded by post, under frank, through the United States postal agency in that city, and through the courtesy of the Zi-ka-wei Observatory parcels for the provinces are distributed with reasonable dispatch.

On account of the difficulty in transporting exchanges from the coast to the city of Quito all transmissions to Ecuador were suspended for twenty-one months, but through the efforts of the American minister consignments were renewed on April 4, 1905, with the mutual understanding that exchanges for Guayaquil and other coast towns should be packed in separate boxes and distributed to addressees from the port of entry. This arrangement is only temporary, and, on the completion of a railroad now in course of construction from Guayaquil to Quito, it is expected that all consignments will be forwarded direct to the last-mentioned city and thence distributed.

Following is a list of correspondents abroad through which the distribution of exchanges is accomplished. Most of those in the larger and many in the smaller countries forward reciprocal contributions to the Smithsonian Institution for distribution in the United States:

Algeria (via France).
Angola (via Portugal).
Argentina: Museo Nacional, Buenos Ayres.
Austria: K. K. Statistische Central-Commission, Vienna.
Azores (via Portugal).
Barbados: Imperial Department of Agriculture, Bridgetown.
Belgium: Service Belge des Échanges Littéraires Internationaux, Brussels.
Bolivia: Oficina Nacional de Inmigracion, Estadística y Propaganda Geográfica, La Paz.

Brazil: Serviço de Permutações Internacionnes, Bibliotheca Nacional, Rio de Janeiro.
British Colonies: Crown Agents for the Colonies, London.[a]
Bulgaria: Dr. Paul Leverkühn, Sofia.
Canada: Sent by mail.
Canary Islands (via Spain).
Cape Colony: Superintendent of the Government Stationery Department, Cape Town.
Chile: Universidad de Chile, Santiago.
China: Zi-ka-wei Observatory, Shanghai.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
Ecuador: Minister of Foreign Relations, Quito.
East India: India Store Department, India Office, London.
Egypt: Société Khédiviale de Géographie, Cairo.
France: Bureau Français des Échanges Internationaux, Paris.
Friendly Islands: Sent by mail.
Germany: Karl W. Hiersemann, Königsstrasse 3, Leipzig.
Great Britain and Ireland: Messrs. William Wesley & Son, 28 Essex street, Strand, London.
Greece: Director of the American School of Classical Studies, Athens.
Greenland (via Denmark).
Guadeloupe (via France).
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Guinea (via Portugal).
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Honduras: Biblioteca Nacional, Tegucigalpa.
Hungary: Dr. Joseph von Körösy, "Redoute," Budapest.
Iceland (via Denmark).
Italy: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
Jamaica: Institute of Jamaica, Kingston.
Japan: Foreign Office, Tokyo.
Java (via Netherlands).
Liberia: Care of American Colonization Society, Washington, D. C.
Luxemburg (via Germany).
Madagascar (via France).
Madeira (via Portugal).
Mexico: Sent by mail.
Mozambique (via Portugal).
Natal: Agent-General for Natal, London.
Netherlands: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.
New Guinea (via Netherlands).
New Hebrides: Sent by mail.
Newfoundland: Sent by mail.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: Colonial Museum, Wellington.

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[a] This method is employed for communicating with a large number of the British colonies with which no means are available for forwarding exchanges direct.

Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.
Paraguay: Ministerio de Relaciones Exteriores, Asuncion.
Persia (via Russia).
Peru: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Queensland: Exchange Board, Parliament House, Brisbane.
Roumania (via Germany).
Russia: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
Salvador: Museo Nacional, San Salvador.
Santo Domingo: Sent by mail.
Servia (via Germany).
Siam: Minister for Foreign Affairs, Bangkok.
South Australia: Astronomical Observatory, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instruccion Publica y Bellas Artes, Madrid.
Sumatra (via Netherlands).
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
Tasmania: Royal Society of Tasmania, Hobart.
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, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Zanzibar: Sent by mail.

With the exception of points otherwise inaccessible and those countries with which the use of the official post-office frank is permitted, parcels sent to foreign countries during the year were packed in boxes and were forwarded by express or freight. Of the 2,027 boxes of publications thus sent, 203 contained complete series of official documents of the United States for designated depositories, and 1,824 boxes contained United States departmental reports and scientific exchanges for miscellaneous addresses. The number of boxes of miscellaneous exchanges sent to each country is given below:

Antigua	1	Cape Colony	12
Argentina	36	China	4
Austria	74	Chile	25
Barbados	2	Colombia	6
Belgium	72	Costa Rica	7
Bermuda	2	Cuba	(a)
Bolivia	3	Denmark	24
Brazil	29	Dutch Guiana	(b)
British colonies	25	East Indies	33
British Guiana	4	Egypt	7
British Honduras	5	France and colonies	177
Canada	(a)	Germany	256

[a] Packages sent by mail.
[b] Included in transmissions to Netherlands.

Great Britain and Ireland	362	Porto Rico	([a])
Greece	12	Portugal	14
Grenada	1	Queensland	8
Guatemala	5	Roumania	([b])
Haiti	1	Russia	72
Hawaii	([a])	Salvador	7
Honduras	5	Santo Domingo	3
Hungary	35	Servia	([b])
Italy	96	Siam	3
Jamaica	4	South Australia	13
Japan	33	Spain	18
Liberia	1	St. Christopher	1
Mexico	([a])	Sweden	59
Natal	8	Switzerland	56
Newfoundland	([a])	Syria	2
New South Wales	24	Tasmania	4
Netherlands	40	Transvaal	4
New Providence	1	Trinidad	2
New Zealand	10	Turkey	5
Nicaragua	6	Turks Island	1
Norway	35	Uruguay	13
Paraguay	5	Venezuela	6
Peru	12	Victoria	19
Philippine Islands	([a])	Western Australia	14
Polynesia	([a])		

During the year four consignments of United States Government official publications were made to each of the fifty depositories for which provision was made under the joint resolution of Congress approved March 2, 1867. Transmissions consisting of one box each were made to each depository on October 1 and December 27, 1904, and on February 28 and April 24, 1905. On the last date mentioned three additional consignments, comprising complete sets, were forwarded to Cape Colony, Manitoba, and France, respectively, thus increasing the number of regular depositories to fifty-three. A list of these depositories follows:

Argentina: Library of the Foreign Office, Buenos Ayres.
Argentina: Biblioteca Pública Provincial, 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, Santiago.
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.

[a] Packages sent by mail.
[b] Included in transmissions to Germany.

England: School of Economics and Political Sciences, London.
France: Bibliothèque Nationale, Paris.
France: Préfecture de la Seine, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Greece: National Library, Athens.
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Secretary to the Government of India, Calcutta.
Ireland: National Library of Ireland, Dublin.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Foreign Office, Tokyo.
Manitoba: Provincial Library, Winnipeg.
Mexico: Instituto Bibliográfico, Museo 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.
South Australia: Parliamentary Library, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instrucción Pública y Bellas Artes, Madrid.
Sweden: Kongliga Biblioteket, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Parliamentary Library, Hobart.
Transvaal: Government Library, Pretoria.
Turkey: Minister of Public Instruction, Constantinople.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Württemberg: Königliche Landesbibliothek, Stuttgart.

The fifty-three sets of United States official publications referred to were delivered to the Smithsonian Institution from time to time as they came from press, and when a sufficient number was received to completely fill the boxes prepared for them a list was printed to accompany each set, which was then shipped to its respective destination.

In addition to the above, partial sets were provided under the joint resolution of Congress approved March 2, 1901, for the purpose of increasing exchanges with countries for which no provision was made under the limited resolution of March 2, 1867. The new depositories that had been designated to the close of the fiscal year 1904–5 were as follows:

Austria-Hungary: Bürgermeister der Haupt- und Residenz-Stadt, Vienna.
Bolivia: United States Minister, La Paz.
British Columbia: Legislative Library, Victoria.
Bulgaria: Minister of Foreign Affairs, Sofia.

Ceylon: United States Consul, Colombo.
Egypt: Bibliothèque Khédiviale, Cairo.
Germany: Grossherzogliche Hof-Bibliothek, Darmstadt.
Germany: Senatskommission für die Reichs- und auswärtigen Angelegenheiten, Hamburg.
Germany: Foreign Office, Bremen.
Guatemala: Secretary of the Government, Guatemala.
Honduras: Secretary of the Government, Tegucigalpa.
Jamaica: Colonial Secretary, Kingston.
Malta: Lieutenant-Governor, Valetta.
Newfoundland: Colonial Secretary, St. John's.
New Brunswick: Legislative Library, St. John.
Natal: Colonial Governor, Pietermaritzburg.
Nicaragua: Superintendente de Archivos Nacionales, Managua.
Nova Scotia: Legislative Library, Halifax.
Northwest Territories: Government Library, Regina.
Orange River Colony: Government Library, Bloemfontein.
Prince Edward Island: Legislative Library, Charlottetown.
Paraguay: Oficina General de Informaciones y Canjes y Commisaria General de Inmigracion, Asuncion.
Roumania: Academia Romana, Bukharest.
Salvador: Ministerio de Relaciones Exteriores, San Salvador.
Straits Settlements: Colonial Secretary, Singapore.
Siam: Foreign Office, Bangkok.

As new countries are constantly being added, the partial sets for the depositories designated under the last resolution are not forwarded simultaneously with those originally provided, but are delivered to the Institution from the Library of Congress and are dispatched with the next succeeding consignments of miscellaneous exchanges to the respective countries in which the depositories are situated.

The agencies in those countries which are supported at the expense of the Smithsonian Institution are represented by Messrs. William Wesley & Son in London, Mr. Joseph von Körösy in Budapest, and Mr. Karl W. Hiersemann in Leipzig.

To those efficient representatives who aid the Institution in promoting the interests of the Exchange Service, both at home and abroad, and to Mr. Charles A. King, deputy collector of the port of New York, grateful acknowledgments are extended.

Respectfully submitted.

F. W. Hodge, *Acting Curator*

Mr. S. P. Langley,
Secretary Smithsonian Institution.

Appendix IV.

REPORT OF THE SUPERINTENDENT OF THE NATIONAL ZOOLOGICAL PARK.

Sir: I have the honor to submit the following report relating to the condition and operation of the National Zoological Park for the fiscal year ending June 30, 1905.

New house for mammals.—The principal work that has been prosecuted during the year for the advancement of the park has been that upon the new house for mammals. The structural ironwork was completed about December 1, 1904, and the tile roof was finished about May 1, 1905. This roof was ornamented by terra-cotta finials after models designed by Mrs. Kemeys. A large conduit for heating and ventilating purposes was constructed under the long axis of the building. The amount expended from the appropriation for the year will reach about $10,000. As the building is situated near the edge of a steep declivity, a heavy fill of earth supported by a retaining wall will be required on the eastern side in order to accommodate the necessary cages and walks. The plastering of this building, the interior and exterior cages, and the woodwork still remain to be done. It is hoped to occupy the building during the coming winter. Considerable delays occur from the difficulty of getting suitable mechanics for the work.

Temporary bird house.—To accommodate the birds kept during the summer in the large flying cage, as well as those received from the St. Louis Exposition, two additions were made to this building. A large indoor cage was fitted up for quail, thrushes, cardinals, etc., and another for finches and other small species, the latter communicating with an outdoor cage. Yards were constructed for the north African and Somali ostriches received from the President, and concrete floors were constructed for several of the larger indoor cages. The total cost of the alterations and extensions was about $1,200.

Carnivora house.—A new boiler for the heating apparatus was put in with satisfactory results. Considerable repairs were made to the metal roof, and the ironwork of the outside cages was thoroughly cleaned and repainted, all at a cost of about $800.

Temporary bear cages.—As funds were wanting for the construction of the permanent dens designed for the collection of bears, the small cages in which those animals are now confined were rearranged so as to give better facilities for drainage. Drains were laid, gutters constructed, and screens planted.

Inclosures for burrowing rodents.—The inclosures heretofore used for this purpose at the park have hitherto not been satisfactory, being badly located and permitting the escape of the animals. Two new inclosures that have proved very satisfactory have been made during the year. One of these, for prairie dogs, was formed by excavating the earth to a depth of 4½ feet, paving and grouting the bottom, and then filling in with gravelly earth. Another, for woodchucks, was not excavated so deeply and was closed at the bottom with telford pavement. The cost of the two inclosures was about $500.

Repairs to inclosures.—Most of the inclosures in the park are made by wire fencing, which has now been in use from five to eight years. In the course of

this time the wire has become seriously weakened by rust in spite of all efforts made for its preservation. A general reconstruction of the fences and paddocks will soon be necessary. During the year considerable repairs have been given to the fences inclosing the deer and the yak, and an additional inclosure and shelter has been made for deer.

Public comfort rooms.—The park is still deficient in suitable public comfort rooms for the accommodation of the public, especially for women and children, and this is especially felt on holidays, when the park is crowded. On Easter Monday thousands of children, with their parents and nurses, remain at the park nearly all day, and the accommodations are wholly insufficient. During the past year the rooms for women have been more than doubled, but they are still too small. A building is badly needed in which a public comfort room and restaurant could be combined.

Seats and benches.—During the past year a special clause for the purchase of seats was inserted in the act making general appropriations for the park. One hundred and sixty movable seats and 30 stationary benches were made and distributed throughout the park at points where they may be convenient for the public.

Coniferous trees.—The park received during the year an important gift of coniferous trees from Mr. Lowell M. Palmer, of Stamford, Conn. These comprise some thousands of specimens of different species. They will be planted in appropriate situations, and it is believed that they will eventually greatly add to the natural beauty of the park.

New survey and map.—The map which was prepared early in the history of the park has gradually become almost useless because of the numerous alterations that have been made. More accurate and abundant detail was also required in order that work might be always effectively planned. For this reason a new survey was made and a map prepared of the most important part of the park, covering about 40 acres. This map shows all trees, shrubbery, water and sewer pipes, and every detail of configuration practicable to express on its scale, which is 50 feet to the inch. Such a survey should be extended to the entire park.

Important accessions.—The following animals were received by gift:

From the President: One zebra, 1 lion, 2 gelada baboons, 1 north African ostrich, 1 Somali ostrich (from the King of Abyssinia), 1 female jaguar (from E. H. Plumacher, American consul at Maracaibo, Venezuela), also several small mammals, an eagle, etc.

From E. H. Plumacher, American consul, Maracaibo, Venezuela: Twenty-two specimens, including a young jaguar, 2 ocelots, 2 monkeys, 2 rough foxes, several parrots, etc.

From the Hon. H. G. Squiers, envoy extraordinary and minister plenipotentiary to Cuba: Eight specimens, including 3 Cuban deer and a hawk-bill turtle.

From Admiral Robley D. Evans, U. S. Navy: One Philippine deer.

There were procured for the park by Dr. F. W. Goding, American consul at Newcastle, New South Wales: Fifteen specimens, including 3 kangaroos, 1 female Tasmanian devil (to complete pair), 1 male Tasmanian wolf (to complete pair), 2 brush turkeys, 2 Australian cranes, and some smaller birds.

From J. N. Ruffin, American consul at Asuncion, Paraguay: One young jaguar, 2 capybaras, 2 coypus, and a king vulture.

By exchange there were received from New York Zoological Park: One llama, 1 mandrill baboon, 1 hornbill, 2 crowned cranes.

From the Zoological Garden at Buenos Ayres, Argentine Republic: One pair guanacos, 1 pair peccaries, 1 hairy armadillo, 1 female rhea (to complete pair), 1 pair upland geese, 1 crested screamer, 2 rufous tinamou.

NORTH AFRICAN OSTRICH PRESENTED TO THE PRESIDENT BY THE KING OF ABYSSINIA.

It has been found extremely difficult to make satisfactory arrangements for transportation from distant South American ports. The steamship companies refuse to receive animals without prepayment of transportation charges, which in the case of the United States Government is impracticable. Certain shipments of animals from Buenos Ayres are now waiting until some satisfactory adjustment can be made.

Through exchange with the New Zealand government (arranged by the President and mentioned in 1904 report) 8 roe deer were received. Ten elk, a number of birds, and several small mammals were delivered to the representatives of the New Zealand government in February and are understood to have reached their destination safely. The elk were desired for propagating purposes.

Births.—The births, 134 in number, included 1 American bison, 7 elk, 4 mule deer, 2 Columbian black-tailed deer, 3 Virginia deer, 2 fallow deer, 2 Barbary sheep, 1 Brazilian tapir, 23 blue foxes, 7 dingo, 9 gray wolves, several kangaroos, various rodents, etc.; also about 30 young of night heron and other birds which nested in the flying cage. The wild turkeys which were hatched in the spring of 1904 have run at large, and 6, together with the hen, still remain in the park.

Deaths.—Gastro-intestinal troubles was the chief cause of death of animals and included 2 young jaguars and several other cats, 2 Tasmanian zebra wolves, a Rocky Mountain sheep, a cassowary, several flamingos, and various other birds and small mammals. A number of blue foxes were lost from uncinaria and two from ascaris canis.

Deaths from tuberculosis, though less in number, included more large animals, among those lost being 1 bison cow, 1 nilghai, 1 red deer, 7 roe deer, 2 elk, and 4 monkeys. The majority of these animals had recently come into the collection and were undoubtedly affected with the disease when received. Three monkeys were lost from osteomalacia, or "cage paralysis," and a tinamou from pulmonary aspergillosis.

Two elk and 1 prong-horn antelope were lost from accident, due in the latter case to fright.

Autopsies were made as heretofore by the pathologists of the Bureau of Animal Industry, either at the park, in the case of large animals, or at the laboratory of the Bureau in the case of the smaller kinds.

Readjustment of boundaries.—An item was again submitted in the estimates for $60,000 to purchase the land between the park and the new highways established along the eastern and western sides of the park. (Public Act, April 28, 1904, "For the opening of connecting highways on the east and west sides of the Zoological Park, District of Columbia.") No action was taken by Congress.

Exhibit at the Louisiana Purchase Exposition.—This was successfully maintained throughout the season with comparatively little loss. Two keepers were employed during the summer and autumn. The exhibit closed about the middle of November on account of cold weather, the birds being removed and transferred to the National Zoological Park. The cage was purchased by the city of St. Louis at its appraised value.

Personnel.—The fixed force of the park numbers about 82 persons, of whom 8 are assigned to the administration, 29 to the care of animals, 20 to the mechanical department, 18 to the care of grounds, and 7 to the watch. Considerable difficulty has been found in obtaining suitable men for positions of keepers of animals. To be effective in this duty it is necessary to be quick, active, always alert, neither timorous nor venturesome, and to have a natural aptitude for

cleanliness. These are qualities that are considerably beyond what is required of a common laborer.

The keepers are divided into three classes receiving compensation as follows:

	Per month.
First class	$65.00
Second class	62.50
Third class	60.00

These men allege that their service is extra hazardous, that they are usually required to work on Sundays and holidays, and that since the cost of living has advanced considerably of recent years some advance should be made in their wages.

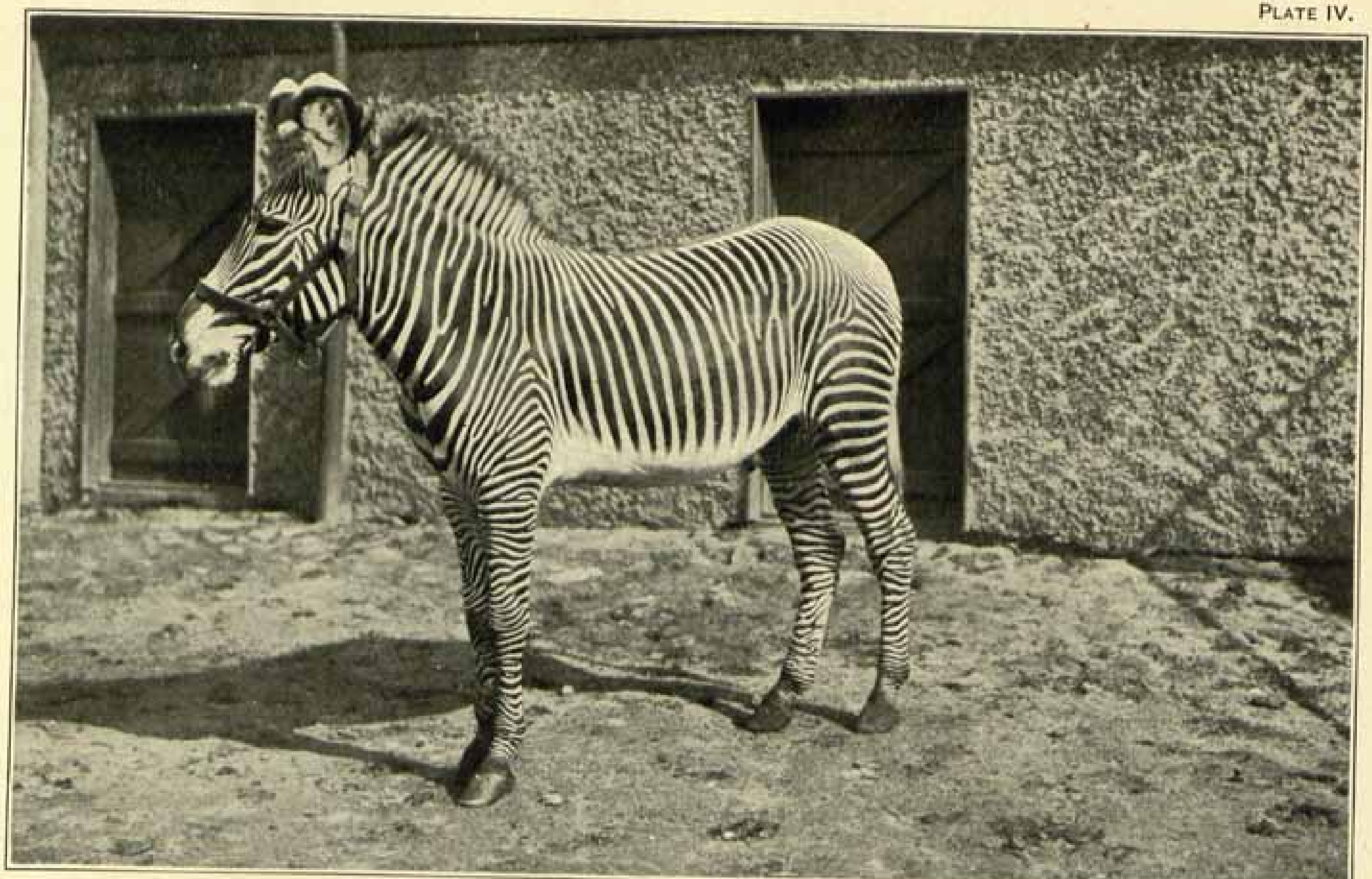
Hospital and laboratory.—At present the park has no adequate provision for the care of sick animals nor for the quarantining of those believed to be affected with contagious or infectious diseases. When ill the animals remain in the exhibition cages, their sufferings being displayed to the public, and enhanced by the disturbance which necessarily goes on about them, or, if removed from their cages, they are placed in unsuitable quarters where they are subject to annoyance and far from comfortable. Several cases of contagious disease have been rapidly propagated to several animals for want of means of promptly isolating the first suspected case. There is need for a suitable building placed in a secluded part of the grounds where animals can be properly isolated and treated.

Connected with this there should be a laboratory in which proper examination can be made of the pathological and anatomical material that may come to hand. But very little is known concerning the diseases that affect wild animals and the parasites that associate themselves with them. An extension of our knowledge in this direction would undoubtedly be of benefit to those who are studying the diseases of man.

In other countries the most significant scientific function of collections of living animals has been the advancement of knowledge with regard to the structure, habits, and activities of animals. Nearly all such knowledge has been derived from zoological collections of a character similar to that of the National Zoological Park. For example, in the Jardin des Plantes at Paris, investigations have been carried on since the middle of the eighteenth century by men who achieved, in this way, a world-wide fame, such as Duverney, Daubenton, Buffon, Cuvier, Geoffroy St. Hilaire, and Milne Edwards; in the garden of the Zoological Society of London worked Owen, Flower, Huxley, Sclater, Beddard, and many others; the garden at Berlin afforded Hartmann material for his work on anthropoid apes, and it was at the Amsterdam garden that Fürbringer was able to prepare his monumental work on the structure of birds. The collections of the National Zoological Park should be utilized in a similar way.

It is thought that a modest hospital and laboratory, similar to the one recently established at the zoological garden in Philadelphia, can be built and equipped at a cost of about $8,000. At the New York Zoological Park an institution of this kind is about to be erected which will probably cost considerably more.

Roads and paths.—The park is much frequented by carriages. Lying, as it does, along the valley of Rock Creek, it affords the most convenient and pleasant access to the Rock Creek Park that lies north of it, and the main driveway in that park communicates directly with the principal road in the National Zoological Park. On this account it is of especial advantage to the public that the roadways in the National Zoological Park should always be in good con-



GREVY'S ZEBRA PRESENTED TO THE PRESIDENT BY THE KING OF ABYSSINIA.

dition. This is not easy, as the descent into the valley of the creek is so abrupt that the surface of the roads and walks is washed away at every heavy rain. Considerable damage of this kind is done every year, and this entails a constant expense for the repair of the roads and walks. Some of the walks on the steeper slopes should be laid in concrete, which, although more expensive, would be cheaper in the end.

The portion of the park about the Quarry road entrance is in very bad condition, owing to the fact that the roads and grades exterior to the park have been recently changed and that no permanent improvements can be made within the park until the exterior changes are completed. It is hoped that sufficient funds may be appropriated to permit the park to take up the work effectively and place all the roads and walks in a suitable condition.

Shade trees and forestry.—Owing to the pressure of other matters, but little attention has been paid to the natural forest in the park. This should, however, be carefully gone over and properly thinned and preserved, as it is one of the principal attractions sought by the public. The trees planted for the shade of the walks and seats are not at present sufficient, and considerable additional planting should be done. It is highly desirable that this should be accomplished as soon as possible, as the trees would increase in beauty and size year by year.

Schools, etc., visiting the park.—Since October 15, 1904, a record has been kept of the various schools and other organizations visiting the park. Up to June 30, 1905, there were 65 classes from normal and other schools, including 9 from out of town, with 1,551 pupils; 7 classes from Sunday schools, including 2 from out of town, with 481 pupils; and 20 miscellaneous organizations, including 4 from out of town, with 595 persons.

Animals in the collection.

	Indigenous.	Foreign.	Domesticated.	Total.
Mammals	321	173	68	562
Birds	366	218	52	636
Reptiles	95	14		109
Total	782	405	120	1,307

Accessions during the year.

Presented	90
Purchased and collected	223
Lent	6
Received in exchange	37
Born in National Zoological Park	134
Received from exhibit at Louisiana Purchase Exposition	128

Cost for purchase, collection, and transportation of above, $3,100.

Animals presented during the fiscal year ending June 30, 1905.

Name.	Donor.	Number.
Rhesus monkey	Miss Justine Ingersoll, New Haven, Conn	3
Pig-tailed monkey	do	1
Gelada baboon	The President	2
Spider monkey	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	2
Capuchin	do	1
Lion	The President	1
Cougar	F. C. Hill, Cananea, Mexico	1
Jaguar	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	2
Ocelot	do	2
Spotted lynx	Sam Mustain, Carbo, Mexico	1
Rough fox	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	2
Kinkajou	Dr. David T. Day, Washington, D. C	1
Gray coati-mundi	George P. Gall, Washington, D. C	1
Raccoon	The President	2
Do	T. W. Edwards, Leesburg, Va	1
Do	Mrs. C. J. Wilcoxen, Frederick, Md	1
Do	J. D. J. O'Connor, Washington, D. C	1
Harbor seal	Bureau of Fisheries exhibit at the Louisiana Purchase Exposition.	2
Somali zebra	The President	1
Philippine deer	Rear-Admiral R. D. Evans, U. S. Navy	1
Cuban deer	Hon. H. G. Squiers, envoy extraordinary and minister plenipotentiary to Cuba, Habana, Cuba.	3
Common goat	Mrs. Theodore Roosevelt, the White House	1
Siberian hamster	Mrs. E. N. Fell, Narcoossee, Fla	1
Hutia-conga	Hon. H. G. Squiers, envoy extraordinary and minister plenipotentiary to Cuba, Habana, Cuba.	2
Common opossum	The President	2
Canary	Miss Emma Cook, Washington, D. C	1
Albino crow	Prof. H. A. Surface, Harrisburg, Pa	1
Keel-billed toucan	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	1
Yellow-shouldered amazon	do	2
Blue-fronted amazon	Samuel Ross, Washington, D. C	1
Sulphur-crested cockatoo	F. S. Tyler, Washington, D. C	1
Barn owl	E. S. Schmid, Washington, D. C	1
Do	George R. Moberly, Frederick, Md	1
Barred owl	Adam S. Richter, Accident, Md	2
Do	No. 6 Engine Co., Washington, D. C	1
Screech owl	Prof. H. A. Surface, Harrisburg, Pa	1
Golden eagle	The President	1
Sparrow hawk	Miss Beryl Macauley, Washington, D. C	1
Venezuelan hawk	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	2
Red-tailed hawk	Mr. Wehrle, Indiana, Pa	1
Black vulture	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	1
Daubenton's curassow	do	3
Jungle fowl	N. R. Wood, Washington, D. C	2
European quail	Dr. R. A. Ralph, Washington, D. C	2
Little blue heron	Nathan Dronenburg, Washington, D. C	1
North African ostrich	The President	1
Somali ostrich	do	1

Animals presented during the fiscal year ending June 30, 1905—Continued.

Name.	Donor.	Number.
Alligator	G. H. Howard, Washington, D. C	1
Do	Mrs. McCallan, Washington, D. C	5
Mexican tortoise	E. O. Mathews, Parral, Mexico	2
Gopher turtle	Dr. A. K. Fisher, Washington, D. C	1
Hawksbill turtle	Hon. H. G. Squiers, envoy extraordinary and minister plenipotentiary to Cuba, Habana, Cuba.	1
Iguana	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	2
Comb lizard	Hon. H. G. Squiers, envoy extraordinary and minister plenipotentiary to Cuba, Habana, Cuba.	1
Cuban lizard	do	1
Banded rattlesnake	Wm. H. Benton, Washington, D. C	1
Common boa	E. H. Plumacher, United States consul, Maracaibo, Venezuela.	3
Cuban tree boa	Hon. H. G. Squiers, envoy extraordinary and minister plenipotentiary to Cuba, Habana, Cuba.	1
Bull snake	Jas. Fullerton, Red Lodge, Mont	1
Black snake	do	1
Do	D. B. Wheeler, Washington, D. C	1
Do	C. H. Roeder, Sligo, Md	1

SUMMARY.

	Number
Animals on hand July 1, 1904	1,111
Accessions during the year	618
Total	1,729
Deduct loss (by exchange, death, and returning of animals)	422
On hand June 30, 1905	1,307

Respectfully submitted.

FRANK BAKER, *Superintendent.*

Mr. S. P. LANGLEY,
Secretary Smithsonian Institution.

Appendix V.

REPORT OF THE OPERATIONS OF THE ASTROPHYSICAL OBSERVATORY FOR THE YEAR ENDING JUNE 30, 1905.

Sir: The equipment of the Astrophysical Observatory is now valued as follows:

Buildings	$7,400
Apparatus	45,300
Library and records	7,200

During the year three wooden shelters, covering, respectively, the cœlostat, the long focus concave mirror, and the bolographic outfit for observing the solar image, have been erected at a cost of $1,135. This item is chargeable to the appropriation for the fiscal year ending June 30, 1904. The fence around the Observatory lot has been renewed at a cost of $554. By permission of the park authorities the Observatory inclosure was at the same time enlarged on the east and south, and now contains 15,300 square feet.

Apparatus chiefly for use in a proposed expedition to a high altitude observing station has been procured at a cost of $3,862. Of this sum, $2,527 is chargeable to the appropriation for the fiscal year ending June 30, 1904. Usual periodicals have been continued, a few books of reference have been purchased, and about 118 volumes have been collated and bound, at a total cost of $369.

No losses of property beyond usual wear and tear have occurred during the year.

Changes in personnel.—In the latter half of 1904 Dr. S. A. Mitchell was employed three months as temporary assistant on stellar radiation experiments.

Richard Norris resigned March 31, 1905.

By request of the Chief of the Weather Bureau Mr. H. H. Kimball was assigned to the Observatory temporarily for a period beginning May 1, 1905, in order that he might learn the methods of bolographic observation employed here.

Mr. L. R. Ingersoll was engaged for three months, beginning May 10, 1905, as temporary assistant for the Mount Wilson expedition.

Joseph Dwyer, messenger, was engaged April 1, 1905.

WORK OF THE OBSERVATORY.

For convenience I describe the work of the Observatory under the following headings:

(1) Observations at Washington on the variability of the sun.
(2) Miscellaneous work.
(3) Expedition to Mount Wilson in California.

(1) OBSERVATIONS AT WASHINGTON ON THE VARIABILITY OF THE SUN.

As indicated in your paper, "On a possible variation of the solar radiation,"[a] and summarized in my last year's report, our observations of several years, but especially of the year 1903, have tended to produce the belief that the total radiation of the sun may vary in comparatively brief periods, these variations of solar radiation being irregular in period, but tolerably frequent

[a] Astrophysical Journal, June, 1904, and London, Edinburg, and Dublin Philosophical Magazine, July, 1904.

and large enough to produce considerable changes of the earth's mean temperature.

During the past year the work of the Observatory has been chiefly directed toward testing the supposed variability of the sun and increasing our knowledge of it. As I have said in my last report, this investigation has three main branches as follows:

First. The determination of the intensity and variation of the total solar radiation reaching the outer limit of our atmosphere. Second, the examination of the distribution of solar radiation over the sun's disk for the purpose of detecting changes of absorption in the solar envelope. Third, the reduction of temperature measurements from numerous meteorological stations to note departures of the temperature of the earth from its mean.

General view of the results thus far obtained since January, 1902.

Before reporting fully this year's work I give in the accompanying chart, Plate V, a general view of the results of the last two and a half years touching this question. Three series of observations are represented in the chart, namely:

A. Average departures from mean temperature for 89 stations distributed over the North Temperate Zone, represented by the full line at the top of the diagram.

B. The transmission of the solar envelope for radiations of wave length 0.50μ[a] (green), as computed from spectrobolometric observations of the sun's disk at Washington, represented by the line at the middle of the diagram.

C. The solar radiation outside the earth's atmosphere as computed from spectrobolometric observations at Washington, represented by the lower line of the diagram.

As the observations of type B and earlier ones of type C are frequently separated by long intervals of time, the lines connecting the points should not be interpreted as necessarily indicating the intervening values of the quantity observed.

Observations of the solar constant taken in Washington are seldom of a satisfactory character, owing to the scarcity of days when uniform transparency of the atmosphere persists for the several hours required for the determinations. Accordingly only a few of the observations of type C are entitled to great weight, and these are designated in the diagram by the letter G to denote it. Observations of good character, but less satisfactory than these first, are designated by M, denoting medium weight. A still less perfect class, to which, unfortunately, most of the observations of 1904 and 1905 belong, is designated by the letter L, signifying of little weight. Some observations still less satisfactory than these I have omitted from the diagram as deserving no weight at all.

Considering now the diagram it will be seen that early in the year 1903 there was a long-continued period of abnormally high terrestrial temperature, and this was followed by a still longer period of abnormally low temperature. Corresponding well with this state of affairs are the observations of total solar radiation, and these observations are fortunately almost all of great, or at least medium, weight. In September, 1903, a single observation of the transmission of the solar envelope was made, and this, compared with others of more recent date, is low, indicating that diminished transparency of the solar envelope was the probable reason for the small amount of radiation and low temperature observed at the same time.

In the year 1904 there was no long-continued period of abnormal temperature

[a] Results of a similar trend are obtained for all wave lengths, and this wave length is chosen merely in illustration.

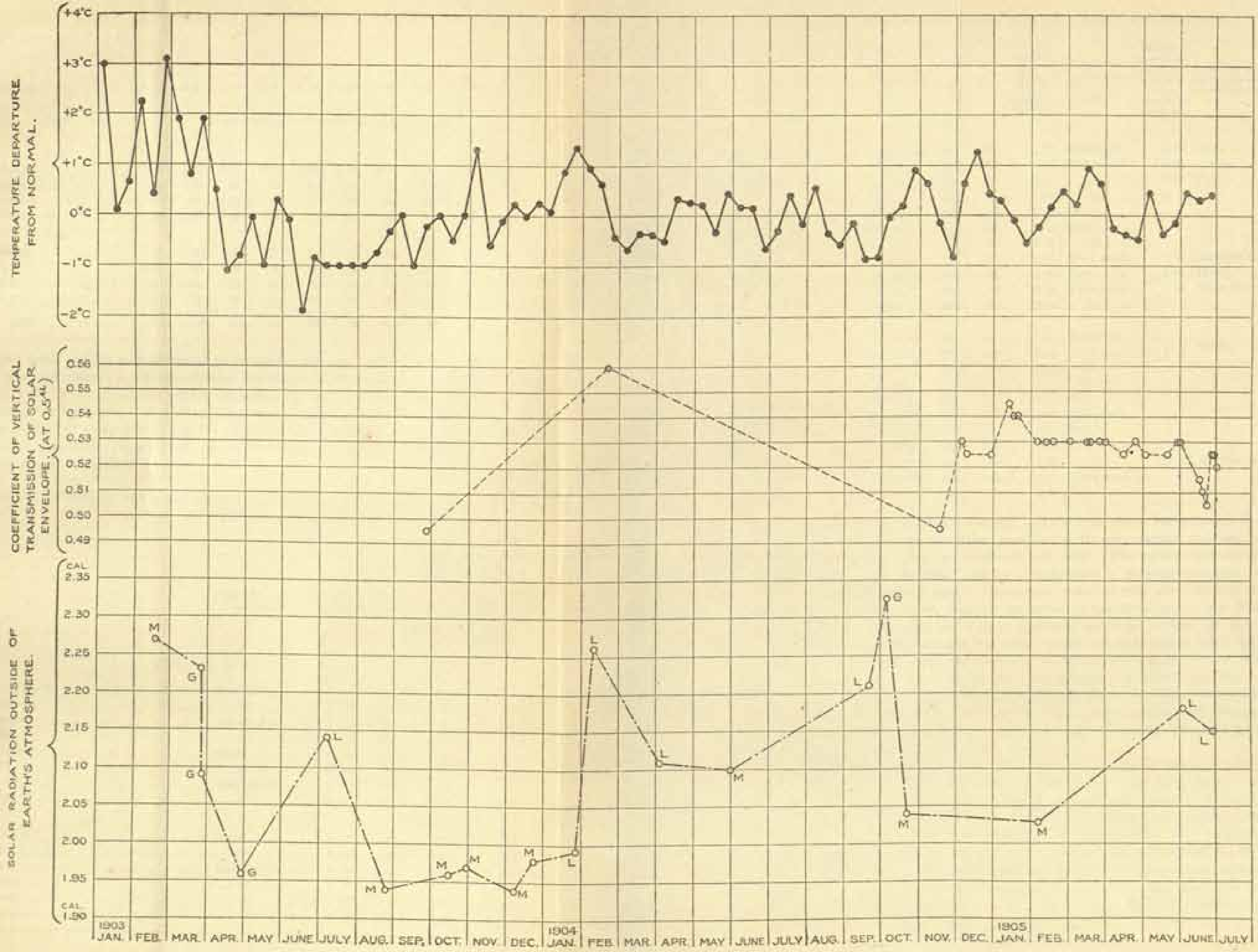
departure comparable with those noted in 1903. So far as there were notable variations from the mean in the temperature of the North Temperate Zone, these occurred in January and February, and in October and November of 1904. On the whole, these departures are confirmatory of the indications of the spectro-bolometric determinations of total radiation for the same periods, but these results, owing to scarcity of good weather, are lamentably inadequate. Still, a medium-weight observation of June indicates average temperature and is followed by it; a first-class observation of October 5 indicates high temperature and is followed by it, and a medium-weight observation of October 22, indicating low temperature, is followed by it. Prior to December there are only two observations of solar transmission, of which the first, a high value, comes just at the end of a period of high temperature, while the second, a low value, in November, comes just preceding a short period of low temperature. In December higher values are found and higher temperatures follow.

The temperature departures of the first half of 1905 also present no such favorable opportunity for comparison with solar radiation phenomena as was presented in 1903. The data on total solar radiation have not been fully reduced as yet, so that they appear still more meager than in former years, and more so than they will after all returns are in. But the weather seldom permitted satisfactory solar constant determinations at Washington in the first half of 1905. Those observations here given fall in fairly well, as will be seen, with the record of temperature departures. Observations of the solar transmission have been made very frequently since December, 1904, and are as a rule nearly average values and indicative of average temperatures, and thus in accord with the facts for the North Temperate Zone. Increasing values in December and January and diminishing ones in February and in April and May have their counterparts in the temperature curve for the North Temperate Zone. The temporarily lower values in June find no counterpart in the temperatures of the North Temperate Zone, but a fall of temperature may possibly be shown early in July.

Taking all the facts together we find high values of solar radiation and solar transmission preceding and accompanying high temperatures of the North Temperate Zone; low values of solar radiation and solar transmission preceding and accompanying low temperatures of the North Temperate Zone, and intermediate values of these solar phenomena accompanying intermediate terrestrial temperatures. The evidence at hand is still too fragmentary to produce full conviction, but subject to later confirmation or rejection, as further work shall prove, the results obtained thus far strongly indicate that the transparency of the solar envelope varies at irregular intervals, with consequent fluctuations of the solar radiation transmitted to the earth, and that this in turn affects the mean temperature of the earth.

Observations of 1904–5.

(a) *Solar constant work.*—Determinations of the radiation reaching the earth's surface, both in toto and for separate wave lengths, have been made at all times when conditions permitted, and have been reduced as in former years to give the transmission of our atmosphere, and the total radiation reaching its outer limit. As above stated the number of days when the sky has continued satisfactorily uniform for this purpose have been few, and besides owing to the press of observing and computing work it has not been possible to compute all the results as yet, so that on both accounts the tables which follow are more than usually meager. Table 1 gives in continuation of similar tables in preceding reports the transmission of the atmosphere at various wave lengths for vertical rays.



Solar Radiation and Terrestrial Temperature.

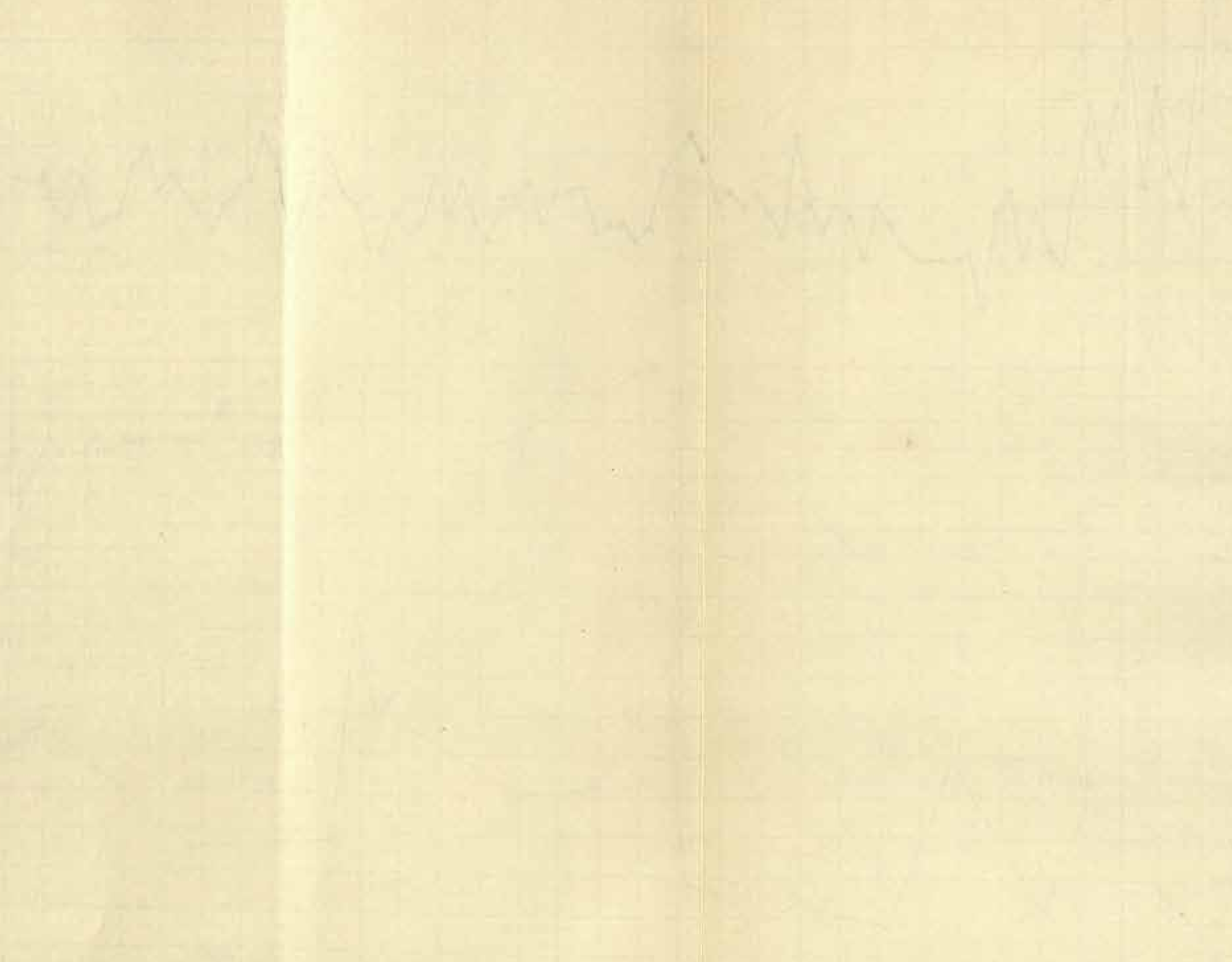


TABLE 1.—*Coefficients of atmospheric transmission for radiation from zenith sun.*

Wave length	μ 0.40	μ 0.45	μ 0.50	μ 0.60	μ 0.70	μ 0.80	μ 0.90	μ 1.00	μ 1.20	μ 1.60
Date.	Transmission coefficients for unit air mass.									
1904.										
September 22	0.55	0.65	0.72	0.81	0.86	0.88	0.89	0.90	0.90	0.90
October 5	.48	.58	.65	.74	.80	.84	.86	.87	.89	.90
October 21	.60	.72	.78	.86	.90	.93	.94	.95	.97	.98
November 16	.54	.62	.65	.74	.85	.88	.90	.90	.91	.91
1905.										
February 7	.53	.63	.68	.77	.81	.85	.87	.88	.91	.92
June 3	.45	.55	.63	.74	.80	.84	.87	.89	.92	.96
June 22	.48	.54	.62	.70	.76	.82	.84	.86	.89	.91
June 27	.45	.55	.63	.74	.80	.84	.87	.89	.92	.96
Mean	.510	.605	.670	.762	.822	.860	.880	.892	.914	.930

The mean results will be found to lie extremely near the corresponding ones for the year 1903–4, so that no further discussion of them seems necessary.

In Table 2 are given the values computed for the solar constant of radiation outside our atmosphere, in continuation of the series published in former years. The method of computation and the assumptions on which it is based have been given in preceding reports and are substantially those employed by you many years ago at Allegheny.

TABLE 2.—*Values of the solar constant of radiation outside the earth's atmosphere from Washington observations.*

Date.	Character of observation.	Hour angle west.	Air mass.	Solar radiation per square centimeter per minute— At earth's surface.	Solar radiation per square centimeter per minute— Outside atmosphere corrected to mean solar distance.
1904.		*h. m.*		*Cal.*	*Cal.*
September 22	Indifferent	3 17	1.97	1.25	2.29
Do	do	4 22	3.09	.99	2.22
October 5	Excellent	2 21	1.72	1.14	2.31
Do	do	4 15	3.37	.74	2.33
October 21	Good	1 15	1.65	1.42	2.03
Do	do	2 12	1.91	1.39	2.05
November 16	Indifferent	2 28	2.59	1.03	1.89
Do	do	2 54	3.00	.92	1.99
1905.					
February 7	Good	1 2	1.78	1.30	2.03
Do	do	2 51	2.59	1.09	2.04
June 3	Indifferent	2 36	1.25	1.32	2.20
Do	do	4 33	1.96	1.07	2.17
June 27	do	1 58	1.15	1.35	2.18
Do	do	3 40	1.52	1.19	2.15

The rating of the character of the observation is made chiefly by inspection of the logarithmic plots used in determining the atmospheric transmission, similar to those published facing page 80 of your report for the year ending June 30, 1903. On an excellent day the observations thus plotted, like those just referred to, lie close to representative straight lines, but such days are unfortunately very rare in Washington, and especially within the last two years, owing in part to building and other operations producing smoky and non-uniform atmospheric conditions. The bearing of the results given in Table 2 on the question of the variability of the sun has already been given.

Before leaving the subject of solar constant observations it may well be remarked that Mr. Fowle has published within the year a valuable paper giving a comparison between the solar constant values deduced by the method of homogeneous rays and those deduced for the same days by the old method of high and low sun observations of the total radiation of the sun by the actinometer alone.[a] This old method, the method of Pouillet, gives necessarily too low results, as you long ago demonstrated.[b]

What is valuable in Mr. Fowle's paper is that he shows that the defect is almost constant at Washington, no matter what the time of the year, the transparency of the air, or the humidity, provided the extrapolation is made with moderate solar zenith distances. Thus if observations be made in Washington with the actinometer alone and extrapolated by the aid of a logarithmic plot to the limits of the atmosphere, and a correction of 14 per cent is then added, the result will be practically the same as if the spectrobolometric method had been used. If additional measurements should confirm this result (that a constant difference between the two methods holds here and at other localities), then the process of detecting variations in solar radiation outside our atmosphere would be much easier, for it could be made to depend on actinometer measures alone, and, indeed, old series of observations made years ago could be utilized.

I give in illustration the following table, taken in part from Mr. Fowle's paper above cited, showing how closely solar constant values deduced from pyrheliometer measures alone, by the application of the 14 per cent correction, agree with values deduced when possible from spectrobolometric work of the same days.

TABLE 2a.—*Solar constant values from pyrheliometry.*

Date.	Range of air masses.	Log. a	a	Radiation computed from pyrheliometry.	Grade of pyrheliometer observations.	Radiation computed by spectro-bolometric method.	Grade of spectro-bolometric observations.
1902.							
October 9	1.5-3.0	0.113	0.771	2.18	Very good	2.19	Fair.
1903.							
February 19	1.8-2.9	.114	.769	2.25	do	2.27	Very good.
March 25	1.4-2.6	.148	.711	2.23	Excellent	2.23	Excellent.
March 26	1.3-2.3	.133	.736	2.07	do	2.09	Do.
April 17	1.2-1.9	.126	.748	2.17	Very good	2.18	Passable.
April 29	1.1-1.6	.170	.676	1.99	Bad	1.98	Very good.
July 7	1.6-1.5	.177	.665	2.36	Short, good	2.14	Poor.
October 14	1.6-3.0	.107	.780	2.13	Very good	1.96	Very good.
December 7	2.2-3.7	.085	.822	1.93	Excellent	1.94	Passable.
December 23	2.2-3.1	.077	.838	1.99	Doubtful	1.99	Do.

[a] F. E. Fowle, Smithsonian Miscellaneous Collections, vol. 47, p. 399, 1905.
[b] S. P. Langley, American Journal of Science (3), XXVIII, p. 163, 1884.

TABLE 2a.—*Solar constant values from pyrheliometry*—Continued.

Date.	Range of air masses.	Log. a	a	Radiation computed from pyrheliometry.	Grade of pyrheliometry observations.	Radiation computed by spectro-bolometric method.	Grade of spectro-bolometric observations.
1904.							
January 27	1.9-4.0	.090	.813	2.02	Excellent	2.02	Fair.
February 11	1.7-2.9	.113	.771	2.27	Very good	2.26	Do.
May 28	1.1-1.9	.121	.757	2.24	do	2.09	Poor.
July 8	1.2-1.7	.158	.695	2.05	do		
September 15	1.4-2.0	.120	.759	2.25	Good		
September 22	1.4-3.0	.099	.796	2.22	Poor		
October 4	1.7-3.2	.126	.748	2.17	do		
October 5	1.5-2.7	.145	.716	2.30	Very good	2.32	Excellent.
October 21	1.6-3.0	.063	.865	2.06	Fair	2.04	Good.
November 16	2.0-3.8	.095	.803	1.95	Very good	1.98	Passable.
December 29	2.4-3.6	.068	.855	2.24	do		
1905.							
January 26	1.9-3.4	.067	.857	2.07	Excellent		
February 7	1.8-3.4	.097	.800	2.12	Very good	2.04	Good.
March 2	1.6-2.6	.088	.816	2.23	Poor		
April 19	1.2-2.0	.154	.702	2.17	Passable		
April 22	1.2-2.1	.112	.773	2.21	Fair		
May 2	1.3-2.0	.151	.706	2.18	Excellent		
May 8	1.3-2.0	.111	.774	2.09	Fair		
May 29	1.2-1.6	.105	.785	2.14	Poor		
June 3	1.1-2.2	.128	.745	2.22	do	2.18	Indifferent.
June 22	1.1-2.0	.096	.802	2.17	Very good		
June 27	1.1-1.5	.140	.724	2.28	Poor		

(b) *Transmission of the solar envelope.*—As stated above the apparatus for examining the solar image has been provided with appropriate shelters, and is now much improved over its condition last year. The great coelostat was exhibited at St. Louis in 1904, and as a substitute a smaller coelostat was arranged at the Observatory shop. The larger coelostat was not returned from St. Louis until January, 1905, and, in the press of preparation for the Mount Wilson expedition, time could not well be spared to set it up, so that the smaller instrument has served throughout the year. Many measurements, both of the distribution of radiation along the diameter of the solar disk and of its distribution in sun spots, have been made after the manner explained last year.[a] A revision has been made of all the data obtained relating to the distribution along a diameter, on the assumptions (1) that we study a phenomenon of absorption only; (2) occurring in a homogeneous medium situated outside the photosphere, and (3) extending to 21 per cent of the solar radius.

With these assumptions it appears that the form of the distribution curves as shown in Plate VIII of last year's report agree within the experimental error with that deduced from the ordinary simple exponential absorption formula. As this formula in a logarithmic form is peculiarly adapted to graphical illustrations and comparison of results, all the measurements have been reduced on the above basis and the results to be given below in Table 3 depend on it. It goes without saying that the assumptions made are not harmonious with our conceptions of the sun's absorbing envelope, and they are only made for want of better and for the sole purpose of more readily comparing the results of dif-

[a] Smithsonian Report for 1904, p. 85.

ferent days. This arbitrary method of reduction is necessary, for differences of atmospheric transparency and differences of solar distance make a direct comparison of one observational curve with another complicated and unsatisfactory.

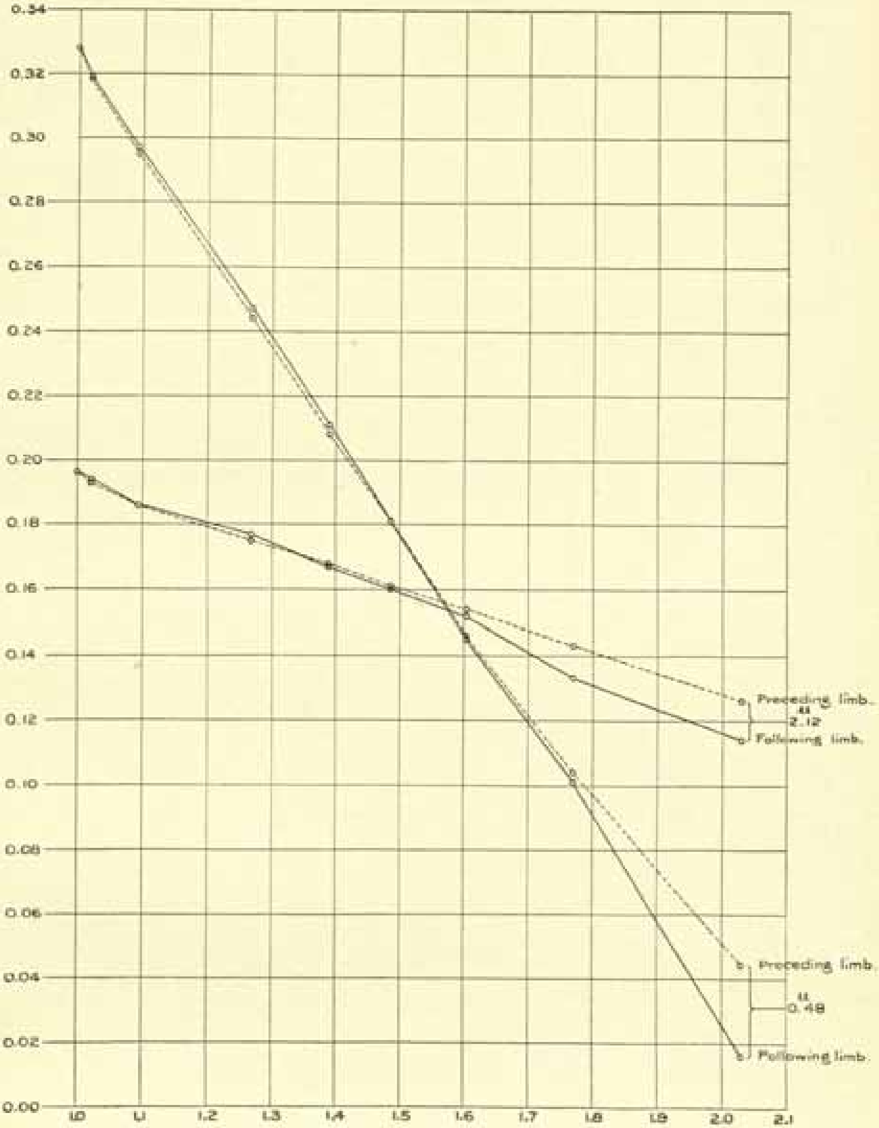
Plate VI shows two of the solar curves plotted with abscissæ as air-masses derived on the above assumptions, and ordinates as the logarithmic deflections.

The general absorption of the solar envelope appears to be like that of the earth's atmosphere, greatest at the violet end of the spectrum. This is shown, and also some of the changes which have been noted in the apparent solar transmission, in Table 3.

In this table the numbers purport to represent the percentage transmission of the solar envelope for vertical rays, on different days, and for various rays between wave lengths 0.4μ in the violet, and 2.0μ in the infra-red. The results are based on the assumptions stated above, and a considerable difference will be noted from the corresponding table of last year, owing to a change in the assumed thickness of the absorbing envelope.

TABLE 3.—*Transmission of solar envelope.*

Wave length	μ 0.40	μ 0.45	μ 0.50	μ 0.60	μ 0.70	μ 0.80	μ 0.90	μ 1.00	μ 1.20	μ 1.60	μ 2.00
Date.	Coefficients for vertical transmission.										
1903.											
September 25		0.445	0.495	0.585	0.635	0.675	0.700	0.715	0.740	0.790	0.830
1904.											
February 20		.510	.560	.640	.690	.730	.750	.770	.800	.830	(.850)
November 17		(.440)	.495	.575	.625	(.660)					
November 28						.69	.71	.73	.76	.80	.835
December 6			(.53)	.615	.665	.695					
December 8		.475	.525	.605	.660	.700	.725	.745	.770	.810	.840
December 29		.475	.525	(.600)	.655	.690					.835
1905.											
January 14			.545	.625	.680	.710	.735	.750	.775	(.805)	.840
January 17			.540	.620	.670	.705	.730	.745	.770	(.805)	.840
January 20			.540	.620	.670	.705	.730	.745	.770	(.805)	.840
February 7		.475	.530	.610	.655	.685	.710	.720			
February 14	(0.415)	.475	.530	(.610)	(.660)	.695	.720	(.740)		(.810)	.840
February 16						.695					.840
February 18	.450	.480	.530	(.610)	.665	.695	.715	(.735)			.840
March 2		.480	.530								
March 16		.480	.530	.605	.660	.690	.710	.730	.760	.795	.830
March 18		.480	.530	.605	.660	.690	.710	.730	.760	.795	.830
March 28		.480	.530	.605	.660	.690	.710	.730	.760	.795	.830
March 31		.480	.530	.605	.660	.690	.710	.730	.760	.795	.830
April 15			.525	.605	.650	.680					
April 25		.465	.530	.605	.650	.680					
May 2	.48?	.475	.525	.605	.655	.690					
May 20	.48?	.475	.525	.600	.655	.690	.710	.730	.760	.800	.830
June 8	.450	.490	.520								
June 9	.450	.490	.530	.620	.670	.710	.725	.740	.765	.810	.845
June 17		(.465)									
June 19		(.480)	.510	.590	.640	.670	.700	.720	.755	.795	.830
June 22			.505	.590	.640	.680					
June 27			.525	.585	.640						
June 28			.525								
June 29			.520	.600	.650	.685					



ABSORPTION OF SOLAR ENVELOPE.

Ordinates, logarithm of intensity of radiation along diameter of solar image.
Abscissæ, computed length of path of ray in solar envelope.

The bolometric examination of sun spots shows that they, too, exhibit much greater absorption at the violent end of the spectrum than in the infra-red. Thus, if our eye were like the bolometer, and could view sun spots by homogeneous rays of different wave lengths of the infra-red as well as violet, we should see the same spot four times as dark in violet light as when viewed by extreme infra-red rays.

In all the observations and reductions involved in the work described above Mr. Fowle has taken by far the greatest share.

The temperature data plotted in Plate V are reduced from the Internationaler Dekadenberichte, published by the Kaiserliche Marine Deutsche Seewarte. The reductions were made partly by R. Norris and partly by J. Dwyer.

(2) MISCELLANEOUS WORK.

Radiation of the stars.

Preliminary preparations were made for the detection of the radiation of the brighter stars. It was at first thought practicable to mount the bolometer in the center of the tube of the 50-centimeter diameter mirror of 1-meter focus and to point the mirror directly upon the star to be examined, but it was quickly found that the disturbances due to exposure to outside air were too great to be permissible with the refined sensitiveness of the bolometric apparatus. Afterwards the mirror and bolometer were placed within the inner chamber of the observatory, and the starlight was reflected in from a 30-inch plane mirror on the coelostat. The galvanometer employed was the one described at pages 91–92 of your report for the year ending June 30, 1902.

The sensitiveness available depends largely on reducing the damping of the needle, and a long time was spent in making the galvanometer case air-tight, so that a pressure of 1/1000 atmosphere or less could be maintained without rapid change. In this we were at length so successful that the change of pressure was hardly appreciable in several months. Great difficulty was encountered in balancing the bolometric apparatus at the high sensitiveness employed on account of small electromotive forces in the galvanometer circuit and its shunts. Thus a balance would be obtained with a certain shunt across the galvanometer, and on passing to the next shunt a very great deflection would be found, due to a new electromotive force in the new shunt circuit. At length it proved necessary to discard shunts wholly, and to employ instead a variable resistance in series with the galvanometer. Great difficulty was still experienced in balancing, but not so great as to render it impossible, as before. When once balanced the apparatus was well behaved. The sensitiveness appeared from tests on candle flames to be very much greater than that obtained by previous experimenters on stellar radiation. Unfortunately the difficulties encountered were not surmounted until early in January, and bad weather prevented a trial on the stars until more important work displaced the investigation for the present.

New apparatus.

Bolometer.—In our previous construction of bolometers we have been guided more by experience than by any theory in their design. While preparing for the research on stellar variation it seemed very desirable to determine the conditions which would insure the highest sensitiveness. Accordingly the subject was studied from the standpoint of Fourier's analytical theory of heat, and numerous experiments were made to further enlighten it. As a result a complete theory of bolometer construction was reached, and it is now possible

to know in advance how to design and construct a bolometer to give the best result under stated conditions.

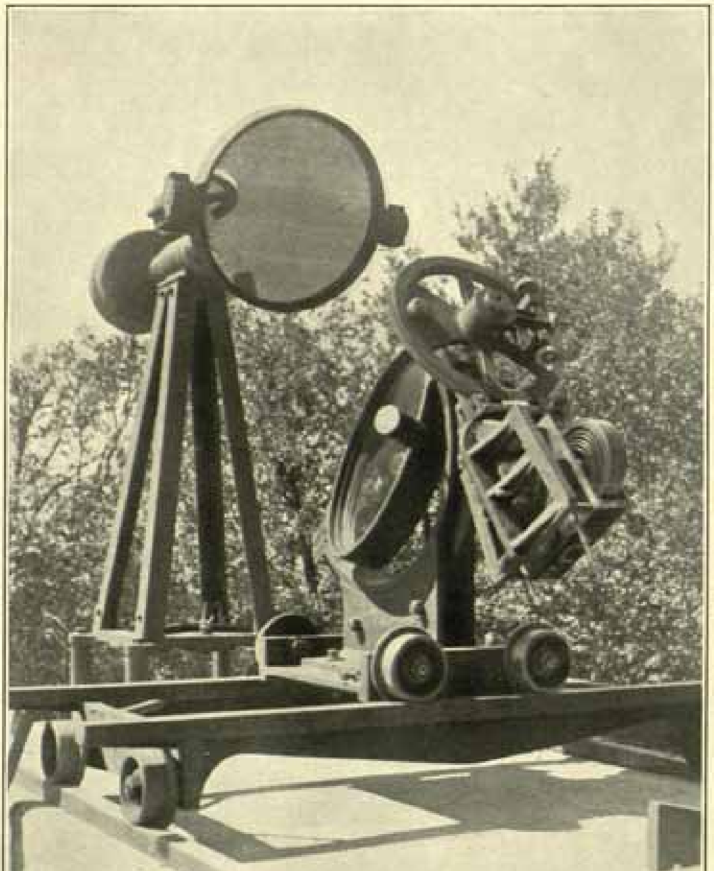
In accordance with the results thus reached, a vacuum bolometer was constructed for the observation of stellar heat which is several times as sensitive for the purpose as the best bolometer hitherto prepared here.

Cœlostat.—A new cœlostat with two 15-inch mirrors was obtained for the proposed expedition to a high-altitude station. The general design was prepared at the Observatory, and the construction was by Mr. M. E. Kahler, of Washington, excepting some work done on the clock at the Observatory shop. A photograph of the apparatus as in use at Mount Wilson is here shown (Plate VII).

Several unusual features may be noted. The rotating mirror is shown mounted on a carriage which may travel on ways either east and west or north and south, so as to be adjusted for the position of the sun at any time in the year. The carriage is of the same height as the lower base of the support of the second mirror, and the two mirrors may be interchanged if desired, so that the rotating one can be fixed in one place and the east-and-west and north-and-south motions can be made with the other. The driving clock is fastened to the support of the polar axis and designed to run equally well in any position, so that the adjustment of the axis for different latitudes can be made without altering the driving mechanism. In order to conform to the motion of the carriage, the clock is driven by springs instead of weights. At your suggestion there was introduced a driving spring, which is itself kept wound to a nearly constant tension by two larger springs. Thus the driving force is uniform though the two larger springs run down. The rate of their unwinding is governed by an escapement driven from the governor train. The governor itself is of the centrifugal type, but has springs instead of gravity as the governing force, and will thus run in any position. The accuracy of the clock is ample, so that the reflected beam from the cœlostat frequently remains constant in direction within one minute of arc for a half hour.

Standard pyrheliometer.—Mention was made in my last year's report of a new form of pyrheliometer then under construction. This instrument has been completed and forms a part of the equipment of the Mount Wilson expedition. It appears to justify all the hopes that had been connected with it. As stated last year, it receives solar rays in a hollow blackened chamber of the shape of a test tube, from which little radiation can escape by reflection, or heat by convection, owing to the deepness of the chamber and to its numerous blackened diaphragms. A current of water circulates around this chamber and takes up the heat absorbed on its walls. Platinum resistance wires serve to determine the temperature of the water before and after its passage around the chamber. Thus the sun's rays entering a known aperture produce a measurable rise of temperature in a known amount of water. A certain check is had on the accuracy of the measurement, for a coil of wire is introduced within the rear end of the chamber, and in this coil heat may be produced electrically at a known rate. This heat warms the air and indirectly reaches the walls of the chamber, and may be measured as if it were produced by radiation.

At nine recent trials made on several different days, with the instrument in different positions and with different rates of flow of the water current, the heat "found" ran between 97 per cent and 103 per cent of the heat introduced. The mean of nine trials gave 100.4 per cent "found." If, then, the electrically supplied heat is thus closely measurable, much more should that



NEW CŒLOSTAT.

of the sun be, which is absorbed at once on the walls of the chamber instead of indirectly by air convection.

The instrument is mounted equatorially and driven by clockwork, and the rate of flow of the water current, lapse of time and temperature change caused by radiation, are all recorded photographically on a moving drum. Hence a continuous automatic record of the solar radiation is produced. In use at Mount Wilson it is not easy to avoid considerable temperature change of the apparatus, and this causes a slight "drift" of the record, but not enough to prevent runs of several hours' duration without attention.

A considerable part of the apparatus for the continuous pyrheliometer was made by the International Instrument Company, of Cambridge, Mass. The more refined parts for the receipt and measurement of the radiation were constructed by Mr. Kramer at the Observatory shop. In this, and in a great amount of other work during the year, Mr. Kramer has combined skill with rare willingness and interest in a way which deserves commendation.

(3) THE EXPEDITION TO MOUNT WILSON, IN CALIFORNIA.

From the very beginning, in 1902, of experiments in Washington on the measurement of the solar constant of radiation it has been your aim to continue these measurements at a more favorable situation as regards cloudiness, and particularly as regards elevation. You long ago showed that in optical quality the lower air is far inferior to that lying above, and you have repeatedly stated your conviction that exact determinations of the absorption of the atmosphere are impossible at stations near sea level. Congress having approved of your plan to conduct these observations at high altitudes, apparatus has been collected during the past three years for an expedition to a favorable station for the measurement of the solar constant.

In the meantime the Carnegie Institution had been founded, and by invitation of one of its officers you stated, in a communication to the Hon. C. D. Walcott, dated February 28, 1902, your belief that the establishment by the Carnegie Institution of an observatory to be situated at some high and cloudless point and engaged for at least a complete sun-spot cycle in the accurate determination of the solar constant of radiation would be a worthy astronomical undertaking and one most likely, in your judgment, to yield results of value both from the standpoint of pure science and from that of practical utility to mankind.

In 1904 the Carnegie Institution began the establishment of a solar observatory on Mount Wilson, in California, under the direction of Prof. G. E. Hale, and the objects of this observatory include the measurement of solar radiation, which you had urged. Almost immediately after the installation at Mount Wilson had been begun, Professor Hale, recognizing the large share you have had from the first in promoting the establishment of such an observatory, and knowing of the preparations making at the Smithsonian Astrophysical Observatory for an expedition to a high station to observe the solar constant, invited you to send this expedition to Mount Wilson, and promised all possible cooperation during its stay, and suggested that the work would, if desirable, be taken up by the new solar observatory when the Smithsonian expedition should be withdrawn. This invitation was accepted. The equipment, consisting of a full spectro-bolographic and pyrheliometric outfit, the equal and in some respects the superior of that installed in Washington, was sent forward in April, 1905. The observers, C. G. Abbot in charge, and L. R. Ingersoll, temporary assistant, reached the ground about May 10. Two shelters for the spectro-bolometer and the continuous pyrheliometer, respectively, already framed in the valley below,

were immediately erected on Mount Wilson, and were finished, including all their piers and accessories, in about two weeks. The spectro-bolometer was completely installed and the first bolographic observations were made June 6, 1905.

In the meantime observations had been made nearly every day with the mercury pyrheliometer, and these had given promise of great transparency and uniformity of sky. From the 1st of June hardly a cloud was ever seen above the level of the horizon for many weeks. Extraordinary calmness adds to the advantages of this site. A few of the earliest bolographs were measured at once to see if all appeared to be well, and, as the measurements turned out very satisfactorily, bolographic work was continued nearly every day thereafter, leaving the reduction of the observations to a later time.

Investigations at Washington, as already reported, have given strong grounds for the conclusion that the solar radiation varies considerably and frequently in its amount. It would be most desirable if the Mount Wilson expedition could give ample opportunity to test this conclusion, but in spite of the too short time at present command it has been thought best by you to initiate it, and at the same time to study more closely the manner of the solar variability. To this end the work includes, not only solar-constant measurements, but other studies designed to add to our knowledge of the whole question.

The expedition is under the greatest obligations for the continued aid furnished by the director and staff of the Carnegie Solar Observatory. The results obtained will doubtless form a principal part of next year's report.

SUMMARY.

The principal object of the Observatory during the past year has continued to be the measurement of the solar radiation. The work of this and the two preceding years strongly supports the view that the radiation of the sun is frequently diminished and augmented for periods of a few weeks or months, in consequence of a variability of the transparency of the solar absorbing envelope, and that this variation of radiation causes and quickly produces changes of several degrees in the mean temperature of the land areas of the earth. It is hoped that the study of the solar radiation will soon prove a valuable aid in forecasting climate.

Important additions and improvements have been made in the equipment of the Observatory, both in buildings and apparatus. The new apparatus includes a standard pyrheliometer, capable of continuously registering the solar radiation and provided with means of certifying the exactness of its measures independently of the theory of the instrument.

An expedition to measure and test the variability of solar radiation has been sent to Mount Wilson, in Southern California.

Respectfuly submitted.

C. G. Abbot,
Aid Acting in Charge.

Mr. S. P. Langley,
Secretary Smithsonian Institution, Washington, D. C.

Appendix VI.

REPORT OF THE LIBRARIAN.

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, 1905:

The publications received by the Institution and recorded in the accession books of the Smithsonian deposit, Library of Congress, number as follows:

	Quarto or larger.	Octavo or smaller.	Total.
Volumes	373	1,302	1,675
Parts of volumes	15,267	8,612	23,879
Pamphlets	545	3,805	4,350
Charts			676
Total			30,580

The accession numbers run from 460377–468086.

As in the past a few of these publications were retained at the Institution for the use of the scientific staff, but the larger number have been sent direct to the Library of Congress. The entire sendings from the Institution required the use of about 274 boxes, which it is estimated contained the equivalent of 10,960 octavo volumes. This estimate does not include, however, a large number of public documents presented to the Smithsonian Institution and sent direct to the Library of Congress without recording.

At the close of the year ending June 30, 1904, there remained in the Museum library a number of the scientific series, together with books and pamphlets on special subjects, belonging to the Smithsonian deposit, to be withdrawn, checked, and sent to the Library of Congress, these publications having been held at the Museum when that Library was overcrowded in its old quarters at the Capitol. While 7,805 parts were transmitted during the past year, it has not been possible to complete the checking, owing to the fact that the time of the small force in the Smithsonian library was fully occupied with current work, but every effort will be made to finish the task before the close of the present year, when all of the series of periodicals and publications belonging to the deposit, with the exception of those in actual use, will be in the hands of the Librarian of Congress.

The libraries of the Secretary, Office, and Astrophysical Observatory have received during the year 418 volumes, pamphlets and charts, and 2,040 parts of volumes, making a total of 2,458, and a grand total, including books for the Smithsonian deposit and the Watts de Peyster collection Napoleon Bonaparte, of 35,820.

The parts of serial publications that were entered on the card catalogue numbered 26,000. One thousand seven hundred and thirty-five slips for completed volumes were made, and about 720 cards for new periodicals and annuals were added to the permanent record from the periodical recording desk.

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

Ann Arbor.
Baltimore (Johns Hopkins).
Basel.
Berlin.
Bern.
Bonn.
Breslau.
Erlangen.
Freiburg.
Giessen.
Grefswald.
Halle.
Heidelberg.
Kiel.
Lawrence (Kansas).
Marburg.
Philadelphia (University of Pennsylvania).
Rostock.
Strassburg.
Toulouse.
Manchester (England).
Zurich.

In continuing the Secretary's plan to effect new exchanges and to secure missing parts to complete sets, 1,405 letters were written, 301 new periodicals were added to the receipts, and 527 defective series were partly or entirely completed. In addition to the letters above referred to there were 175 postal cards sent asking for current numbers that failed to reach the Institution, which resulted in 103 being received.

The scientific staff and others have continued to consult the proceedings and transactions of the learned societies in the reference room, and from the reading room 21 bound volumes of periodicals were withdrawn and 4,368 scientific periodicals and magazines were borrowed for consultation.

The sectional libraries maintained in the Institution, the Secretary's library, Office library, and the Employees's library, together with those of the Astrophysical Observatory, Aerodromics, International Exchanges, and Law Reference, have been used by persons from the other scientific bureaus of the Government, as well as members of the immediate staff.

In the Secretary's and Office library 107 books were bound, and special attention was given to collating the publications in the Astrophysical Observatory, with the result that 118 completed volumes were bound at the Government bindery. At the National Zoological Park 8 volumes have been added to the library by purchase.

THE EMPLOYEE'S LIBRARY.

The popularity of the Employee's library has continued, and during the year 3,262 books were borrowed. The new books added to the library by purchase numbered 19, and 78 completed volumes of magazines were bound. The sending of about 40 of the books from this library to the National Zoological Park and 26 to the Bureau of American Ethnology each month has been continued with marked appreciation from the two bureaus.

THE WATKINS LIBRARY.

Within the last few months the trustees of the estate of the late Dr. J. Elfreth Watkins have turned over to the Smithsonian Institution his large and valuable library consisting in the main of books relating to engineering and transportation. A book plate has been provided and the books listed, and it is hoped that they may soon be available for the use of those interested in the subject to which they relate.

THE JOHN DONNELL SMITH LIBRARY.

Through the munificence of Capt. John Donnell Smith, of Baltimore, the library of the Smithsonian Institution has become enriched by his collection of botanical works, numbering about 1,600 volumes, containing books bearing upon the flora of tropical America, carefully selected and substantially and

artistically bound. This donation was made in connection with the gift to the Institution of his herbarium, and brings to the National Museum, where the library will be deposited, an unrivaled basis of equipment for the prosecution of a complete botanical exploration of Central America and a critical study of its whole flora.

WATTS DE PEYSTER COLLECTION NAPOLEON BUONAPARTE.

It is very gratifying to report the rapid increase of the Watts de Peyster Collection Napoleon Buonaparte through the continued gifts of Gen. John Watts de Peyster. The additions during the year numbered 1,775 volumes and 1,007 maps.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The Institution has continued to act as the representative in the United States for the International Catalogue of Scientific Literature, and has indexed and classified for the Central Bureau at London the scientific literature of the United States. During the past year the number of references sent to the Central Bureau at London was 24,182, an increase of nearly three thousand over the previous year, as follows:

Literature of 1901	1,619
Literature of 1902	2,780
Literature of 1903	11,143
Literature of 1904	8,640
Total	24,182

All of the first annual issue of the International Catalogue has been published, together with all of the second annual issue, excepting the volume of Zoology and five volumes of the third annual issue, namely, Mathematics, Mechanics, Physics, Astronomy, and Bacteriology.

MUSEUM LIBRARY.

In the Museum library there are now 24,170 bound volumes and 38,643 unbound papers. The additions during the year consisted of 3,573 books, 3,048 pamphlets, and 563 parts of volumes. There were catalogued 1,952 books, of which 101 belonged to the Smithsonian deposit, and 3,755 pamphlets, of which 185 belonged to the Smithsonian deposit, and 12,216 parts of periodicals, of which 1,309 belonged to the Smithsonian deposit. In the accession book 3,573 volumes, 3,048 pamphlets, and 563 parts of volumes were recorded. The number of cards added to the author's catalogue was 5,942, which does not include 847 cards for books and pamphlets recatalogued.

In connection with the entering of periodicals 55 memoranda were made reporting volumes and parts missing in the sets, together with a few titles of publications that were not represented in the library. The result of this work was the completing or partly filling up of 23 sets of periodicals.

Throughout the whole year attention has been given to the preparation of volumes for binding, with the result that 1,371 books were bound, and at the close of the year there were several hundred more ready for the binder.

The number of books, pamphlets, and periodicals borrowed from the general library amounted to 40,400, including 9,192 which were assigned to the sectional libraries.

There has been but one addition to the sectional libraries established in the Museum, that of the Division of Physical Anthropology, and the complete list now stands as follows:

Administration.	Geology.	Parasites.
Administrative assistant.	History.	Photography.
Anthropology.	Insects.	Physical anthropology.
Biology.	Mammals.	Prehistoric archæology.
Birds.	Marine invertebrates.	Reptiles.
Botany.	Materia medica.	Stratigraphic paleontology.
Children's room.	Mesozoic fossils.	Superintendent.
Comparative anatomy.	Mineralogy.	Taxidermy.
Editor.	Mollusks.	Technology.
Ethnology.	Oriental archæology.	
Fishes.	Paleobotany.	

In the following table are summarized all the accessions during the year for the Smithsonian deposit, for the libraries of the Secretary, Office, Astrophysical Obsrvatory, United States National Museum, and National Zoological Park. That of the Bureau of American Ethnology is not included, as it is separately administered:

Smithsonian deposit in Library of Congress	30, 580
Secretary, Office, and Astrophysical Observatory libraries	2, 458
Watts de Peyster collection Napoleon Buonaparte	2, 782
United States National Museum library	7, 184
National Zoological Park	8
Total	43, 012

Respectfully submitted.

CYRUS ADLER, *Librarian.*

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

APPENDIX VII.

REPORT OF THE EDITOR.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its bureaus during the year ending June 30, 1905:

I. CONTRIBUTIONS TO KNOWLEDGE.

To the series of Contributions but one memoir has been added during the past year—

1651. A Continuous Record of Atmospheric Nucleation. By Carl Barus. City of Washington: Published by the Smithsonian Institution, 1905. Hodgkins fund. Part of Vol. XXXIV. Quarto. (In press.)

II. SMITHSONIAN MISCELLANEOUS COLLECTIONS.

To the series of Miscellaneous Collections the following numbers have been added, all but four of them having appeared in the Quarterly Issue:

1444. A Catalogue of North American Diptera (or Two-winged Flies). By J. M. Aldrich. City of Washington: Published by the Smithsonian Institution, 1905. Part of Vol. XLVI. 8vo. Pages 1–680.

1543. Index to the Literature of Gallium, 1874–1903. By Philip E. Browning. City of Washington: Published by the Smithsonian Institution. Part of Vol. XLVI. 8vo. Pages 1–12.

1544. Index to the Literature of Germanium, 1886–1903. By Philip E. Browning. City of Washington: Published by the Smithsonian Institution. Part of Vol. XLVI. 8vo. Pages 1–8.

1549. Inquiry into the Population of China. By William Woodville Rockhill. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 303–321.

1550. The Seeds of Aneimites. By David White. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 322–331, plates XLVII, XLVIII.

1551. Birds in Vroeg's Catalogue, 1764. By C. Davies Sherborn and Charles W. Richmond. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 332–347.

1552. The Sculpin and its Habits. By Theodore Gill. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 348–359, plate XLIX.

1553. Report on the Construction of a Vowel Organ. By E. W. Scripture. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 360–364, 5 figures.

1554. Habits and Life History of the Social Spider. By N. S. Jambunathan. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 365–373, plate L.

1555. Description of a new Sylvietta. By H. C. Oberholser. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 373–375.

1556. The Tugda, or Rice Planter, of the Coyunos, Philippine Islands. By E. Y. Miller. Pages 375–377, plates LI–LII. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII.

1557. Fossil Plants of the Group Cycadofilices. By David White. Reprinted from the Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 377–390, plates LIV–LV.

1560. The Discrepancy between Solar Radiation Measures by the Actinometer and by the Spectro-Bolometer. By F. E. Fowle, jr. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 399–408.

1561. A New Philippine Landshell. By Paul Bartsch. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 409–410, plate LVI.

1562. A New Species of Fern of Genus Polypodium from Jamaica. By William R. Maxon. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 410–411, plate LVII.

1563. Contributions of American Archeology to Human History. By William H. Holmes. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 412–420.

1564. The Birds of the Genus Cinclus and their Geographical Distribution. By Leonhard Stejneger. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 421–430.

1565. Description of a New Swiftlet from Mount Kina Balu, Borneo. By Charles W. Richmond. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 431–432.

1566. Report on Land and Water Shells collected in the Bahamas in 1904, by Mr. Owen Bryant and others. By William Healey Dall. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 433–452, plates LVIII–LIX.

1567. Glacial Studies in the Canadian Rockies and Selkirks. By William Hittell Sherzer. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 453–496, plates LX–LXII.

1568. Photographing on Wood for Photo-engraving. By Thomas W. Smillie. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 497–499.

1569. The Life History of the Angler. By Theodore Gill. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVII. Pages 500–516, plates LXXIII–LXXV.

1571. Index to the Literature of Indium, 1863–1903. By Philip E. Browning. City of Washington: Published by the Smithsonian Institution, 1905. 8 vo. Pages 1–15.

1575. The Structure of Wing Feathers. By E. Mascha. Hodgkins Fund. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 1–30, plates I–XVI.

1576. The Tarpon and Lady Fish. By Theodore Gill. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 31–46, plates XVII–XXI.

1577. A Fossil Sea Lion from the Miocene of Oregon. By F. W. True. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 47–49.

1578. Diatoms, the Jewels of the Plant World. By Albert Mann. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 50–58, plates XXII–XXV.

1579. Notes on the Nomenclature of Certain Genera of Birds. By H. C. Oberholser. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII.

1580. The Bibliography of Halley's Comet. By E. F. McPike. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 69–73.

1581. The Ancestral Origin of the North American Unionidæ. By C. A. White. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 89–112.

1584. Smithsonian Exploration in 1904 in search of Mammoth and other Fossil Remains. By A. G. Maddren. Smithsonian Miscellaneous Collections, part of Vol. XLIX. City of Washington: Published by the Smithsonian Institution, 1905. Pages 1–117, plates I–VI.

1586. The Diplomatic Service of the United States, with some Hints toward its Reform. By Hon. Andrew D. White. Hamilton Lecture. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 117–138.

1587. The History of the Whale Shark (Rhinodon Typicus Smith). By Barton A. Bean. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 139–148, plates XXXIV–XXXVI.

1588. The Avian Genus Bleda Bonaparte and some of its Allies. By Harry C. Oberholser. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 149–172.

1589. Scaphoceros Tyrelli, an Extinct Ruminant from the Klondike Gravels. By Wilfred H. Osgood. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 173–185, plates XXXVII–XLII.

1590. A New Genus and several New Species of Landshells collected in Central Mexico by Dr. Edward Palmer. By William Healey Dall. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. Pages 186–194, plates XLIII–XLIV.

1591. The Family of Cyprinids and the Carp as its Type. By Theodore Gill. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. (In press.)

1592. The International Catalogue of Scientific Literature. By Cyrus Adler. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. (In press.)

1593. Instances of Hermaphroditism in Crayfishes. By W. P. Hay. Reprinted from Smithsonian Miscellaneous Collections (Quarterly Issue), Vol. XLVIII. (In press.)

III. SMITHSONIAN ANNUAL REPORT.

The annual report, as usual, is issued in two volumes: Part I being devoted to the Institution proper, Part II to the National Museum. The contents of the Smithsonian volume for 1903 were listed in last year's report, although the book itself was still in the hands of the printer. The same is here true with regard to the volume for 1904.

1595. 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, 1904. Washington: Government Printing Office, 1905. Octavo. Pages I–LXXIX, 1–804; 146 plates, 62 text figures.

The Secretary's Report for the year ending June 30, 1904, was put in type in November, 1904, for the use of the Regents. The General Appendix to

the volume was sent to the Public Printer in February, 1905, and had been put into type before the closing of the fiscal year. The contents of the Smithsonian Report for 1904 is as follows:

1596. Journal of Proceedings of the Board of Regents of the Smithsonian Institution at Meetings of December 8, 1903, and January 27 and March 7, 1904. Report of Executive Committee. Acts and Resolutions of Congress. Pages xv–lxxix.

1547. Report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1904. Pages 1–108, plates i–xiv.

1597. Experiments with the Langley Aerodrome. By S. P. Langley. Pages 113–125, plate i.

1598. The Relation of Wing Surface to Weight. By R. Von Lendenfeld. Pages 127–130.

1599. The Rumford Spectroheliograph of the Yerkes Observatory. By George E. Hale and Ferdinand Ellerman. Pages 131–161, plates i–xvii.

1600. Construction of Large Telescope Lenses. By Dr. C. Faulhaber. Pages 163–170.

1601. Some Reflections suggested by the Application of Photography to Astronomical Research. By H. H. Turner. Pages 171–184.

1602. Radiation in the Solar System. By Prof. J. H. Poynting. Pages 185–193.

1603. Condensation Nuclei. By C. T. R. Wilson. Pages 195–206, plates i–viii.

1604. Present Problems of Inorganic Chemistry. By Sir William Ramsay. Pages 207–220.

1605. The Evolution of the Scientific Investigator. By Simon Newcomb. Pages 221–233.

1606. Metals in the Atmosphere. By Alfred Ditte. Pages 235–247.

1607. Observations on Vision in Brightness and in Obscurity, with a Hypothesis on the Cause of Color Blindness. By O. Lummer. Pages 249–258.

1608. A Lightning Spiral Observed Near Basel. By Fr. Klingelfuss. Pages 259–260, plates i–ii.

1609. Variations of Specific Gravity. By G. W. A. Kahlbaum. Pages 261–266.

1610. Some new Methods of Lighting. By A. Berthier. Pages 267–274, plate i.

1611. Progress in Wireless Telegraphy. By William Maver, jr. Pages 275–280.

1612. Electric Welding Development. By Elihu Thomson. Pages 281–285, plates i–v.

1613. History of Discoveries of Photography. By Robert Hunt. (Revised by T. W. Smillie.) Pages 287–308, plates i–vii.

1614. Theories of Ore Deposition Historically Considered. By S. F. Emmons. Pages 309–336.

1615. On Mountains and Mankind. By Douglas W. Freshfield. Pages 337–354.

1616. Morocco. By Theobald Fischer. Pages 355–372.

1617. The Work of the Reclamation Service. By F. H. Newell. Pages 373–381, plates i–viii.

1618. The Yuma Reclamation Project. By J. B. Lippincott. Pages 383–388, plate i.

1619. The Evidence of Evolution. By Hugo De Vries. Pages 389–396.

1620. The Evolutionary Significance of Species. By O. F. Cook. Pages 397–412.

1621. Some Bird Life in British Papua. By R. A. Vivian. Pages 413–418.

1622. Bird Sanctuaries of New Zealand. Pages 419–422.

1623. The House Sparrow. By Dr. J. O. Skinner, U. S. Army. Pages 423–428.

1624. Some Tibetan Animals. By R. Lydekker. Pages 429–435.

1625. The Multiple Origin of Horses and Ponies. By Dr. J. Cossar Ewart. Pages 437–455, plates I, II.

1626. Egyptian and Arabian Horses. By E. Prisse D'Avennes. Pages 457–467, plates I–IV.

1627. Bees and Flowers. By E. L. Bouvier. Pages 469–484.

1628. The Pearl Fisheries of Ceylon. By W. A. Herdman. Pages 485–493.

1629. Flying Fishes and their Habits. By Theodore Gill. Pages 495–515, plates I–IV.

1630. The Stature of Man at Various Epochs. By A. Dastre. Pages 517–532.

1631. Old Age. By Elie Metchnikoff. Pages 533–550.

1632. Contributions of American Archeology to Human History. By W. H. Holmes. Pages 551–558.

1633. Excavations at Goúrnia, Crete. By Harriet A. Boyd. Pages 559–571, plates I–III.

1634. Archeological Researches on the Frontier of Argentina and Bolivia in 1901–2. By Eric Von Rosen. Pages 573–581, plates I–X.

1635. A General View of the Archæology of the Pueblo Region. By Edgar L. Hewett. Pages 583–606, plates I–XVIII.

1636. The Painting of Human Bones among the American Aborigines. By Ales Hrdlicka. Pages 607–617, plates I–III.

1637. Sling Contrivances for Projectile Weapons. By F. Krause. Pages 619–638, plates I–IV.

1638. Materials Used to Write Upon before the Invention of Printing. By Albert Maire. Pages 639–658, plates I–VIII.

1639. An Inquiry into the Population of China. By William Woodville Rockhill. Pages 659–676.

1640. Chinese Architecture. By Stephen W. Bushell. Pages 677–692, plates I–XIX.

1641. Pewter and the Revival of its Use. By Arthur Lasenby Liberty. Pages 693–713, plates I–VI.

1642. Cameos. By Cyril Davenport. Pages 713–719, plates I–IV.

1643. The Economic Conquest of Africa by the Railroads. By A. Fock. Pages 721–735.

1644. The Present Aspects of the Panama Canal. By William H. Burr. Pages 737–744.

1645. The Sanitation of the Panama Canal Zone. By W. C. Gorgas. Pages 745–749.

1646. The Projected New Barge Canal of the State of New York. By Thomas W. Symons. Pages 751–757, plate I.

1647. Rapid-Transit Subways in Metropolitan Cities. By Milo R. Maltbie. Pages 759–771.

1648. George Gabriel Stokes. By Ernest W. Brown. Pages 773–777, plate I.

1649. Karl Alfred Von Zittel. Translated by Charles Schuchert. Pages 779–786, plate I.

1650. Carl Gegenbaur. By Oscar Hertwig. Pages 787–791, plate I.

IV. 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 of the Smithsonian Institution; (*b*) the Proceedings of the United States National Museum; (*c*) the Bulletin of the United States National Museum.

(*a*) The Report for the year ending June 30, 1903, was completed during the past fiscal year, and the Report for 1904 is now in press.

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, 1903. Report of the United States National Museum. Washington: Government Printing Office. 1905. Octavo. Pages I–XV, 1–646. Plates, 120; text figures, 120.

CONTENTS.

Part I. Report upon the condition and progress of the United States National Museum during the year ending June 30, 1903. By Richard Rathbun, assistant secretary of the Smithsonian Institution, in charge of the United States National Museum.

Part II. Papers descriptive of Museum buildings.

The United States National Museum: An account of the buildings occupied by the national collections. By Richard Rathbun.

Studies of museums and kindred institutions of New York City, Albany, Buffalo, and Chicago, with notes on some European institutions. By A. B. Meyer.

(*b*) Although enough separate papers have been published to make up Volume XXVIII of the Proceedings of the United States National Museum, they have not yet been put together in bound form.

The separates so far issued are as follows:

No. 1382. A Treatise on the Acarina, or Mites. By Nathan Banks. Pages 1–114, text figures 1–201.

No. 1383. Notes on Hawaiian Reptiles from the Island of Maui. By Richard C. McGregor. Pages 115–118.

No. 1384. Labracinus the Proper Name for the Fish Genus Cichlops. By Theodore Gill. Page 119.

No. 1385. Note on the Genus Prionurus or Acanthoaulos. By Theodore Gill. Page 121.

No. 1386. Description of a New Species of Fish (Apogon Evermanni) from the Hawaiian Islands, with Notes on other Species. By David Starr Jordan and John Otterbein Snyder. Pages 123–126.

No. 1387. Descriptions of New Genera and Species of Hymenoptera from the Philippine Islands. By William H. Ashmead. Pages 127–158, with plates I–II.

No. 1388. On the Systematic Relations of the Ammodytoid Fishes. By Theodore Gill. Pages 159–163, text figures 1–4.

No. 1389. The Dragonflies (Odonata) of Burma and Lower Siam.—I. Subfamily Calopteryginæ. By Edward Bruce Williamson. Pages 165–187, text figures 1–18.

No. 1390. On the Liparis (Trismegistus) Owstoni Jordan and Snyder. By Peter Schmidt. Pages 189–191, text figures 1–2.

No. 1391. On a Collection of Fishes made in Korea, by Pierre Louis Jouy, with Descriptions of New Species. By David Starr Jordan and Edwin Chapin Starks. Pages 193–212, text figures 1–11.

No. 1392. The Mount Vernon Meteorite. By Wirt Tassin. Pages 213–217, plates III–IV, 1 text figure.

No. 1393. The Scorpænoid Fish, Neosebastes Extaxis, as the Type of a Distinct Species. By Theodore Gill. Pages 219–220, figures 1–2.

No. 1394. Note on the Genera of Synanceine and Pelorine Fishes. By Theodore Gill. Pages 221–225, text figure 1.

No. 1395. Cambrian Brachiopoda, with Descriptions of New Genera and Species. By Charles D. Walcott. Pages 227–337.

No. 1396. On the Generic Characteristics of Prionotus Stearnsii. By Theodore Gill. Pages 339–342, text figure 1–4.

No. 1397. Three New Frogs and One New Gecko from the Philippine Islands. By Leonhard Stejneger. Pages 343–348.

No. 1398. Descriptions of New Species of Tortricid Moths, from North Carolina, with Notes. By William Dunham Kearfott. Pages 349–364.

No. 1399. Note on the Salmon and Trout of Japan. By David Starr Jordan. Pages 365–366.

No. 1400. Descriptions of a New Genus of Isopoda belonging to the Family Tanaidæ and of a New Species of Tanais, both from Monterey Bay, California. By Harriet Richardson. Pages 367–370, text figures 1–13.

No. 1401. A Critical Review of the Literature on the Simple Genera of the Madreporia Fungida, with a Tentative Classification. By T. Wayland Vaughn. Pages 371–424.

No. 1402. Descriptions of New Genera and Species of Mammals from the Philippine Islands. By Edgar A. Mearns. Pages 425–460.

No. 1403. On a Collection of Orthoptera from Southern Arizona, with descriptions of New Species. By Andrew Nelson Caudell. Pages 461–477, text figures 1–6.

No. 1404. North American Parasitic Copepods belonging to the Family Caligidæ. Part 1. The Caliginæ. By Charles Branch Wilson. Pages 479–672, plates v–xxix, text figures 1–50.

No. 1405. Notes on Mammals collected and observed in the Northern Mackenzie River District, Northwest Territories of Canada, with Remarks on Explorers and Explorations of the Far North. By R. MacFarlane. Pages 673–764, plates xxx–xxxiv.

No. 1406. Description of a New Toad from Cuba. By Leonhard Stejneger. Pages 765–767, text figures 1–6.

No. 1407. List of Fishes collected by Dr. Bashford Dean on the Island of Negros, Philippines. By David Starr Jordan and Alvin Seale. Pages 769–803, text figures 1–20.

(*c*) Of the Bulletin of the National Museum there was issued volume 3 of Bulletin No. 50, forming the third part of Mr. Robert Ridgway's monograph of the "Birds of North and Middle America;" part 4 of volume 8 of "Contributions from the National Herbarium," entitled "Studies of Mexican and Central American Plants, No. 4," by J. N. Rose; volume 9 of the same series, composed of a single paper on "The Useful Plants of the Island of Guam," by William E. Safford.

V. PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

Twenty-second Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1900–1901. By J. W. Powell, Director. Washington: Government Printing Office, 1904. In two parts. Part II. Pages 1–373; plates 9; text figures 11.

CONTENTS: The Hako: A Pawnee Ceremony. By Alice Fletcher, assisted by James R. Murie.

VI. REPORT OF THE AMERICAN HISTORICAL ASSOCIATION.

The annual report of the American Historical Association for the year 1904 was received from the Association and transmitted to the Public Printer in May, 1905. Its contents are as follows:

Report of the Proceedings of the Twentieth Annual Meeting, at Chicago, Ill., December 28–30, 1904, by Charles H. Haskins, corresponding secretary.

The Treatment of History, by Goldwin Smith.

On Roman History, by Ettore Pais.

On the Necessity in America of the Study of the Early History of Modern European Nations, by Friedrich Keutgen.

The Chief Currents of Russian Historical Thought, by Paul Milyoukov.

The Work of American Historical Societies, by Henry E. Bourne.

Public Records in Our Dependencies, by Worthing Chauncey Ford.

The Exploration of the Louisiana Frontier, 1803–1806, by Isaac J. Cox.

The Campaign of 1824 in New York, by C. H. Rammelkamp.

Report of the Conference on the Teaching of History in Elementary Schools, by J. A. James.

Report of the Conference on the Teaching of Church History, by Francis A. Christie.

First Report of the Conference of State and Local Historical Societies, by Frederick W. Moore.

State Departments of Archives and History, by Thomas McAdory Owen.

Report of the Proceedings of the First Annual Meeting of the Pacific Coast Branch, by Max Farrand.

Bibliographical Notes on Early California, by Robert Ernest Cowan.

The Nootka Sound Controversy, by W. R. Manning.

Report of the Public Archives Commission on Archives of Alabama, Pennsylvania, North Carolina, Kansas, and Georgia.

Report on the Collection of Materials in English and European History and Subsidiary Fields in Libraries of United States, by Wilbur H. Siebert.

VII. REPORT OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The seventh report of the National Society of the Daughters of the American Revolution was received from that Society in May, and was submitted to Congress in accordance with the requirements of the law.

Respectfully submitted.

A. Howard Clark, *Editor.*

Mr. S. P. Langley,

Secretary of the Smithsonian Institution.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1905.

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 1905.

NEW MEASUREMENTS OF THE DISTANCE OF THE SUN.[a]

By A. R. Hinks, M. A.

When I received the honor of an invitation to lecture at the School of Military Engineering on some astronomical subject, I had little difficulty in making my choice of a topic. There is just one subject on which I may speak with some little first-hand knowledge; and by great good fortune that subject is concerned with a problem which has both in its nature and its history a connection with the Corps of Royal Engineers.

The problem of the determination of the distance of the sun is, in some respects at least, the most fundamental in the whole range of astronomy, for the number which represents it is involved in almost any calculation of distances and masses, of sizes and densities, either of planets or their satellites or of the stars. The distance of the sun bears somewhat the same relation to other problems of celestial surveying as the size and shape of the earth bear to terrestrial. It may not always appear on the surface, but it is generally concealed somewhere in the depths of the calculations. And I am compelled to confess that in one respect the earth measurers have the advantage over astronomers. The utmost that the astronomer can do is to show that the distance of the sun is so many times the radius of the earth. But ask him to put it into miles and he is powerless to do so until the geodesists have told him how large the earth is; and it is there that, in the very nature of the case, we are compelled to depend in the end upon the scientific labors of your corps.

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[a] Lecture delivered at the Royal Engineers' Institute on February 9, 1905. Reprinted, by permission, from the Royal Engineers' Journal, Volume II, No. 1, July, 1905. Chatham, England, Royal Engineers' Institute.

Distance of sun corresponding to different values of the solar parallax and Clarke's figure of 1880.

π.	Miles.	Kilometers.
$''$		
8·760	93,321,000	150,180,000
8·770	214,000	150,010,000
8·780	108,000	149,840,000
8·790	2,000	670,000
8·800	92,896,000	500,000
8·810	791,000	330,000
8·820	686,000	149,160,000
8·830	581,000	148,990,000
8·840	476,000	820,000

A difference of 0·01″ in the parallax is equivalent to 106,000 miles, or 170,000 kilometers.

Let us look at the matter for a moment as a problem in pure surveying. To measure the distance of the sun we have as a base a chord somewhat less than the diameter of the earth, since observations can not be made on a heavenly body when it is actually on the horizon. Suppose we put our base line at nine-tenths of the diameter. Our problem is to determine the distance of a body so far away that the whole diameter of the earth subtends at it an angle of only about 17.6 seconds of arc; and with our somewhat diminished base this angle is reduced to a little less than 15 seconds. I believe that the length of your base upon the great lines of Chatham is about 1,730 feet. Imagine that from that base you had to determine with an accuracy greater than one in a thousand the distance of an intersected point about 4,500 miles away, as far away as Chicago, and you have a problem which is by comparison simplicity itself. For the ends of our 7,000-mile base are not visible from each other, being on opposite sides of the world, and our angles at the base must be determined by a complicated reference to the zenith, with all the well-known impossibilities of determining absolute places in the sky increased by the special difficulties that arise when the object to be observed is the sun. You will readily grant that to determine the distance of the sun by direct observation of that body is impossible, unless you are content with an accuracy of about 1 in 10.

Now, it is a curious fact that there is a way of obtaining the distance of the sun with an accuracy of 10 per cent with no other instrument than a clock keeping accurate time. You do it by observing the times of minima of the variable star Algol. Every two days twenty-one hours Algol drops more than a magnitude, and does this with a regularity which would be unfailing were it not for the fact that at one season of the year we are nearer the star by nearly the whole diameter of the earth's orbit than we are at the opposite

season; and light takes about sixteen minutes to traverse that distance. In the middle of November the eclipses of Algol are taking place eight minutes earlier than the average. In May, could we observe the star so near the sun, they would be found eight minutes behind their time; and a practised observer could, on a long series of observations, determine that inequality, with a total range of sixteen minutes, well within two minutes—that is to say, with an accuracy of about 10 per cent. We have then only to combine this quantity with the known velocity of light and we have a measure of the sun's distance. A mere curiosity in itself, it will serve to introduce us to some indirect ways of determining the distance of the sun which have, both practically and historically, a peculiar interest and importance.

At the present time we are in the thick of a new determination of the distance of the sun on a scale of operations greater than has been known before. More than fifty observatories of the Northern Hemisphere are engaged more or less deeply on the work, which has occupied a great many of us closely for the last four years and will give plenty of trouble to some of us for several years to come. Before we enter upon the consideration of the new method and the new opportunities we might well pause to answer the question, which is by no means superfluous, How does it come about that, at the end of the nineteenth century, which had seen attempts almost innumerable to measure the distance of the sun, the result was still so much in doubt that it was worth while to concentrate quite a large proportion of the total astronomical energy of the world upon a new attempt? I believe that we shall find some explanation of this fact if we examine the history of the various values of the solar parallax that were used in the Nautical Almanac during the nineteenth century.

A determination of the distance of the sun by direct observation of the sun itself is impracticable; the sun is too difficult an object to observe with any great accuracy; its distance is too great, and our base is too small for any method of direct trigonometrical survey to be possible. But we can in effect diminish its distance by substituting for it one of the planets, which can be more accurately observed, for when the distance of any one planet from the earth is known, the dimensions of other orbits follow by the application of Kepler's third law. And at the same time we can, as we shall see, secure the inestimable advantage that the measures to be made are relative and not absolute.

Let me digress for a moment to insist upon the importance of this distinction. If you wished to find the difference in latitude and longitude between your Institute and the trigonometrical point at Darland, you might determine the latitude and longitude of each and take the differences, or you might triangulate from one to the other.

One is an absolute method, the other a relative, and it is scarcely necessary to emphasize the difference in accuracy between the two. We shall see that, various as are the kinds of measurement which may be made to contribute to a knowledge of the solar parallax, they are all of them relative measurements. For example, one may observe the displacement of the planet Mars among the stars, as seen from a northern and a southern station—say Greenwich and the Cape—or one may observe the displacement of the place of Venus in transit across the sun from stations suitably chosen. In each case we are measuring the displacement as viewed from different stations of a near object with respect to one farther off, the displacement of Mars among the stars or of Venus against the sun. We have secured the advantages that the parallactic displacement to be measured is greater than that of the sun itself; that the objects to be observed, Mars or Venus, are better adapted for observation, and that the measures are relative.

In the middle of the eighteenth century Lacaille made observations of Mars at the Cape of Good Hope, which were compared with others made at various observatories in Europe, and he deduced a parallax of about ten seconds. In the same century there occurred the two famous transits of Venus of 1761 and 1769, which were very extensively observed, among others by Captain Cook on his celebrated expedition for that purpose to the South Seas. Many and various were the results obtained by different discussions of the observations, lying between eight and one-half and nine and one-half seconds, but decidedly less than the parallax found from Mars, and we find that at the beginning of the nineteenth century the Nautical Almanac adopted a value in round numbers, nine seconds, as the best that could be made of them.

Values of the solar parallax used in the Nautical Almanac during the nineteenth century.

	π
1801–1833	9″
1834–1869	8·5776″
Encke, from transits of Venus, 1761 and 1769.	
1870–1881	8·95″
Leverrier, from parallactic inequality of moon (1858).	
1882–1900	8·848″
Newcomb, from general mean of many methods (1867).	

In 1824 the German astronomer Encke submitted to a very searching examination the collected results of the transit of 1769 and deduced the result 8·5776 seconds, which, with its imposing train of decimals intact, was incorporated in our Nautical Almanac for 1834, survived until 1869, and was responsible for the statement, which many of us can remember in the schoolbooks, that the distance of the sun is 95,000,000 miles.

Meanwhile the attack upon the problem had been maintained in several different ways, and particularly by an indirect method that has many points of interest.

In the lunar theory there occurs, among the short-period perturbations to which the motion of the moon is subject, an inequality in a period of a month which depends upon the fact that the disturbing action of the sun is greater on that half of the moon's orbit which lies toward the sun than upon the other half. The result of this is that the moon is more than two minutes behind at first quarter and two minutes ahead at last quarter of the place which she would occupy were there no perturbation. It is clear that the magnitude of the effect must depend upon the ratio of the distances of the sun and moon from the earth; and since the effect is large, an oscillation either way of about one hundred and twenty-five seconds, this should give a strong determination of the solar parallax, provided that the moon can be observed with the required accuracy and that the theoretical relation between the perturbation and the solar parallax is firmly established. In 1858 Leverrier found in this way a value of 8·95 seconds; several other determinations supported this large value, and practically all the determinations made since 1830, however much they might disagree among themselves, agreed at any rate in one thing, that Encke's value was much too small. We find, therefore, that in the Nautical Almanac for 1870, published in 1866, Leverrier's value, 8·95 seconds, is adopted, and the official distance of the sun changed at one swoop from 95,000,000 to 91,000,000 miles.

But now preparations were in full swing for the observations of the transit of Venus of 1874 and 1882, which for many years had been eagerly awaited in the full expectation and belief that then, with all the manifold improvements in the arts of observation, in the invention of the heliometer and the application of photography to celestial measurement, the question of the solar parallax would be definitely settled. We can not do more than glance at the most beautiful and most complicated geometrical problems involved in the consideration of all the circumstances of a transit of Venus. But these two diagrams[a] will show some of the circumstances of the very important phenomena, the times of internal contact at ingress and egress, the times when Venus is just completely on the sun and just about to begin to go off. Great preparations were made for observing these times of ingress and egress, and the results would undoubtedly have been successful had it not been for the cruel way in which the geometrical sharpness of the phenomenon is ruined by the lighting

[a] Showing the passage of the earth through the cones enveloping the sun and Venus. (Not reproduced.—Edr.)

up of the atmosphere of Venus; there was no instant when tangency was perceptible, and, to be frank, the transit of Venus as a means of determining the distance of the sun was a failure. The photographic and heliometer observations had for various reasons met with no better success than the observations of contacts; there was no consistency about the results.

But just as the preparations for the transits were beginning in 1867 Prof. Simon Newcomb had published an elaborate discussion of the solar parallax based upon several different methods. With some of these we are already familiar, and I will call attention to one only, the last, which we have not as yet discussed.

Components of Newcomb's value.

		π
Newcomb, "Observation of Mars, 1862"	seconds	8·855
Hall, "Observation of Mars, 1862"	do	8·842
Hansen, Stone, and Newcomb, from "Parallactic inequality of moon"	seconds	8·838
Newcomb, "Lunar equation of the earth"	do	8·809
Powalky, "Transit of Venus, 1769"	do	8·832
Foucault's "Velocity of light," and Struve's "Aberration const."	do	8·860
Weighted mean	seconds	8·848

It is an effect of aberration that every star describes yearly in the sky an ellipse of which the semimajor axis is about 20·5 seconds, and this number is called the constant of aberration. It is the ratio of the velocity of the earth in its orbit to the velocity of light. When the constant is known and the velocity of light is known, the velocity of the earth in its orbit is known; and since the time of describing that orbit is also known, the size of the orbit and the distance of the earth from the sun follow immediately.

In 1876 it appeared then that there was strong evidence against the value 8·95 seconds; and without waiting for the results of the transit of Venus expeditions, the Nautical Almanac adopted for the while the value 8·848 seconds found by Newcomb from this galaxy of results which looked so accordant; and that value was first used in the Almanac for 1882, the year of the second transit.

But meanwhile Sir David Gill, who had observed the transit of 1874 at Mauritius and had made up his mind very definitely that no good would come out of the transit of 1882, had borrowed Lord Lindsay's heliometer and established himself on the island of Ascension to observe with the heliometer the opposition in 1877 of the planet Mars. Every night the observing station in Mars Bay was carried some six or seven thousand miles by the rotation of the earth and the planet thereby displaced among the stars by some forty seconds. The heliometer is by far the most refined instrument for the

visual measurement of distance from star to star; the observations extended over months instead of hours; they could be pursued without any of the disquieting feelings that a temporary breakdown would ruin everything; and they were brought to a successful end in a parallax of 8·78 seconds. But one doubt was cast upon the result. Was it possible that the red color of Mars had influenced the measures systematically? It could not be denied that the effect of the dispersion of the air, which gave the planet a blue fringe above that might be lost in the blue sky, and a red fringe below that would be indistinguishable from the red planet itself, might have produced some effect; and Sir David Gill resolved to try again, utilizing this time three minor planets farther away than Mars, with less parallax therefore but with disks so small that they were indistinguishable from stars.

In 1888 and 1889 five observatories, the Cape in the Southern Hemisphere, and Yale, Göttingen, Leipzig, and the Radcliffe Observatory at Oxford in the Northern Hemisphere, combined to observe the planets Victoria, Iris, and Sappho with the heliometer. The labor was immense. The observations proved to be so accurate that they demanded the use in a great part of the work of eight figure logarithms. When only a few years ago the whole work was published in two enormous volumes of Annals of the Cape Observatory, it might well have been thought that here was the last word of observation for many years. Yet we are now attacking the problem with more energy than ever.

About ten years ago the end of the century was in sight, and there was a general impression abroad that it was time to set one's house in order and to make a good start on the 1st of January, 1901. The directors of the four nautical almanacs (the British, French, German, and American) resolved to meet in Paris in 1896, and with the help of certain distinguished advisers to agree upon a uniform set of constants to be adopted in all the Almanacs from the year 1901. Among these constants was the solar parallax. We may summarize the information which was at the disposal of the conference thus:

Solar parallax from—	Seconds.
Gill's heliometer, minor planets	8·802
Constant of aberration of light	8·799
Parallactic inequality of moon	8·794
Mass of earth from motion of node of Venus alone	8·762
Mass of earth from secular variation of four inner planets	8·759

Gill's heliometer measures of minor planets gave 8·802 seconds, and no other direct observational result could be compared with this; the transits of Venus were discredited even though some of the final results had not, and have not even now, been published. The most recent determinations of the constant of the aberration of light gave 8·799 seconds, the parallactic inequality of the moon, 8·794 seconds.

There were thus three powerful methods which converged upon a value close to 8·80 seconds. But to set against them was a method which we have not yet noticed.

The perturbations in the motions of other planets produced by the earth depend upon the mass of the earth, and from them that mass can be determined. There is further a well-known relation between the mass of the earth, the value of the gravitation constant, the length of the year, and the distance of the sun, from which the latter may therefore be derived when we know the others. Professor Newcomb had thus determined the parallax in two different ways, and had found two results agreeing closely among themselves, with mean 8·76 seconds, but differing widely from the others. No explanation of this divergence could be found. But the evidence was 3 to 1 in favor of 8·80 seconds, and 8·80 seconds was adopted in 1896 as the value to be used in all the almanacs from the beginning of this century.

It might well have been thought that the question would have been allowed to rest there for a while. At the end of a century of labor four principal results had emerged, and there was a majority of 3 to 1 in favor of 8·80 seconds. But there is a phenomenon, known in politics as the swing of the pendulum or the flowing tide, by whose operation a majority hardly won begins immediately to melt away. A like phenomenon appears to affect the solar parallax. We have seen how its adopted value has swung from 8·57 to 8·95 seconds, and back again to 8·85 and 8·80 seconds. Scarcely had the resolution of the Paris Conference been taken than the majority in favor of 8·80 seconds began to melt away. The beginning of the century had been chosen as an auspicious moment in which to make a change, without considering that there were at the end of the preceding century many investigations just then drawing to a close. The value of the aberration constant corresponding to 8·80 seconds is 20·478 seconds. Almost every determination of that constant published since 1896—and there are many—had come out above 20·50 seconds, many of these a long way above. Further investigation of the parallactic inequality of the moon had not only altered the observed value of the inequality, but had modified the theoretical relation by which the parallax is deduced therefrom. The evidence for 8·80 seconds was giving way badly; and before the 1901 Almanac came into use we had this revised table propounded by one of the chief instigators of the adoption of 8·80 seconds. The majority was now 3 to 1 in favor of a value at least as low as 8·77 seconds.

Revised table.

Solar parallax from—	Seconds.
Gill's heliometer, minor planets	8·802
Constant of aberration of light	8·77
Parallactic inequality of moon, probably	8·77
Mass of earth from secular variations	8·759

I suppose that there will always be two opinions upon the question: Is the adopted value of the solar parallax to depend upon direct observation or are the indirect determinations through the constant of aberration, the parallactic inequality, and the mass of the earth to be allowed a weight in some proportion to their numbers? I take it that those of us who have determined the parallax by direct observations may not unnaturally look upon these indirect methods as interesting confirmations of our result if they agree with it, while if they differ there must be something wrong with them. But in the absence of a direct determination of overwhelming weight there must always be a feeling of uneasiness when one sees three or more results conspiring to deny the truth of one. And however that may be, it is certainly true that about the year 1898 there was a very general suspicion abroad that the value 8·80 seconds was too large.

At this moment there came a curious stroke of fortune. Doctor Witt, of the Urania Sternwarte, Berlin, was engaged in a photo-

FIG. 1.—Eros campaign 1900-01. Distribution of Observatories.

graphic search for a minor planet which had long been lost. He failed, but found instead a minor planet for which one would willingly barter the remaining five hundred odd; a minor planet indeed, but moving in a most remarkable orbit, lying for the most part within that of Mars, very eccentric, considerably inclined to the elliptic, and approaching the earth on favorable occasions within about 15,000,000 miles. It was immediately recognized that here was a new opportunity for determining the solar parallax and that the determination must be made at once or left alone for thirty years, for a comparatively favorable opposition was due in 1900 and no more good ones till 1930 and 1937. At the meeting of the permanent committee which directs the making of the astrographic chart and catalogue of the whole sky it was resolved to invite a great cooperation of observatories to make a combined onslaught on the problem. The suggestion was readily taken up, with an alacrity, indeed, which might almost have suggested that the observatories concerned had nothing to do and were glad of a job, an imputation which is immedi-

ately rejected when one finds that some of the most energetic participants were precisely those observatories that had their hands most full with the astrographic chart (fig. 1). By a cruel stroke of fate Sir David Gill at the Cape was compelled to remain a spectator of the work, for the planet came so far north that it was practically unobservable in the Southern Hemisphere, while in England we had the unique spectacle of a planet north of the zenith.

Figure 2, borrowed from Professor Wilson's articles in Popular Astronomy, shows very clearly the circumstances. Corresponding

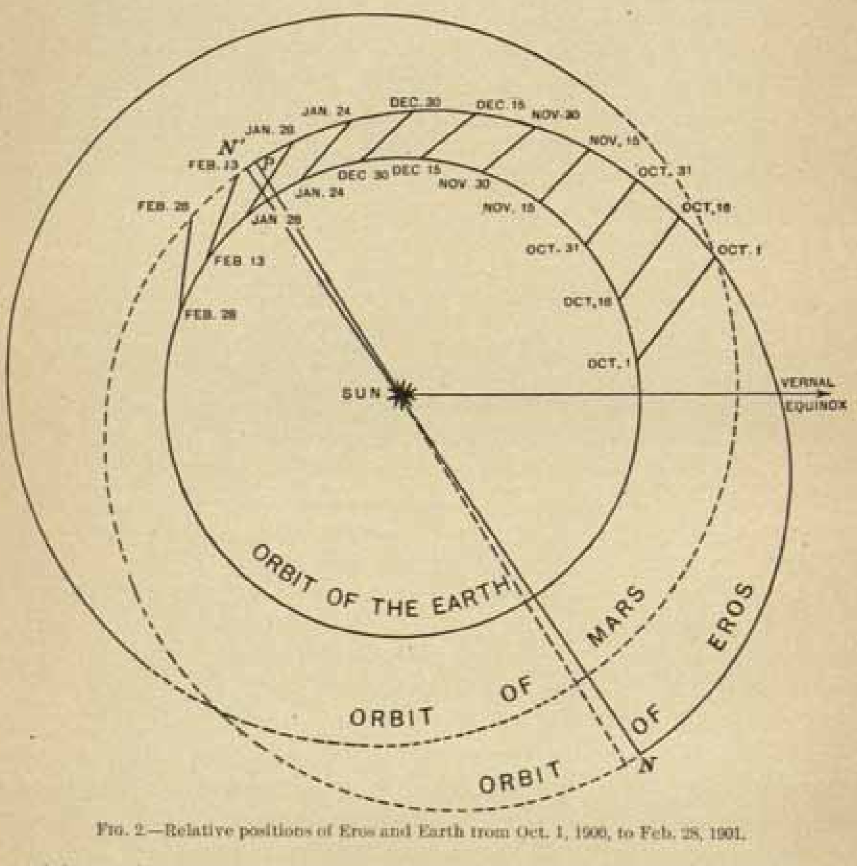


FIG. 2.—Relative positions of Eros and Earth from Oct. 1, 1900, to Feb. 28, 1901.

positions of the earth and the planet are joined, and if we follow out in imagination the directions that these lines must have, remembering that the orbit of the planet is inclined 10° to that of the earth, we see that the planet described a loop at opposition, as all exterior planets do, but that the loop was of very unusual proportions (fig. 3).

To discuss in any detail the circumstances of the apparition and the way in which they can be utilized for a determination of the parallax would take too long. But we may get a good idea of a

fairly typical case by transplanting ourselves in imagination to the planet Eros on the evening of the 2d of December, 1900, armed with an imaginary telescope ridiculously out of proportion to the real size of the planet, which is probably not more than 20 miles in diameter (fig. 4). The earth is past inferior conjunction with the sun, and appears as a crescent. The North Pole of the earth is tilted toward us, and by the aid of this projection of the meridians and parallels of latitude we can with great ease trace the path of each observatory as it is carried round by the rotation of the earth and can measure from the scales the angular distance at any moment of an observatory from the center, or the distance between two observatories, which angular distances as seen from the planet are the precise equivalents of the parallactic diplacements of the planet as seen from the earth.

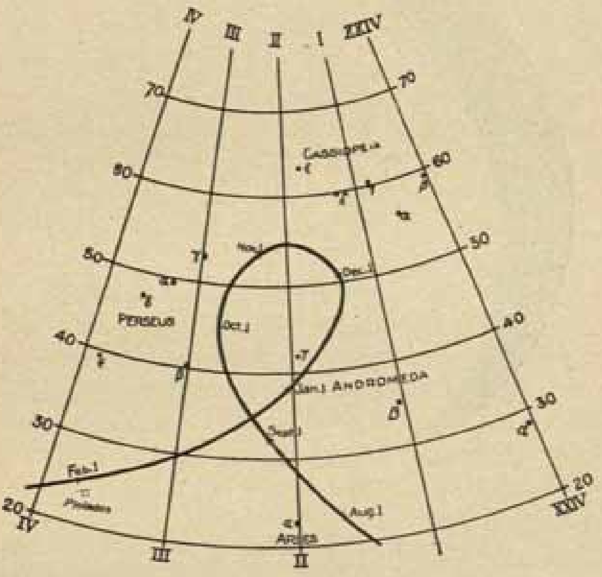


FIG. 3.—Path of Eros, 1900-01.

In the programme of observations there was one novel and promising feature—the application of photography. With the exception of the transit of Venus observations, in which its success was not striking, photography had not been previously applied in a determination of the solar parallax, for the very good reason that in 1889, at the time of the opposition of Victoria, there was practically only one telescope in existence which was capable of taking photographs for exact measurement, that pioneer photographic equatorial made by the Brothers Henry at Paris. The fact that there were in 1900 eighteen photographic telescopes engaged in observing Eros shows how rapidly the equipment of astronomy has grown in the last few years. We were so fortunate at Cambridge as to have our new

photographic equatorial just completed and made to work. (I may remark parenthetically that it took longer to make the machine work than to build it, for when one embarks upon a large experiment and sets up an instrument, the first of its kind, built upon improved lines, one sets out upon a sea of troubles.)

The great advantage of the photographic method in such an undertaking must be sufficiently well known by you. It is, of course, this, that one is rendered very much more independent of continued fine weather. A photograph of the planet and the surrounding stars could be made in two or three minutes of actual exposure. Given an hour's break in the clouds, one could accumulate far more valuable

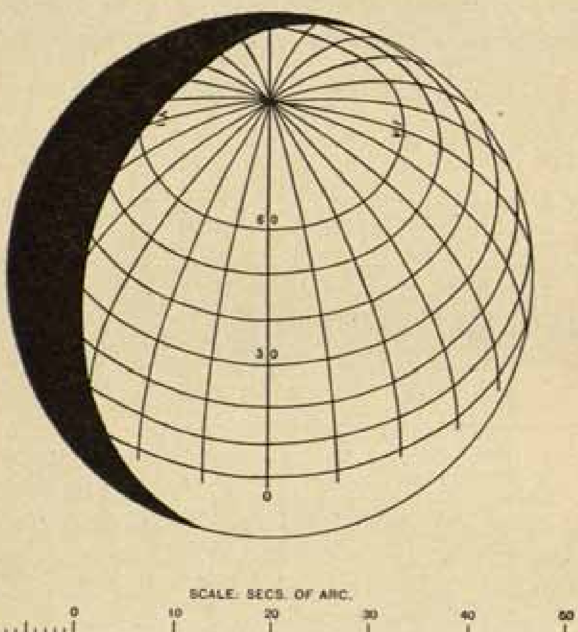


FIG. 4.—Meridians and parallels of latitude of the Earth as seen from Eros, Dec. 2, 1900 (negative). The blackened portion represents the bright crescent of the Earth, the planet being more than a month past opposition.

material than could be obtained in a whole night's visual observation, for the photograph once secured could be measured at leisure, by day or on cloudy nights.

Throughout Europe the skies of that winter were far from clear. I had the pleasure at Cambridge of sitting up from dusk till dawn for nearly three months on end and during that time had not half a dozen nights clear right through. Had I been making visual observations I should have done little; as things turned out I was able to get some five hundred exposures. The programme was to get four exposures per hour throughout the night, making a number of exposures on each plate, and moving the plate a little between each exposure.

The stars are then arranged in columns of fours; the images of the planet, owing to its rapid motion, are in echelon.

Now each exposure gives very accurately the place of the planet with reference to the group of stars around it, and for merely parallax purposes the ideal would be to have pairs of such photographs taken at the same instant at stations widely separated. By a very simple use of the measures of some ten or twelve stars suitably disposed about the planet, it would be possible to allow almost automatically for the differences of refraction, orientation, scale value, etc., which make the plates not immediately comparable, and to find at once the parallactic displacement.

We have been speaking of the displacement as very large, and so it is when compared with the displacements dealt with in previous determinations. But look at it this way: We saw that the earth as seen from Eros subtended an angle of 53 seconds. The scale of the Cambridge plates is such that if we draw a circle having a diameter of a little over $1\frac{1}{2}$ mm. we represent the apparent diameter on our plate of the earth as seen from Eros; and within that small circle the whole of the parallactic displacement must necessarily lie. About a millimeter was the average displacement obtained in a favorable combination of observations, and when we consider that we are trying to measure that with a resultant accuracy of 1 in 1,000 it does not seem so very great after all.

We have put the problem heretofore in its very simplest form. In actual fact the exposures at different stations were not simultaneous. Early morning observations made at Cambridge might be combinable with evening observations at Lick more or less simultaneous, or with evening observations ten or twelve hours before at (say) Oxford; or they might have to stand alone. Any general method of utilizing all the results must secure the possibility of reducing each plate, so to speak, on its own merits, to allow it to contribute its quota, be it large parallactic displacement or none at all, to the general collection of equations of condition. This requires that we shall know the relative places of all those stars which are to be used as comparison stars for the planet, right along the whole track of the planet. And this derivation of a standard star system is by far the most delicate and difficult part of the whole work. One must start with a foundation of stars observed with the meridian circle, and fill in the fainter stars from the photographs themselves, taking care to provide at the same time the places of all those faint comparison stars which have been used by the visual observers. And all these places of stars must be tied together, so to speak, by the overlapping of the photographs, so that the system may run smoothly throughout its length. Absolute errors of zero there no doubt will be, and must be, but it is

required that there shall be no sudden jumps in the errors exceeding one or two hundredths of a second of arc.

Now, when one comes to face a problem like this, one must inquire very carefully what is the real accuracy of the photograph. There is no doubt that the ordinary photographic telescope properly worked will repeat itself very well; it will take two plates of the same region which agree with one another excellently. But the question is, How would two plates of the same region taken with different telescopes agree? We know that individual observers have peculiarities of their own which they can repeat almost ad infinitum. Does a photographic telescope do the same, or has it at last conquered that bad habit of idiosyncrasy which has made so much trouble in all refined astronomical work of the older kinds? When we started on the Eros campaign there was practically no information to be obtained upon this point. Almost all the photographic telescopes at work had been engaged upon their own zone of the chart, and almost nothing was known of how the results from different instruments would combine. But in our parallax problem this question is fundamental, and must be answered as soon as possible. I therefore ventured to propose to myself to undertake the reduction of a small section of the photographic results, for a period of nine days in November, 1900, having before me two objects: Firstly, to discover how far it is possible to combine photographs taken at different observatories, how far, in fact, photographic telescopes are giving really accurate results or merely reproducing their own errors; secondly, to obtain a provisional value of the solar parallax, with a probable error if possible as small as that found by Sir David Gill with the heliometer, and to find out provisionally whether Eros was going to confirm that result or to join in the secession from the adopted value.

Perhaps I may venture to think that the results of this enterprise have been in some measure successful. I found that as a general rule the results from different telescopes do not combine directly as well as could be hoped and that there are many precautions which must be taken in using them if we are to avoid serious systematic error and a ruination of the parallax determination; but I believe that it is possible to avoid these difficulties and that the photographs properly treated will give a determination of the parallax of far greater accuracy than has hitherto been obtained. I found also that the 300 exposures in that period of nine days, contributed altogether by nine different observatories, gave a value of the solar parallax, 8·797 seconds ± 0·0047 second, which is in such nice agreement with Gill's 8·802 seconds ± 0·005 second that one may feel in one's heart (though of course must never express the feeling so prematurely as this) some hope that, in adopting 8·80 seconds as the official value of the solar parallax, the conference of 1896 was not so wrong as some people have been prepared to believe.

	Distance of sun in miles.
From heliometer observations of Victoria, Iris, and Sappho.	
$\pi = 8{\cdot}802$ seconds $\pm\ 0{\cdot}005$ second.	92,875,000
From 295 photographs of Eros.	
$\pi = 8{\cdot}797$ seconds $\pm\ 0{\cdot}0047$ second.	92,928,000

I can not refrain from calling your attention to a by-product of this work which has for me a singular interest, because it seems to exhibit in a favorable light the accuracy which we may obtain with these photographic methods. After Eros had been under observation for some time it was discovered that its light was varying in a short

FIG. 5.—Light curve of Eros. Whole period 5 h. 16 m.

period, which was at first thought to be 2h. 38m. Afterwards it was found that the alternate minima of light was unequal, and that the true period should be reckoned as 5h. 16m., two equal maxima and two unequal minima being included within that space of time (fig. 5). The variation appears to be continuous, without sensible pause, which precludes the idea that the planet is double and that the minima are due to eclipses of one body by the other. We must find some other cause. There are two which suggest themselves quite naturally—irregularity of shape and irregularity of surface bright-

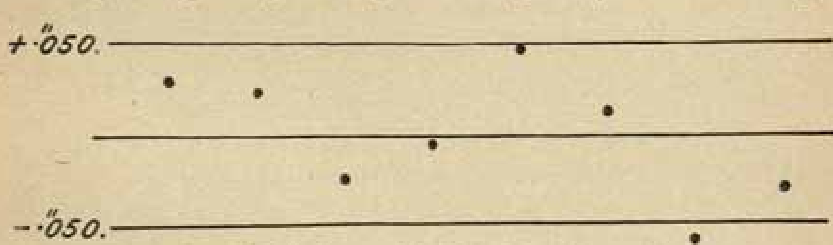


FIG. 6.—Residuals grouped in eighths of the whole period.

ness. For our purpose the important point is this—that either of these causes might produce an apparent oscillation in the place of the planet. To discover if this were so, I grouped the residuals in my equations of condition according to their epoch into eight columns, corresponding to successive eighths of the whole period of 5h. 16m., and took the means for each column. If there were a sensible oscillation in a period of 5h. 16m., these would lie on a sine curve. They obviously do not; there is no sensible oscillation in that period (fig. 6). But notice that if we add together the first and fifth, the second and sixth, and so on—that is to say, if we search for the half period of 2h. 38m.—we get quite strong evidence of periodicity (fig. 7).

Now, the semiamplitude of the oscillation is only 0·03 second, a quantity so small that one can not but feel doubts as to its reality. At first I was myself inclined to disbelieve; but when a new distribution of the residuals, starting from a different zero of time, gave a similar periodicity, it began to look as if there were something in it. The more I look at it the more I believe that it is a reality, and that the photographs have shown themselves accurate enough to detect an inequality of 0·03 second, corresponding to a shift of 5 miles at a distance of 25,000,000 miles—by far the smallest inequality in the motion of a planet ever brought to light by observation.

It is this circumstance that encourages one to believe in the accuracy of the photographs. There are altogether 10,000 separate exposures of the planet which will within the next few years be measured and made available for discussion. If 300 give a P. E. of 0·005 second, what will 10,000 give, added to 6,000 or 7,000 sets of

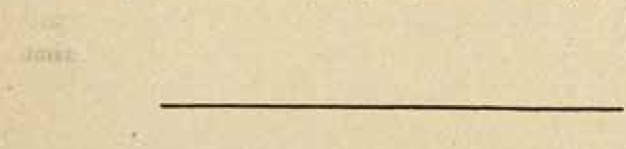


FIG. 7.—Residuals grouped in quarters of the half period.

visual observations? It would be going too far to apply the simple rules of probability and say a good deal less than 0·001 second. But I fully believe that if this great array of observations is ever submitted to complete discussion the probable error of the result will not be much above 0·001 second. And supposing that it should support with its greater weight the value 8·80 seconds which has been assailed, I believe that we should be justified in saying that the solar parallax is 8·80 seconds, and in maintaining the proposition that the determination of the solar parallax is a problem of geometry and celestial surveying, and that upon the sponsors of the indirect methods lies the onus of showing cause for their disagreement.

This opens up an interesting prospect. Suppose that in course of time there should come to be a clear and definite agreement among the values found for the constant of the aberration of light, and that its value was (let us say) 20·54 seconds, corresponding, as this table shows, to a parallax of 8·77 seconds, not 8·80 seconds, on the assumption at least that the velocity of light is exactly determined, as it seems to be, and that the simple theory of aberration is correct.

Relation between solar parallax and constant of aberration.

Aberration.	π.
$''$	$''$
20·46	8·808
·48	·799
·50	·790
·52	·782
·54	·773
·56	·764

And suppose that by that time we are prepared to say quite definitely that the geometrical value is not 8·77 seconds but 8·80 seconds. The most obvious solution of the difficulty would be to conclude that the simple theory of aberration is not true, and to hand over the problem to the mathematical physicists, who might in the result find that a definite geometrical determination of the solar parallax had provided just the criterion which they required to settle certain vexed questions in dynamics.

Again, should further investigation confirm the conclusion that 8·76 seconds is the only value of the solar parallax which will reconcile the existing theory of the motion of the planet with the observed value of the constant of gravitation, it may be that the contradiction between the direct and the indirect methods will at last enable the dynamical astronomers to lay a finger upon that flaw which exists somewhere or other in the theory and makes it impossible to say at the present time that all the motions of the solar system can be completely explained.

I have ventured to point out that the determination of the solar parallax is a problem of wide interest, since it throws upon so many different people the task of keeping up their particular end against an attack whose accuracy is gradually becoming more and more deadly. The dimensions of the earth, as obtained by geodetic operations, are necessarily beyond the reach of any criticism derived from solar parallax results.

Equatorial radius of earth.

	Miles.
Méchain and Delambre, 1799	3,961·74
Airy, 1830	3,962·82
Everest, 1830	3,962·67
Bessel, 1841	3,962·76
Clarke, 1858	3,963·31
Clarke, 1866	3,963·28
Clarke, 1878	3,963·37
Clarke, 1880	3,963·29

Extreme range of these determinations is only $1\frac{1}{4}$ in 4,000.

But it is interesting to speculate whether astronomers will ever be in the position to say, "We have now determined the solar parallax in seconds of arc to a higher degree of accuracy than that of the measurement of the earth," and to call upon geodesists for better results. I can conceive only one direction in which we may be able to worry the successors in your corps of Everest and Clarke. Is the form of the equator a circle or an ellipse? I believe that there is some slight evidence for ellipticity, and that it has been put as high as one in three thousand. If that is so, it is just barely possible that we may have to introduce into the computation of the parallax factors for different observatories a term depending upon the shape of the equator. But I confess that this prospect is remote, and that for many years, in all probability, geodesists who achieve accuracies of one in a hundred thousand and even talk of one in a million will be able to take a serene view of the labors of astronomers to arrive at the distance of the sun to one part in ten thousand.

PHOTOGRAPHING LIGHTNING WITH A MOVING CAMERA.[a]

By Alex Larsen, Chicago, Ill.

Lightning, with its accompaniment of thunder, has always exerted a fascinating influence on the thinking mind. It is not strange that a people living in an age when the laws of nature were less perfectly understood should have associated this beautiful and awe-inspiring natural phenomenon with the powers and attributes of their gods.

The ancient Norsemen recognized in the rumbling of the thunder the approach of Thor, their most powerful god, in his heavenly chariot, drawn by his two he goats; and in the lightning flash they saw the path cleaved through the air by the never-failing hammer "Mjolner," wielded by the mighty arm of Thor when battling with the enemies of the gods, the hammer always returning to his hand. The myth is beautiful, and it would seem as if its authors had noticed the peculiar flickering of most lightning flashes and associated it with the forward and return movement of the hammer.

The principal object of this paper is to place before its readers certain facts to account for this flickering of lightning flashes.

In the latter part of the summer of 1901, while taking some ordinary pictures of lightning, the idea occurred to the writer while noticing this flickering that if the camera be moved in a circle at right angle to the flash the picture ought to show a widening of the flash, if it was composed of separate parts, and thereby also determine its duration. The attempt to do this was made that year, but without success. It was repeated again in 1902, and on July 17 several successful exposures were made which clearly showed that most flashes are composed of several discharges following one another at certain intervals in the path made by the first discharge. The writer was unaware at the time that others had experimented in the same line and had published their results.

[a] The study of lightning flashes herewith presented was aided by a grant from the Hodgkins Fund of the Smithsonian Institution.

The camera was moved by hand, being swung from right to left and back again, each swing lasting about one second and covering an angle of about 60°, which was also the angle of the lens. The apparatus employed was an ordinary magazine plate camera, which for all ordinary purposes is the most convenient on account of the rapidity with which the plates can be changed, this being of great importance, because, as a rule, the time most favorable for obtaining good pictures is very short, seldom lasting longer than from ten to fifteen minutes.

Several more pictures were obtained in 1903. The three most interesting ones up to that year are shown in figures 1, 2, and 3. (See plates.) Figure 1 shows a flash obtained on July 17, 1902. The discharge took place between two clouds. It will be noticed that it is composed of a number of separate discharges (or rushes) and bands; as many as thirty-four can be counted on the negative. As the flash covers about half of the plate, and as the approximate speed of the camera was about one second to cover the plate, or 60°, it follows that the approximate duration of this flash was about half a second. Figure 2 shows a flash obtained on July 11, 1903. This flash is interesting for several reasons. It is composed of fourteen separate discharges, the first one being the brightest, and having side branches pointing downward, proving that the first discharge passed from the cloud to the earth and that the resistance which it had to overcome must have been excessive (the side branches prove that). At a distance of 3 millimeters from the first rush is another discharge following the same path, but without side branches (what appear as such are really branches from the first rush). At a distance of 12·5 millimeters from the last discharge will be seen two rushes 0·5 millimeter apart, and from there for a distance of 10 millimeters are a series of discharges close together, forming a broad band. The dark space which divides this flash is a cloud through which the discharge is passing. Another interesting fact about this flash is that the path of it is spiral shaped, the motion is from right to left, or opposite to the motion of the hands of a clock, looking downward from the cloud. Figure 3 was obtained October 1, 1903. We have here a flash composed, first, of two bright discharges close together, then there appears to be an interval of about a fourth of a second, which in all probability was filled in with a number of fainter oscillations (the lines running across seem to indicate that), and at the conclusion of the flash are four fairly bright rushes.

In the summer of 1904 copies of some of the photographs were sent to the Smithsonian Institution for examination, and through the suggestions and assistance of the experts of that Institution a new method of moving the camera was devised.

A spring-motor movement (of the kind used to operate revolving stands for exhibiting goods in show windows) was procured and mounted inside a table specially constructed for the purpose, and a stand for supporting the cameras was fitted to the central shaft.

As the speed of the motor was too slow, the fly-vane shaft was removed and the vane moved to the next shaft, which was lengthened so as to extend under the table. Thus arranged the fly vane could be made to revolve in a liquid placed in a vessel under the table, thereby preventing much of the vibration and getting a more uniform speed. Figure 4 shows the arrangement of the apparatus. The table top is removed in order to show how the motor movement is placed; the fly vane is seen under the table. The stand is usually revolved at a speed of one revolution in ten seconds, which the writer has found to be the most suitable for ordinary purposes. The reason for employing a motor movement with a uniform speed to move the camera is to ascertain the exact duration of a flash or the intervals between the rushes.

If the angle of the lens and the speed of the camera be known, it is a simple matter of measurement to ascertain the duration of a flash. The formula employed is as follows:

Call the angle of the lens (in degrees) $=A^\circ$
Time for one rotation of stand (in seconds) $=T$
Width of plate (in millimeters) $=W$
Width of flash measured on plate (in millimeters) $=N$

$$\text{Then time for flash (in seconds)} = \frac{\frac{A^\circ}{360}\times T}{W}\times N$$

The measurements should be taken from the middle of the plate, owing to the distortion of the lens.

A number of photographs have been taken by this method, and about nine out of ten show the multiplicity of a flash. The average number of rushes for each flash is about five or six, and the time varies from an almost instantaneous value up to about half a second for a complete discharge.

The most interesting discharge obtained is shown in figure 5. It was taken September 1, 1905, at 9 p. m. The storm during which this flash was photographed began about 7 p. m., with the wind northeast, which is something very unusual for Chicago. The wind gradually changed to north and northwest. The temperature during the storm was about 24° C., and the barometer varied between 29·89 and 29·92. The flash was obtained when the storm was most severe and while it was raining very hard.

This flash is composed of forty separate discharges, made up of one band, which in all probability is composed of a number of sepa-

rate rushes or oscillations very close together and one black discharge. It is this dark discharge which makes this flash interesting, and the photograph shows it running parallel and on both sides of the first bright rush, extending 0.6 millimeter on one side and 0.1 millimeter on the other, the boundary line on the latter side not being very marked. From this black discharge issue several side branches on both sides, a large one spreading out over the other rushes quite prominently. These side branches all pointing downward indicate that the black flash was a downward stroke, and they also tend to prove that it must have had a good deal of resistance to overcome. It must have cleared the way for the first bright discharge, which in all probability proceeded from the ground upward. The difference in width of the bright flash, measured at its lower and upper part, would confirm this opinion, being for the lower part 0.38 millimeter and for the upper part 0.22 millimeter.

An interesting question here presents itself. Have we here two separate discharges with different rates of oscillation traveling the same path? Can such a condition be possible? To the writer's mind the most plausible explanation would be that the two discharges occupied two separate paths, one inside of the other, one discharge forming, so to speak, a tube through which the other passed.

It may also be claimed that the bright flash is probably part of the dark discharge for some reason rendered more luminous. This explanation may be the true one, although it appears as if the bright flash is entirely separate. The measurements of the width of the upper and lower parts of both flashes confirm this opinion, the difference in width of the bright flash being 40 per cent and for the dark discharge only 20 per cent. Authorities vary in their opinions as to the probable cause of these dark flashes. It has been suggested by some that there really are no black discharges, but what appear as such are excessively bright flashes causing a reversal of the image on the plate. This explanation may be the true one if we understand the word "brightness" to mean increased actinic power of the light. In the black flash represented this chemical effect must have been extremely high, owing to the fact that the smallest hair-like extremities of the side branches are well reproduced on the picture as black, in comparison with the broader and to all appearance more powerful discharges which followed after.

It was at first thought probable that we had to deal with an interference phenomenon, but that idea was discarded. Then it was suggested that the black discharge was probably due to slow oscillations (the width of it would tend to confirm this opinion), and that what appeared as black on the plate would in reality be a dark red discharge on a partially illuminated background. This opinion had to be discarded for the reason that, if such be the case, the side

branches of the dark flash would have been obliterated by the other rushes following. The effect of halation and solarization was also considered, but rejected. There was thus but one way to account for the phenomenon, namely, that the flash must have given out light of a wave length much shorter than the wave lengths of visible light and with a power sufficient to render the portion of the plate struck by it nonsensitive to ordinary light. Such a flash would appear black on a partially illuminated background or be invisible.

Dark flashes have been observed by the writer on several occasions and only when raining very hard. They appear to the eye the same as the accidental image produced after looking at a bright flash. Such an image may be retained in the eye for quite a while after, but can not easily be confounded with a real flash.

Two other pictures of dark discharges have been obtained with the moving camera, but are not so prominent; they likewise show the first rush as black, but without a bright core and with no side branches; one is of a horizontal and the other a vertical flash.

Below is a table of the measurements of this flash. The angle of the lens was 60°. Time of rotation of camera, 1 revolution in 10 seconds. Width of plate, 127 millimeters. The width of the whole flash, 48 millimeters. Time for the whole flash, 0.624 second. The average distance between the rushes, 1.2 millimeters. Average time for each rush, 0.0156 second. The plate used was a "Standard" ordinary plate. The contrast of the picture has been increased by means of a double-contact print with lantern-slide plates. The developer was "Rodinal." Time for developing, five minutes.

Lightning flash (fig. 5).

Designation.	Distance.	Time.	Designation.	Distance.	Time.
	Mm.	*Second.*		*Mm.*	*Second.*
Width of black rush	1.0	0.0130	From fifteenth to sixteenth rush	0.5	0.0065
From first to second rush	2.6	.0338	From sixteenth to seventeenth rush	.6	.0078
From second to third rush	.2	.0026	From seventeenth to eighteenth rush	.5	.0065
From third to fourth rush	1.2	.0156	From eighteenth to nineteenth rush	1.3	.0169
From fourth to fifth rush	1.0	.0130	Width of nineteenth rush	.6	.0078
From fifth to sixth rush	1.0	.0130	From nineteenth to twentieth rush	1.4	.0182
From sixth to seventh rush	.7	.0091	From twentieth to twenty-first rush	.7	.0091
From seventh to eighth rush	.9	.0117	From twenty-first to twenty-second rush	1.4	.0182
From eighth to ninth rush	.9	.0117	From twenty-second to twenty-third rush	2.0	.0260
From ninth to tenth rush	1.7	.0221	Width of twenty-third rush	.4	.0052
From tenth to eleventh rush	.7	.0091			
From eleventh to twelfth rush	.6	.0078			
From twelfth to thirteenth rush	.9	.0117			
From thirteenth to fourteenth rush	1.0	.0130			
From fourteeenth to fifteenth rush	.7	.0091			

Lightning flash (fig. 5)—Continued.

Designation.	Distance.	Time.	Designation.	Distance.	Time.
	Mm.	*Second.*		*Mm.*	*Second.*
From twenty-third to twenty-fourth rush	0.6	0.0078	Width of thirty-third rush	0.6	0.0078
Width of twenty-fourth rush	.4	.0052	From thirty-third to thirty-fourth rush	.9	.0117
From twenty-fourth to twenty-fifth rush	.7	.0091	Width of thirty-fourth rush	.2	.0026
From twenty-fifth to twenty-sixth rush	.7	.0091	From thirty-fourth to thirty-fifth rush	.5	.0065
From twenty-sixth to twenty-seventh rush	.8	.0104	Width of band	.4	.0520
From twenty-seventh to twenty-eighth rush	1.0	.0130	From thirty-fifth to thirty-sixth rush	1.6	.0208
From twenty-eighth to twenty-ninth rush	.5	.0065	From thirty-sixth to thirty-seventh rush	1.6	.0208
Width of twenty-ninth rush	.4	.0052	Width of thirty-seventh rush	.9	.0117
From twenty-ninth to thirtieth rush	.7	.0091	From thirty-seventh to thirty-eighth rush	.4	.0052
Width of thirtieth rush	.4	.0052	Width of thirty-eighth rush	.6	.0078
From thirtieth to thirty-first rush	1.3	.0169	From thirty-eighth to thirty-ninth rush	.4	.0052
Width of thirty-first rush	.8	.0104	Width of thirty-ninth rush	.4	.0052
From thirty-first to thirty-second rush	.3	.0039	From thirty-ninth to fortieth rush	3.6	.0468
From thirty-second to thirty-third rush	.2	.0026	Total	48.0	.6240

In the summer of 1905 a new departure was undertaken by the writer at the suggestion of the Secretary of the Smithsonian Institution, the object being to obtain spectrum photographs of lightning.

Spectroscopic examinations of lightning have been made by many, but most of these observations have been visual, which at their best can only be rough approximations of the number of lines and their relative positions. As far as the writer knows, only one institution in the country—the Harvard College Observatory—had undertaken any work in photographing the spectrum of lightning.

A crude apparatus was constructed, consisting of a camera with a 35-millimeter prism fitted in front of the lens, no slit being used, as a lightning flash is a relatively narrow streak of light yielding a practically parallel beam. By means of this arrangement a few photographs have been obtained, two of which are reproduced in figures 6 and 7. A spectrum photograph of a spark from a static machine, for comparison, is shown in figure 8.

The spectrum shown in figure 6 is from a vertical flash, the picture of which was obtained June 18, 1905. It was about 1¼ miles distant and was taken at the end of a storm of local character. The spectrum of this flash resembles that from the static machine in most of its details.

Figure 7 shows the spectrum of one of those horizontal meandering flashes often seen at the conclusion of a storm of long duration. It was obtained September 1, 1905. It differs considerably from figures 6 and 8, several lines being absent. The first line of this spectrum is probably the same as the eighth line of the spark spectrum.

No definite opinion can at present be offered by the writer as to the meaning of these changes of the lines in the spectra of different flashes; more material must be obtained before a positive statement can be made.

Below is a table of measurements of the three spectra and their probable relations. Several measurements have been taken, and the average are here presented.

Spark (fig. 8).						Lightning (fig. 6).						Lightning (fig. 7).					
Line.	Intensity.	Width.	Distance.	Hyd.	Wave length.	Line.	Intensity.	Width.	Distance.	Hyd.	Wave length.	Line.	Intensity.	Width.	Distance.	Hyd.	Wave length.
		mm.	mm.					mm.	mm.					mm.	mm.		
1	2	0.1	0.87	H β	4,861	1	(?)	(?)		H β	4,861						
2	1	.05	.43						1.0								
3	3	.15	.62			2	1	([a])									
4	3	.15	.5						1.4								
[b]5	12	.25	.2														
[b]6	8	.15	.68	H γ	4,341	3	15	0.37	.70	H γ	4,341						
7	6	.3	.74			4	3	.12	.72								
8	12	.4	.87			5	10	.25	.85			1	8	0.25	0.5		
9	6	.2	.68			6	6	.25				2	8	.15			
10	1	.05	.40						1.08								
11	10	.25	.55			7	10	.28	.75						2.55		
12	6	.4	.85			8	3	.26									
[b]13	4	.25	.25						.65			3	8	.25	.45		
[b]14	4	.25	.5			9	3	.2	.75			4	6	.2	.55		
15	10	.3	.55			10	3	.2				5	2	.1	.4		
[b]16	4	.2	.2						.65			6	6	.2	.4		
[b]17	4	.2	.9			11	2	.2				7	5	.25	.75		
18	5	.4	1.3			12	2	.65	1.2			8	4	.3	1.3		
19	5	.6	1.6			13	2	.65	1.3			9	4	.25	1.5		
20	4	.6										10	4	.2	1.3		
												11	2	(?)			

[a] Band. [b] Double.

It may not be out of place here to give a few brief hints as to the best method for obtaining lightning photographs, for the benefit of the large number of amateur photographers scattered over the world. Thunder storms are nearly always cyclonic in their character, their diameter varying. When they extend over large areas it will usually be found that most of the vertical flashes are at the circumference of the circle through which the storm is passing. In the central part of a storm the flashes are usually horizontal, or passing between two

strata of clouds, therefore the best time for obtaining photographs is either at the beginning or the end of a storm. At the beginning the wind is usually very strong, hindering the work, so that it is generally best to wait until the front of the storm has just passed overhead and then to expose the camera from a window or other suitable place facing a direction opposite to that of the wind. In this way the camera as well as the person will be protected from the wind and rain. This rule holds good in most cases, although there are many exceptions, especially when the storm is local in character and of small extent. A person must be on the lookout at all times and note the direction in which most of the downward strokes appear and direct the camera toward them.

It is useless to expose plates when there is nothing but sheet lightning, for it will only result in spoiling them. Oftentimes there is a mixture of sheet lightning and a few scattered ground strokes at uncertain points. When that be the case, the chances for obtaining pictures are slight, the sheet lightning soon fogging the plates, the time for fogging in such cases being from five to ten minutes, depending on the frequency of the reflections. The best rule to follow is to wait until a favorable opportunity presents itself, when the flashes are about half a mile distant, then act quickly, have plenty of plates ready to insert in place of the exposed ones, and trust to luck. The best way of holding the camera when swung by hand is to place it close to the body, tilting it somewhat upward, so as to get as much as possible of the sky in the picture, and swinging the body from side to side. The time and angle of the swing can be regulated with a little practice so as to be fairly accurate, say one second to the swing, although the writer has found by experience that when a sudden flash appears in front of the camera the evenness of the swing will be somewhat disturbed, particularly if the flash is close to the observer, unless the person be in possession of unusually strong nerves. When pictures of horizontal flashes are desired the camera must naturally have an up and down swing. These flashes are usually less intense and the pictures of them sometimes require a very long time to develop.

The developer preferred by the writer is "Rodinal," being convenient and clean, although any good developer will do, particularly such contrast developers as "Glycin" or "Hydrochinon."

Different kinds of plates have been tried, but the writer has no special preference for any one of the standard plates. The orthochromatic plates do not seem to give better results than the ordinary ones. Films give trouble in developing, because each exposure must be developed separately.

Figure 9 shows the barometer devised by the writer, which he has found very useful in the study of the variations of the atmospheric

pressure preceding and during storms. The instrument recommends itself on account of the simplicity of its construction, its accuracy, and the ease with which the readings can be made, less than one two-hundredth part of an inch being easily read off without the aid of a vernier.

The instrument shown in the illustration consists of a glass tube, one-fourth inch inside diameter, 38 inches long, bent to an angle of 100° at a distance of 8½ inches from the closed end, filled with mercury, and mounted with the open end dipping into a reservior, which in this case is 1 inch in diameter. The open end can also be bent up to form a siphon barometer. The scale is placed along the upper slanting part of the tube. A pointer is fastened to the lower part of the instrument, the use of which is to indicate when it is in an exact vertical position, a mark on the wall indicating this position. The surface tension of the mercury is overcome by gently swinging the instrument and returning it to its vertical position. The calibration may be done by comparison with a standard instrument or by actual measurements. The bend of the tube may be made at a different angle, but should not be much less than 100° owing to the surface tension of the mercury. With this angle the instrument will magnify about six times, which has been found by the writer to be sufficient for ordinary use. The range of the instrument described is about 2 inches, and if a greater range is desired the slanting portion of the tube may be made longer or a different angle of the bend be substituted, although the proportions given have been found by experience to give the best satisfaction. A tube with a small internal diameter does not give good satisfaction owing to the surface tension being greater.

FIG. 1.—LIGHTNING FLASH TAKEN JULY 17, 1902.

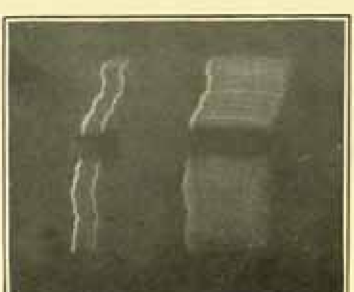


FIG. 2.—LIGHTNING FLASH TAKEN JULY 11, 1903.

FIG. 3.—LIGHTNING FLASH TAKEN OCTOBER 1, 1903.

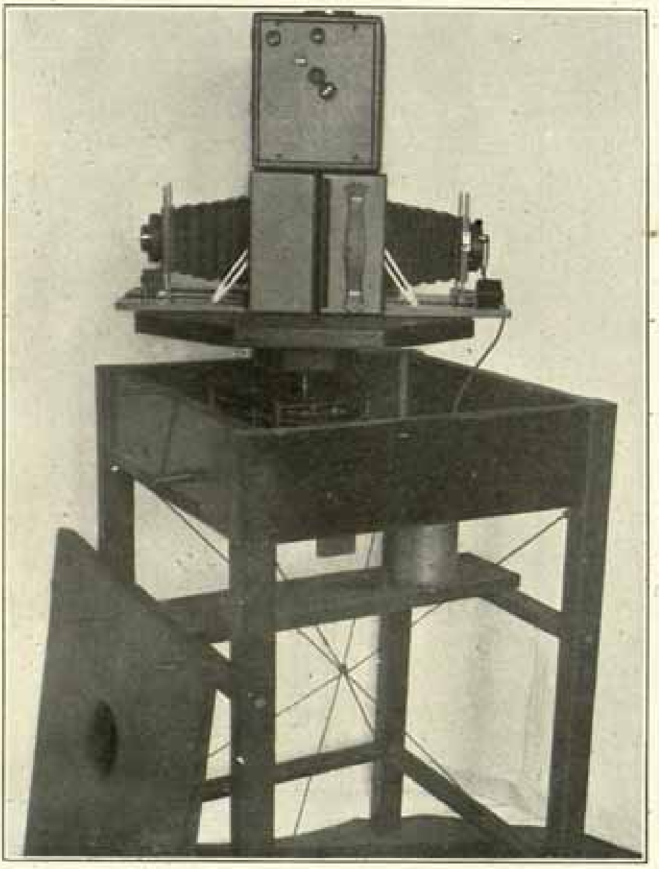
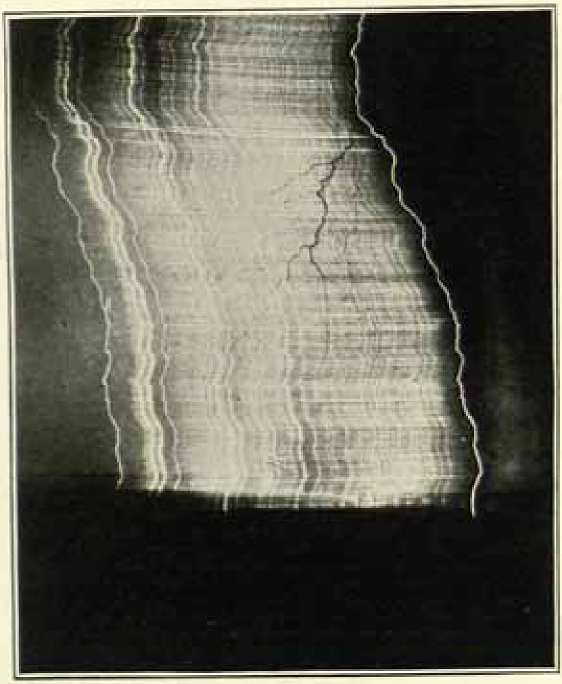


FIG. 4.—MOVING CAMERA APPARATUS FOR TAKING LIGHTNING FLASHES.



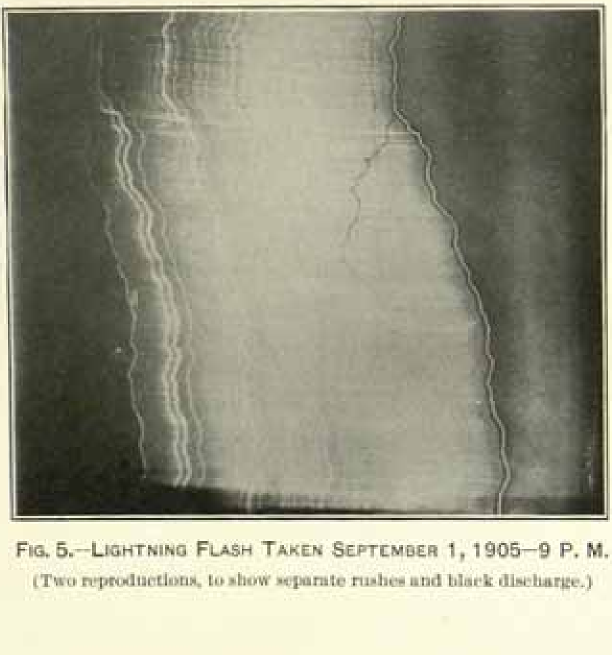


FIG. 5.—LIGHTNING FLASH TAKEN SEPTEMBER 1, 1905—9 P. M.

(Two reproductions, to show separate rushes and black discharge.)

FIG. 6.—SPECTRUM PHOTOGRAPH OF LIGHTNING FLASH, JUNE 18, 1905.

FIG. 7.—SPECTRUM PHOTOGRAPH OF LIGHTNING FLASH, SEPTEMBER 1, 1905.

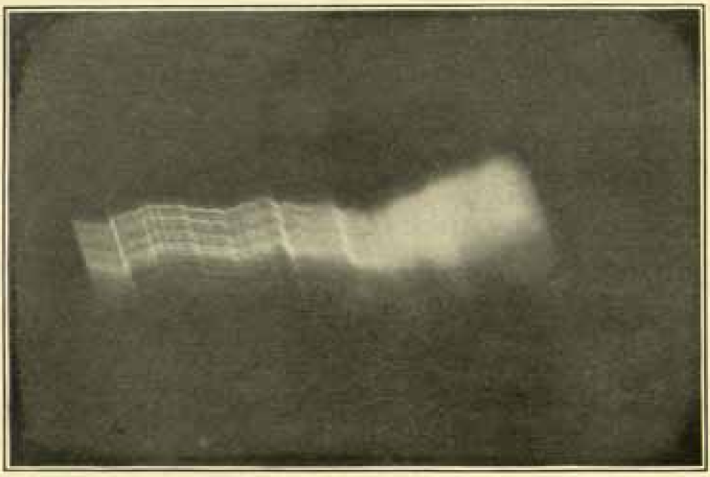


FIG. 8.—SPECTRUM PHOTOGRAPH OF SPARK FROM STATIC MACHINE.

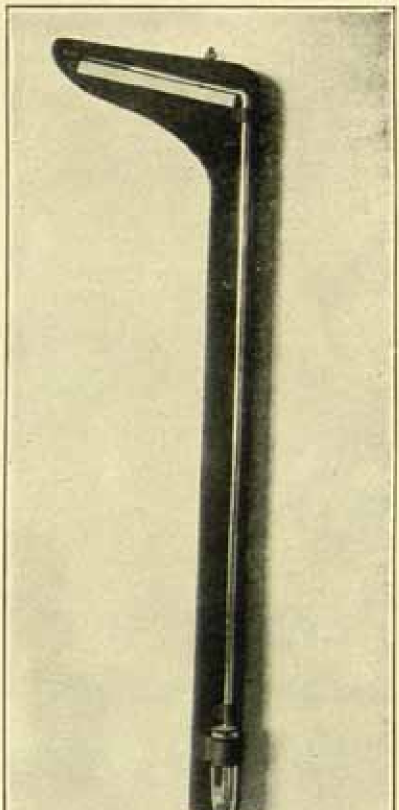


FIG. 9.—LARSEN BAROMETER.

THE TANTALUM LAMP.[a]

By Dr. W. von Bolton and Dr. O. Feuerlein.

Part I.—By Dr. W. von Bolton.

Whilst the carbon-filament incandescent lamp remained for nearly two decades the sole representative of glow-lamp manufacture, progress was being quietly made in this art. The firm of Messrs. Siemens & Halske has for many years been working at a solution of the problem of an economical incandescent lamp, and arrived, some time ago,[b] at the fundamental principle that the visible part of the radiation of an incandescent body increases progressively with its temperature. This warrants the postulate that the most economical lamp will be that whose incandescent material will withstand the highest temperature.

Messrs. Siemens & Halske had arrived at this conclusion and charged me several years ago with the task of discovering a material which should have a melting point considerably above the temperature at which incandescent lighting becomes highly economical, so that filaments made of such a material would not melt or disintegrate at that temperature. Whilst our laboratory work, founded upon this idea, was going on, the first two advances in incandescent lighting were made public, one being the "Nernst" and the other the "Osmium" lamp.

There are certain metals the melting points of which are known to be considerably above 2,000° C., and the task resolved itself into finding one which, while fulfilling the above requirement, could be easily worked to form a filament, and not be very rare or difficult to procure. It was early observed that brown vanadium pentoxide, which, according to Berzelius, does not conduct electricity, is, as a matter of

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[a] Translation (through the courtesy of Mr. Alexander Siemens) of a paper read before the Elektrotechnischer Verein of Berlin on January 17, 1905.

Reprinted, by permission, from the Electrician, London, No. 1393, Vol. LIV, No. 15, January 27, 1905.

[b] Cf. W. Siemens in Elektrotechnische Zeitschrift, Vol. IV., p. 107, 1883.

fact, a conductor even when cold. This observation induced me to try whether vanadic acid could not be electrolytically decomposed. In this I succeeded, but the melting point of the vanadium obtained proved too low for the purpose in view. Since the metals niobium and tantalum are members of the vanadium group, niobium having an atomic weight double that of vanadium, while the atomic weight of tantalum is double that of niobium, it was thought that one or both of these metals might prove to have the desired qualities. On experimenting with niobium on the lines adopted for vanadium it appeared that this metal has a considerably higher melting point than that of vanadium, but not, however, sufficiently high. Moreover, some of the niobium filaments which I made had a very strong tendency to break up when heated by the electric current.

Tantalum was tried next. I reduced potassium tantalo-fluoride in the manner prescribed by Berzelius and Rose and found that the finely divided tantalum so produced became fairly coherent on rolling, so that by this treatment metallic strips of it could be made. It was also attempted to work tantalum oxide into the shape of a filament by mixing it with paraffin and to reduce it directly into the form of a metallic thread. In these experiments there was observed for the first time a minute globule of molten tantalum, and this globule was of sufficient toughness to permit hammering and drawing into wire. Following out this observation, tantalum powder was melted in a vacuum, and then it was found that the highly heated metal parted with the gases it contained. In this manner I produced my first filaments of pure metallic tantalum, which were, however, very small. When these had been used in lamps with promise of good results, an attempt was made to devise a definite process of purification. The potassium tantalo-fluoride was reduced to metallic powder; this powder contains a small proportion of oxide and of hydrogen which is absorbed during the reduction. When the powder was melted in a vacuum the oxide and absorbed gas disappeared and a reguline metal remained; on carefully remelting this it became so pure that no appreciable impurities could be detected in it.

The chemical properties of this pure tantalum are very remarkable, and some of them are of such a nature as to lead me to suppose that nobody other than myself has ever had metallic tantalum in his hands. When cold, the material strongly resists chemical reagents; it is not attacked by boiling hydrochloric acid, aqua regia, nitric acid, or sulphuric acid, and it is also indifferent to alkaline solutions; it is attacked solely by hydrofluoric acid. Following the behavior of steel, when heated in the air it assumes a yellow tint at about 400° C., and the tint changes to dark blue when the tantalum is exposed for some time to 500° C., or for a shorter time to 600° C. Thin wires of the substance burn with low intensity and without

any noticeable flame when ignited. It absorbs hydrogen as well as nitrogen with great avidity, even at a low red heat, and forms with them combinations of a metallic appearance, but rather brittle. It combines with carbon very easily, forming several carbides which, as far as they are at present known, are all of metallic appearance, but also very hard and brittle. The product which Moissan thought to be tantalum was clearly a carbide of this nature or an alloy of a carbide with pure tantalum, for Moissan himself stated that his metal still contained one-half per cent of carbon. Considering the high atomic weight of tantalum (183) it is obvious that a very small quantity of carbon suffices to carburize a relatively large quantity of tantalum. This view of the constitution of Moissan's product is confirmed by the properties he ascribed to the metal—namely, specific gravity 12·8, great hardness and brittleness. These are not properties of pure tantalum. When in the form of powder, still containing, as previously stated, oxide and hydrogen, the specific gravity of my material is about 14; when purified by fusion and drawn into wire it has a specific gravity of 16·8. It is somewhat darker than platinum, and has a hardness about equal to that of mild steel, but shows greater tensile strength than steel does. It is malleable, although the effect of hammering is relatively small, so that the operation must be rather long and severe to beat the metal into a sheet. It can be rolled, as well as drawn, into very fine wire. Its tensile strength as a wire is remarkably high, and amounts to 95 kilograms per square millimeter, while the corresponding figure for good steel is 70 to 80 kilograms, according to Kohlrausch.

The electrical resistance of the material at indoor temperature is 0·165 ohm for a length of 1 meter and a section of 1 square millimeter (specific conductivity as compared with mercury 6·06). The temperature coefficient is positive and has a value of 0·30 between 0° C. and 100° C. At the temperature assumed by the incandescent filament in the lamp at 1·5 watts per candlepower, the resistance rises to 0·830 ohm for a length of 1 meter and a section of 1 square millimeter. The coefficient of linear thermal expansion between 0° C. and 60° C. is 0·0000079, according to experiments made by the Imperial Normal-Aichungs commission. Fusion is preceded by a gradual softening, which appears to extend over a range of temperature of several hundred degrees. The specific heat is 0·0365, so that the atomic heat is 6·64, which is in accord with the law established by Dulong and Petit.

Part II.—By Dr. O. Feuerlein.

The results of the work carried out in our chemical laboratory, as described by Doctor von Bolton in the first part of this paper, were, of course, of the utmost interest to our incandescent lamp manufac-

turing department. As soon as Doctor Bolton's experiments showed that the originally brittle tantalum could be made ductile enough to draw into wire by the usual methods, and that this wire could be bent and coiled like a thin steel wire, it became possible to test it thoroughly as to its usefulness for incandescent lamps. The first trials with wires of about 0·3 millimeter diameter gave most promising results. They confirmed the fact that tantalum has a very high melting point and that it is but slightly subject to disintegration in a vacuum, even when subjected to a heavy current.

The first tantalum lamp that proved moderately satisfactory in that it admitted of an exact measurement of the electric photometric conditions and stood a burning test for some time, was completed just over two years ago, viz, on December 28, 1902. This lamp had a loop-shaped filament made of the first tantalum wire ever drawn. The diameter of the wire was 0·28 millimeter, its effective lighting length 54 millimeters, and its electrical resistance when cold 0·29 ohm. This corresponds to a specific resistance (1 meter length, 1 square millimeter section) of 0·331. The photometric measurements made at efficiencies of 2, 1½, and 1 watt per Hefner candlepower showed potential differences of 4·9, 4·95, and 5·9 volts, currents of 5, 5·46, and 6·2 amperes, and illuminating values of 11, 18, and 37 Hefner candlepower, respectively. On being burnt at 1 watt per candlepower the lamp had a life of twenty hours, during which it blackened considerably.

As the chemical and mechanical manufacturing processes developed and the material became purer and the wires more uniform, the results obtained also improved. The lamps lasted longer and blackened less; at the same time the specific resistance decreased until it had dropped to the present figure of 0·165 for the pure metal. It is clear that the material used for the first lamps still contained a considerable quantity of impurities, probably niobium and carbides, which caused the great disintegration and the nearly double specific resistance. During these first trials we looked very carefully into the question as to what dimensions the filament of a tantalum lamp ought to have for ordinary voltages and illuminating values. From the dimensions of the filament used in the first lamp we calculated that, with this rather impure material, we should require a filament about 520 millimeters long and 0·06 millimeter diameter for a lamp for 110 volts, 32 Hefner candlepower, and 1·5 watts per candlepower. These unusual figures increased when the specific resistance of the material had diminished to the present value of 0·165, at which, for a 32 Hefner candlepower lamp, a filament of about 700 millimeters in length by 0·055 millimeter in diameter was required; for a 25 Hefner candlepower lamp a filament of about 650 millimeters by 0·05 millimeter diameter was required. Thus, in order to con-

struct a practical and useful lamp for standard voltages and illuminating values, we had to solve the problem of drawing the tantalum wire in sufficient length down to a diameter of 0·05 millimeter to 0·06 millimeter; this we succeeded in doing after long and laborious trials.

In July, 1903, we possessed the first tantalum lamp with a filament of about 0·05 millimeter diameter. It had a loop-shaped filament 54 millimeters long, and it took 0·58 amperes at 9 volts and gave 3·5 Hefner candlepower at 1·5 watts per candlepower. On the basis of these figures a lamp having the same quality and diameter of wire and working at the same efficiency on a 110-volt circuit would have a filament 650 millimeters long and would give 43 Hefner candlepower. The experiments thus far had proved that the task of producing lamps for 110 volts and a maximum of 25 to 32 Hefner candlepower was not an easy one in several respects. We had to solve the problem of suitably and reliably fixing a filament rather more than 2 feet long within a glass globe which should not exceed to any great extent the dimensions of the usual incandescent lamps. The first and most obvious attempt was made, of course, by adhering to the loop shape and accommodating the required length of wire by connecting several such bows in series within the lamp. However, lamps made according to this plan with two to four tantalum loops gave results which were anything but satisfactory.

It appeared that, like all other metallic filaments which have hitherto been used for incandescent lamps, tantalum wire softens sensibly at the temperature attained when worked at 1·5 watts per candlepower. To use loop-shaped or spiral filaments similar to the carbon filaments of the common incandescent lamps was, therefore, out of the question. There was no difficulty in suspending the loops, but in that case the lamps would have to be used exclusively in a vertical position, a limitation which we wished to avoid in all circumstances. Besides, such a construction would necessitate staying the loops firmly to prevent them from becoming entangled with each other during transport of the lamps. Nor did lamps made with loops of corrugated wire (fig. 1) or of plain or corrugated metal ribbon give satisfaction; for although the loops were certainly shortened in this way, there were other drawbacks which caused us to abandon this construction. It soon became apparent that the one road to success lay in the direction of dividing the filament into a number of short straight lengths supported at their ends by insulated holders. In this manner we succeeded at last, in September, 1903, in producing the first really serviceable lamps for about 110 volts. This lamp is illustrated in figure 2, and it will be seen that it contains two glass disks cast to a central wire holder; each disk carries laterally twelve arms having small hooks at their ends and insulated from each other. Through these

twenty-four hooks the thin tantalum wire is drawn up and down between the two disks. This is believed to be the first metallic incandescent lamp for nearly 110 volts which, like the common carbon glow lamp, can burn in any position whatsoever. This lamp supplied about 30 Hefner candlepower on a 94-volt circuit at 1·5 watts per candlepower. It lasted for 260 hours, and lost during that time 9·5 per cent of its illuminating power.

After this first practical success we redoubled our efforts to improve the lamp further. As far back as about the middle of October, 1903,

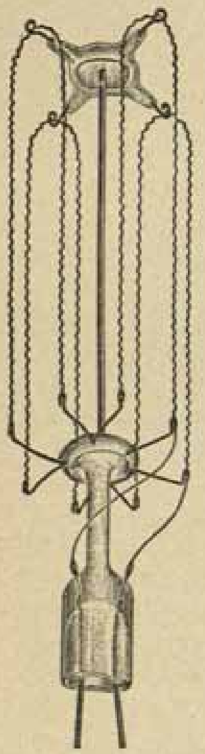


FIG. 1.—Lamp with corrugated filament.

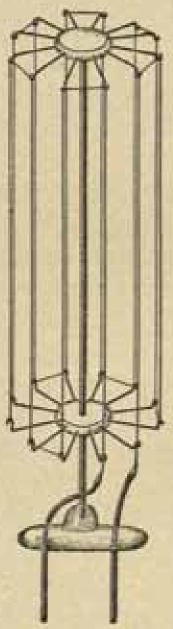


FIG. 2.—Early type of tantalum lamp.

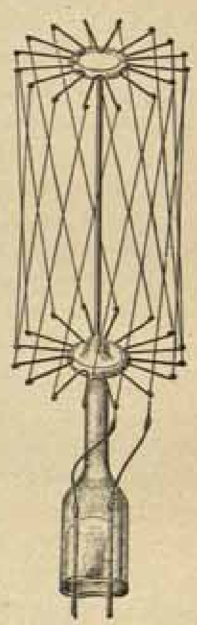


FIG. 3.—Tantalum lamp with filaments fixed obliquely.

we succeeded in making the first 200-volt tantalum lamp, which was of a design similar to the lamp just described, but with eighteen arms on each disk and with a greater distance between the two disks. I may add at once that it is of interest only as a curiosity, for it has served no practical purpose. The length of its filament was 1,350 millimeters and the illuminating value about 60 Hefner candlepower. In the course of further development the form of the frame of wire filament for the 110-volt lamp went through different stages, the principle of subdivision being always followed. Among other constructions, we tried some in which, instead of one long filament,

a number of short pieces of wire were fixed on a supporting frame: these pieces, connected in series, made up the total length required. Figure 3 represents a lamp thus constructed, the wire being fixed obliquely in sixteen straight pieces between two insulated supporting stars. Such lamps offer the advantage that short pieces of filament can be used in the manufacture, but they are only reliable if the wires used in the same lamp are absolutely uniform in diameter and quality. In the end we arrived at the shape represented in figure 4, which is for 110 volts, 25 candlepower, and 1·5 watts per Hefner candlepower. In this form, differing from most of the previous constructions, the central support consists of a short glass rod carrying two disks, into which the arms, bent upward and downward in the shape of an umbrella, are cast. The upper star has eleven, the lower twelve arms, each upper arm being in a vertical plane midway between the vertical planes in which two adjacent lower arms lie. Between these eleven and twelve arms, which are bent into hooks at their ends, the entire length of the filament is drawn in a zigzag fashion. Its extremities, held by two of the lower arms, are connected with the foot of the lamp by means of platinum strips.

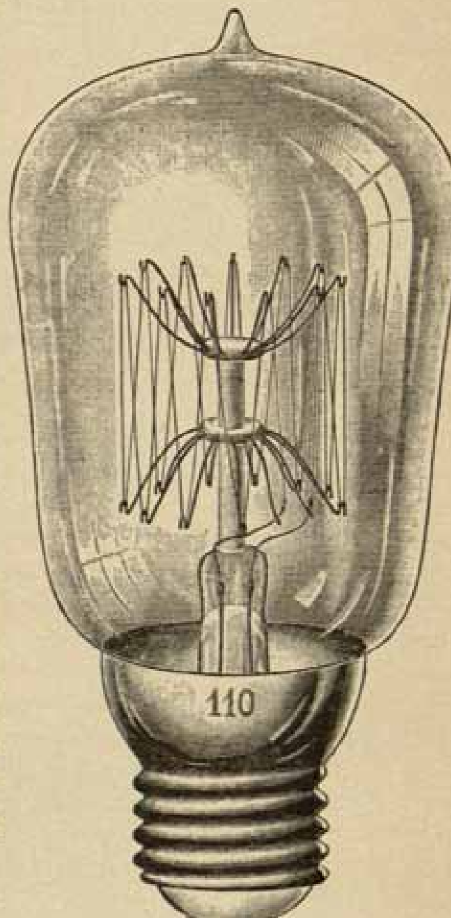


FIG. 4.—Complete lamp, full size.

The standard type for 110 volts 25 Hefner candlepower and 1·5 watts per candlepower has a filament 650 millimeters long and 0·05 millimeters in diameter. The weight of this filament is 0·022 gram, so that about 45,000 lamps contain together 1 kilogram of tantalum. The shape of the glass globe is adapted to the frame described above. Care has been taken to make it of a size not exceeding the usual maximum dimensions of common incandescent lamps of the same candlepower

(25 Hefner candlepower 110 volts). This shape offers a number of noticeable advantages. In the first instance it is very stable and will stand strong shocks without damage to the lamp. A considerable number of such lamps sent across the sea to test their ability to withstand the hardships of transport came back unhurt, although they had been packed just like common glow lamps, and no special care in any respect had been taken in their handling. The lamp burns, of course, in any position, and can therefore be held in any kind of fitting. The light is rather white and agreeable, and its effect is particularly uniform if the lamp is provided with a ground-glass globe.

We shall now proceed to describe the electric and photometric properties of the lamp and its behavior in actual use. Numerous trials for lengthy periods of time at 1 to 3 watts per candlepower have proved the vast superiority of the tantalum lamp over the carbon filament lamp under equal electric and photometric conditions. Expressing this fact in figures, we can state that the tantalum lamp consumes about 50 per cent less current at the same voltage, with the same intensity of light and the same useful life; or that, at the same economy, its life is several times that of the carbon type. Moreover, at an initial efficiency of 1·5 volts per Hefner candlepower the tantalum lamp has an average life quite sufficient for all practical requirements, so that this rating has been standardized for the 110-volt lamp. Trials have also proved that the lamps have a life of several hundred hours at 1 watt per Hefner candlepower, but in that case they were very sensitive to variations of pressure and often showed an early decrease of illuminating power. The useful life of the tantalum lamp—i. e., the time within which it loses 20 per cent of its initial illuminating power—averages between 400 and 600 hours at 1·5 watts per Hefner candlepower. Some specimens have proved to have a useful life of as much as 1,200 hours. The absolute life, in general, amounts to 800–1,000 hours under normal working conditions. Further, we have to remark that the tantalum lamp blackens but little unless it has been strongly overheated during work in consequence of partial short-circuiting of the filament.

It is very interesting to observe the behavior of the tantalum lamp during the whole course of its life. The first fact worthy of note is that, like some carbon lamps, the illuminating value increases at the beginning, generally after a few hours, by 15 to 20 per cent. In the same way the consumption of current rises by about 3 to 6 per cent, while the consumption of energy drops to 1·3 to 1·4 watts per candlepower. After that the illuminating value gradually decreases, while a corresponding increase of the consumption of energy occurs. The average behavior of the 25-candlepower lamp

at 110 volts with reference to its various periods of life is shown in the following table:

Life in hours.	Intensity of light in Hefner candle-powers.	Consumption of current in amperes.	Watts per Hefner candlepower.
0	25-27	0·36-0·38	1·5-1·7
5	28-31	0·37-0·39	1·3-1·5
150	25-27	0·36-0·38	1·5-1·6
300	22-24	0·36-0·38	1·6-1·7
500	20-22	0·36-0·38	1·9-2·0
1,000	18-20	0·35-0·37	2·1-2·2

The initial increase of illuminating value and of current consumed is doubtless caused by a change in the structure of the tantalum wire, this change being accompanied by a reduction of resistance and, consequently, of the phenomena resulting therefrom. We may say at once that after a certain amount of use the filament presents a radical change in appearance when viewed with the naked eye. While the fresh filament has a perfectly smooth and cylindrical surface, it acquires a peculiarly glistening aspect as it grows old, so that a lamp having served for some time can be readily distinguished from a new lamp. When looked at under the microscope, the filament that has burned for a length of time shows a clear tendency toward contraction and formation of drops or beads. Figure 5 is an illustration of a piece of filament in its fresh state and of the same piece after 1,000 hours of service, the specimen in each case being magnified one hundred times. This gradual shortening of the filament can also be observed in the lamps themselves, and offers a further indication of the age of a lamp.

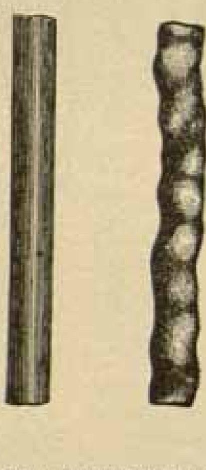


Fig. 5.—Tantalum filament, before and after 1,000 hours' use.

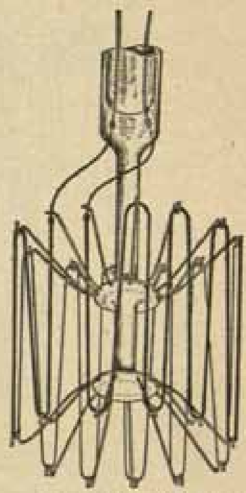


Fig. 6.—Filament frame of a new lamp.

Figure 6 represents the filament frame of a new lamp. It will be noticed that the tantalum wire is led up and down and hangs loose on the supporting frame in easy wide arches, without sharp bends.

But after being used for some time the aspect of the lamp is quite different. As shown in figure 7, the wire has contracted, the wide arches have disappeared and sharp-pointed angles have taken their place.

The behavior of these lamps is most peculiar when the filament has burnt through. While with all other incandescent lamps the burning through of the filament is tantamount to the economical death of the lamp, it may happen with tantalum lamps that they burn through several times without being rendered useless; on the contrary, each burning through is followed by an increase, often considerable, of the illuminating power. This peculiar result is due to the fact that in many cases a broken wire comes in contact with its neighbor, so that the circuit is again established. A part

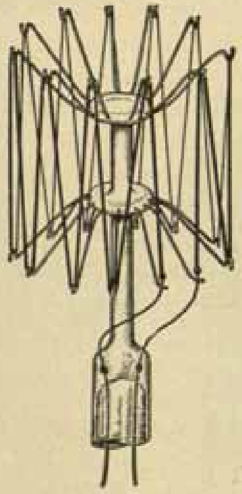


FIG. 7.—Appearance of filament after having been in use.

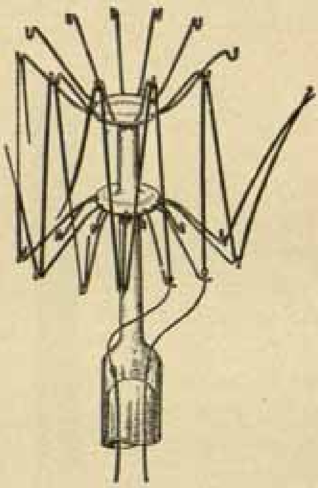


FIG. 8.—Filament frame, showing broken filament.

of the filament is thus cut out of the circuit, and the lamp consequently burns more intensely, and sometimes even too intensely, in which case, of course, only a short span of life is left to it. Yet we have had more than one lamp under observation, the filament of which broke for a first time after a short period of service and then broke repeatedly, but notwithstanding this the lamp lived more than 1,000 hours. We have often succeeded in rendering a lamp with a broken filament serviceable again by tapping it to bring the broken piece into contact with its neighbor. Figure 8 represents the frame of a lamp in which the filament was burnt through in three places, and yet continued to do service. For the sake of clearness, the back spans of the filament have been omitted in the drawing, while the front spans which were carrying the current are drawn in specially heavy lines.

It must further be mentioned that after serving for some time, say 200 to 300 hours, the tantalum filament loses a great deal of its mechanical resistance, while, as has been stated by Doctor Von Bolton, tantalum wire, when new, has a greater tensile strength than steel. It becomes brittle and will break easily in the course of its life as a filament. It is therefore advisable when lamps have served for some time not to remove them from their old fittings and put them into new ones, as that might easily cause the filament to break. New lamps are not very sensitive to strong shocks, even while burning, but when this alteration in the filament has occurred it is well to preserve them from shocks.

The behavior of the tantalum lamp under a very great increase of voltage is of special interest to the incandescent-lamp maker. As was to be expected, the trials made in this respect have also shown the superiority of this lamp over the carbon lamp. It has been ascertained that tantalum lamps for 110 volts, 25 Hefner candlepower and 1·5 watts per candlepower only burn through at 260 to 300 volts if the pressure is increased slowly and gradually, while with carbon lamps designed to work under the same conditions nothing like that figure can be obtained. The superiority of the tantalum lamp over the carbon lamp with regard to blackening of the glass globe can also be proved in a few hours by means of comparative burning tests at about 30 per cent overload.

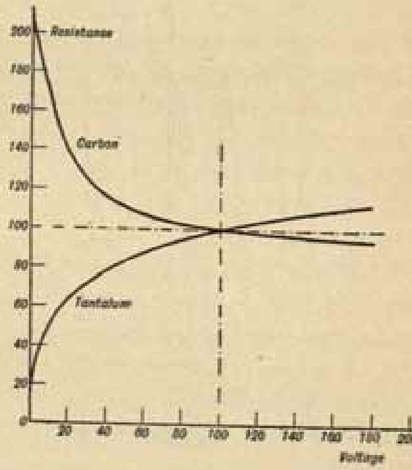


FIG. 9.—Variation of resistance with voltage of tantalum as compared with carbon.

Another advantage of the tantalum lamp over the carbon lamp is that the resistance of tantalum, like that of all other metals, strongly increases with the rise of temperature, while carbon is known to diminish in resistance when it is hot. In figure 9 the variation of the resistance of tantalum and of carbon as a function of the voltage is graphically represented, the pressure being assumed as 100 volts and the resistance at 100 arbitrary units when the efficiency is 1·5 watts per Hefner candlepower, so that for each per cent of variation of voltage the respective percentage of variation of resistance is shown. It will be seen in the first instance that the resistance of the tantalum increases to more than five times its original value from the cold state to 1·5 watts per Hefner candlepower, while the resistance of the carbon decreases to about one-half of its initial value. It will

further be noticed that even afterwards the resistance of tantalum goes on rising, while the resistance of carbon keeps dropping. Therefore the increase or decrease of pressure causes the strength of current, and with it the illuminating value, to rise or fall at a quicker rate in the carbon lamp than in the tantalum lamp, and, consequently, the latter is less sensitive to variations of pressure than the former.

Having thus related the whole history of the development of the tantalum lamp and fully entered into a critical comparison between it and the carbon filament lamp, we need scarcely add that we do not intend, of course, to be satisfied with what we have already obtained. For the time being, however, and until a larger building has been erected for the production of tantalum, our firm has resolved to keep to the type for which there is an immediate practical demand. That is the lamp for 100 to 120 volts, which supplies 25 Hefner candlepower at 110 volts, or will have a higher or lower illuminating value if worked at correspondingly higher or lower voltages. In conclusion, I would recapitulate the properties which we claim as peculiar characteristics of our invention as follows:

1. The tantalum lamp has a filament made of a metallic conductor, and burns at once on being connected without any previous heating.

2. The light-giving wire is prepared by melting in a vacuum and drawing. It is tough even in the cold state, and can therefore be coiled and fixed in the lamp when cold.

3. A relatively great length of wire can be placed in a simple manner within a bulb of ordinary dimensions.

4. Tantalum ore exists in considerable quantities and can be easily procured.

5. Similar principles of treatment can be adhibited to other metals of a very high melting point.

SOME REFINEMENTS OF MECHANICAL SCIENCE.[a]

By Ambrose Swasey, Cleveland, Ohio.

As we open this, the twenty-fifth annual meeting of the American Society of Mechanical Engineers, the history of the society for a quarter of a century comes before us, and it is an occasion when it is especially appropriate to make some mention of the growth and progress of the society since it was organized.

At the beginning of the society who would have dared to predict the wonderful advance that has been made in mechanical engineering. There was indeed a great field for work for just such a society. The long list of meetings which have been so fully attended and so valuable to the members; the transactions, with their records of addresses, papers, and discussions by men of experience in nearly every branch of mechanical engineering, and the constant growth of the society until at the present time it has a membership of nearly 2,900, all go to show that from the beginning it has been an earnest and progressive organization, and a most important factor in the progress of mechanical science and of the mechanic arts.

Not only those of us who were counted among its first members, but those who from year to year have been added to its membership, may well feel proud of its splendid record.

The scope and influence of the society, which has been constantly increasing in the past, will surely continue, and never was its future brighter than at present.

For the subject of my address I wish to speak of a few of those methods and mechanisms which have been developed and perfected to such a degree of refinement that they may be considered as almost beyond the practical, and yet were it not for such refinements they could not possibly be made to serve the utilitarian purposes which make them of such inestimable value to us all.

The division and the measurement of time is to-day, as it has been for ages, among the most important of the subjects affecting the welfare of mankind, and as time has rolled on and there has been a better

[a] President's address, American Society of Mechanical Engineers, December 6, 1904. Reprinted from author's corrected copy.

understanding of the laws governing the universe, nearer and nearer has been the approach to perfection in the working out of these difficult problems, but the many limitations surrounding them have always kept their full solution somewhere in the future.

The diurnal revolution of the earth, which gives the solar day, and the revolution of the earth around the sun, the solar year, are the arbitrary divisions of time marked off with the utmost precision by the celestial bodies; and while the length of the solar day has, from before the Christian era, been fairly well defined, the length of the solar year was but approximately known until within a few hundred years.

The length of the year as counted by the Julian calendar was too long by eleven minutes and fourteen seconds, and this error amounted to ten full days in the sixteen hundred years from the time the Julian Calendar went into effect until the introduction of the Gregorian calendar.

A few years ago, when visiting the Vatican Observatory, I was particularly interested in the Gregorian tower, which forms a part of the Vatican Library Building. After passing through a number of rooms which are used in connection with the observatory, when near the top of the tower, I was taken into the spacious and beautiful calendar room, the walls of which are covered with paintings of the highest order, executed centuries ago, under the direction of Pope Gregory XIII. In the center of the room and forming a part of the floor there was a large marble slab, on which was cut a fine line exactly in the true meridian, and upon the line was a special mark which indicated the altitude of the sun at noon of a certain day. On the south wall, near the top of the room, there was a small aperture through which the direct rays of the sun passed at noon, projecting a bright spot on the meridian line.

All of this had been planned and executed by the astronomers in order that they might demonstrate the necessity of reforming the calendar, and when at noon on the 11th of March, 1582, Pope Gregory saw that the altitude of the sun as shown by the beam of light was not for that particular day, but for the day ten days later, he directed that ten days be stricken from the calendar, and that day should be the 21st of March instead of the 11th.

With such precision had the astronomers determined the true length of the year that our present calendar, with its intercalations, will continue on for twenty thousand years with an error not to exceed a single day.

The line on the marble slab and the aperture through the wall of the calendar room were devices simple in the extreme, and in this day of instruments such a method would hardly be considered, yet they served their purposes admirably, and the placing of that line on the

true meridian, with an accuracy never before attained, was considered one of the greatest scientific achievements of that age.

Since an unknown time the day has been divided into twenty-four hours, and as civilization has advanced the greater has been the necessity for the utmost precision in the measurement of each hour with its subdivisions.

The sun dial is not only the earliest, but the most interesting of all the numerous arrangements that have been devised for measuring the divisions of the day. Notwithstanding its limitations, it has been a subject which has attracted the brightest minds for ages. Within these later years there has been a renewed interest in this ancient timekeeper, not only in copying the types of dials, which are valuable because of their antiquity, but in working out new forms. Recently a new dial has been invented by which the rays of the sun will indicate the true mean time for each day of the year with an error not to exceed one minute.

The hour glass, which came later, was considered a much more practical method, inasmuch as it could be used either day or night, and because its use was not confined to a particular location; however, as a timekeeper it was not satisfactory, even in those early days.

The clepsydra, or water clock, which is supposed to have been invented by the Greeks, was found to be a much better timekeeper than either the sun dial or hour glass, and it was a great step in advance toward the accurate measurement of time.

These water clocks are to this day used extensively in the East, more especially in China. Those first used by the Greeks consisted of two water jars so arranged that the water from the upper ran into the lower, and the time of day was determined by measuring the depth of water in the upper jar, and at sunrise each day the water was returned to the upper jar. In the city of Canton there is a water clock which has been running for eight hundred years, and at the present time it is the standard clock of that city. This clock consists of four water jars, each having a capacity of 8 or 10 gallons. The jars are placed one above the other in the form of a terrace, the three upper ones being provided with a small orifice near the bottom through which the water drops into the jar next below, and so on down from one to the other until the water reaches the lowest or registering jar. In this there is a float, to which is attached an upright, having graduations for the hours and parts of hours, and as the water rises the time can be determined by noting the height of the float in relation to the crossbar at the top of the jar.

In this improved form of water clock the variation in the flow of water due to the difference in height is overcome by having a series of jars, the outlet of the upper being so graduated that there is but

little variation in the height of water in the second jar, and in the third the height remains practically uniform, thus insuring a constant head for the water which drops into the registering jar. At the beginning of each day the water is taken from below and carried up a flight of steps to the top.

That such an arrangement has some elements favorable to the accurate measurement of time there can be no doubt. It certainly has the element of simplicity, and notwithstanding its long service, the only wear noticeable was confined to the steps leading to the upper jar.

Clocks of the present type, although used as far back as the twelfth century, and possibly earlier, were but fair timekeepers until several centuries later. Those which the astronomers used in their observatories at the end of the fifteenth century were so unreliable that modified forms of the clepsydras of the ancients were used, and as they did not prove to be satisfactory, most of the observations were made without the use of clocks.

Galileo's beautiful discovery of the isochronism of the pendulum from the swinging chandelier in the cathedral at Pisa was of great value in many respects, but in none more so than in its application to the measurement of time.

Soon after that great discovery the English clock maker, Graham, invented the mercurial pendulum, by which the variation in its length caused by the difference in temperature was fully compensated, and some years later Harrison, another English clock maker, invented a compensating pendulum, which consisted of a series of metal bars having different coefficients of expansion—so that two hundred years ago, as it is to-day, the pendulum was the nearest perfect of all the devices that have been employed for governing or controlling the motions of a clock mechanism.

Every part of the clock down to the minutest detail has been the subject of study and improvement, and clocks are made and adjusted with such precision and delicacy that in testing them the question is within how small a fraction of a second will they run. Not content with their marvelous performance when under normal conditions, some of the finest astronomical clocks are surrounded by glass or metal cases, in which a partial vacuum is maintained, and in order that the cases may not be opened or disturbed the winding is done automatically by means of electricity, the frequency of the winding in some cases being as often as once every minute. These clocks are set up in especially constructed rooms or underground vaults, where they are free from jar or vibration, where the temperature and barometric conditions remain practically constant, and where every possible precaution is taken to further minimize the errors of the running rate.

A clock in the observatory at Berlin has run for several months under these favorable conditions with a rate having a mean error of but fifteen one-thousandths of a second per day and a maximum error of thirty one-thousandths of a second per day.

Another clock, installed at the observatory of Case School of Applied Science, at Cleveland, running under similar conditions, also has a mean error of fifteen one-thousandths of a second per day, with a maximum error for several months of but twenty-two one-thousandths of a second per day.

These are notable examples of the present state of the art of clock making and show the wonderful precision with which minute intervals of time can be measured.

From the time of the invention of Peter Hele, in 1477, of the "Nuremburg animated egg," or "pocket clock," which required winding twice a day and varied an hour and a half in the same length of time, the development of the watch has kept pace with the "mother clock" and followed closely to it in time-keeping qualities.

These marvelous little machines, whether made at the homes of the peasants among the hills and mountains of Switzerland, where the skill required for making a single part has been handed down from generation to generation, or made in the great factories of this country, where fully 2,000,000 high-grade movements are turned out annually and where the skill of the workmen has been supplemented by modern methods and machinery, are, notwithstanding the difficulties attending their manufacture, produced so cheaply as to be within the reach of almost everyone.

The larger watch, or ship chronometer, with its escapement so delicately made and adjusted that it must always be kept in the same position, was greatly improved through the efforts of the British Government in 1714 by offering rewards of ten, fifteen, and twenty thousand pounds to any who should make chronometers that would run so accurately that the longitude of a ship at sea could be determined within 60, 40, and 30 miles. Harrison, the inventor of the compensating pendulum and the compensating balance, which is now used in watches, succeeded in making a chronometer which, after being tested on a long voyage, was found to run so closely that the position of the ship was determined within 18 miles, and he was therefore paid the full award of £20,000. That historic chronometer, which marked a new era in navigation, is now numbered among the treasures of the Greenwich Observatory.

Modern ships are equipped with chronometers so accurate and so reliable and with sextants of such precision that navigators can determine their position in latitude and longitude within a few miles. Therefore, with the increased speed of the powerful ships, carrying hundreds or even thousands of passengers, together with their val-

uable cargoes, the methods and instruments used in navigation have been so improved as to greatly diminish the dangers in crossing the seas.

The perfection attained in the measurement of time, which is of such great practical value in nearly every sphere of life, would not have been possible were it not for the even greater refinements that have characterized the methods and instruments used by the astronomer in determining the length of the day and of the year, which are the fundamental standards of time.

The division of the circle and the measurement of angles have ever been among the unsolved problems of the astronomer, yet in the instruments used by him circles have formed a most important part.

Long before the telescope was invented, Tycho Brahe, the Danish astronomer, "the founder of modern astronomy," constructed for his observatory instruments of various kinds having graduated circles and arcs of circles. His instruments for the most part were improvements on those used by Arabian astronomers in the eighth and ninth centuries, and these in turn were copied after similar instruments used by the Greeks and Egyptians a thousand years previous, and it is supposed that such instruments were used by the Chinese at an even earlier period, so that graduated circles have come down to us from the far-off ages.

The longer the radius the more accurate the graduations, was the principle upon which the early instruments were made. The Arabians in about the year 1000 built a sextant with a 60-foot radius and a quadrant with a 21-foot radius, but to Tycho Brahe is due the credit of constructing instruments having circles much smaller in diameter and graduated with a greater precision than ever before. It was by the use of such improved instruments of his own making, and by his observations which were made without a telescope or any means of magnification, that he was able to give the positions of a large number of stars within less than one minute of arc from the positions given by modern astronomers.

The graduation of an 8-foot mural circle in 1725 by Graham, of England, for the National Observatory, and of an 8-foot quadrant by Bird, in 1767, were notable steps in advance in the division of the circle and the measurement of angles; but these and similar instruments, although their efficiency was greatly augumented by the use of the telescope, have been supplanted by others more practical.

The first circular dividing engine was made in 1740 by Henry Hindley, of York, England, for cutting the teeth of clock wheels, and it is interesting to note that in the same year Huntsmann, another clockmaker, of Sheffield, invented the process of making crucible steel, that he might have a metal suitable for the springs of his clocks.

Of the several engines constructed later the one most successful and representing the greatest progress was that made by Ramsden in 1777. This engine, automatic in its movements, was made especially for graduating circles, and because of the great precision with which he divided the circles of the instruments used by the Government the board of longitude awarded him the sum of £615. A further and most potent recognition of the excellence of his work lies in the fact that all subsequent circular dividing engines have followed closely the same general principles of construction embodied in the Ramsden engine.

It is most gratifying to all those who are interested in mechanical progress that the Ramsden engine has been preserved throughout all these years and now stands in the Museum of the Smithsonian Institution at Washington as a monument to the one who made it and as the best example of that time of the art of graduating circles.

Many excellent dividing engines have been made that are quite sufficient in point of accuracy for the work for which they were intended, but the perfection required in the graduation of circles for astronomical instruments is such that it has been found to be one of the most difficult of all mechanical problems to make an engine that will meet such requirements.

In such an engine the chief essential is that the spindle carrying the master plate shall be as nearly round and as closely fitted in its bearings as is possible, for the degree of excellence with which that work is done determines how closely a circle can be divided.

It seems almost incredible that a well-lubricated spindle of 4 inches in diameter at its largest part and tapering three-quarters of an inch to the foot can be made so nearly round and so closely fitted in its bearings that a movement of one-thousandth of an inch in or out of its bearings will in one case cause it to turn with difficulty and in the other with perfect freedom; yet this has been found to be within the limits of mechanical refinements.

The greatest accuracy thus far attained in such engines is one second of arc, which arc, with a radius of 3 miles, equals 1 inch, and at 20 inches, which is the radius of the silver ring upon which the graduations on the master plate are made, a line one-thousandth of an inch in width is equal to twelve seconds of arc, or twelve times the accumulated errors of any number of divisions, or twenty times the greatest error of any single division.

In automatically graduating a circle, it has been found to be impracticable to cut more than six lines in a minute, and it requires about thirty-three hours to divide a circle into two-minute spaces. As with the running of the finest clocks, so only can the best results be obtained when the engine is surrounded with every favorable

condition possible. Instead of the large circles and sectors used by the ancients, circles of smaller diameter have been made as the methods for graduating have been improved, until those of the more modern instruments are seldom greater than 30 inches, and some of the latest meridian instruments have circles of but 25 inches.

The smaller circles, which can be made and graduated with greater precision than the larger ones, are also less liable to change in form, owing to their weight and the variation in temperature, and with the aid of the reading microscope the results obtained would not be possible with the larger circles.

A 25-inch circle read with a microscope having a power of 40 would be equivalent to a circle of about 80 feet in diameter, and a single second of arc as seen through the microscope would be equal to 0.0024 of an inch, a quantity easily subdivided.

A most important adjunct to the astronomer's instrumental equipment is the filar micrometer. With it he determines the errors of divisions, the eccentricity of his circle, and measures the angles to within a fraction of a second; and when used at the eye end of the telescope he determines the positions and motions of the stars and the distances and diameters of the planets. In these little instruments, whether of the simple or complex form, the chief requisites are the screw and the cross wires, for upon them the value of the observations and measurements depend.

To make the screw of a micrometer so true that the errors in the threads can not be detected by its own magnifying power is an extremely difficult task. These micrometer screws are often made with 100 threads to the inch, and are provided with graduated drums having 100 divisions, the readings being made in tenths of a division.

The cross wires, which are but common spider lines, because of their fineness and the remarkable qualities they possess, are indispensable in micrometric work.

That the repulsive and even dangerous spider has plenty of enemies among the human family there can be no doubt, yet if the value of the contributions which it has made to the cause of science was generally known, it would surely have a greater number of friends than at present, and most certainly the astronomer will say naught against it; for after the experience of many years he has found that the spider furnishes the only thread which can be successfully used in carrying on his work.

The spider lines mostly used are from one-fifth to one-seventh of a thousandth of an inch in diameter, and in addition to their strength and elasticity, they have the peculiar property of withstanding great changes of temperature, and often when measuring the sun spots, although the heat is so intense as to crack the lenses of the micrometer eyepiece, yet the spider lines are not in the least injured.

The threads of the silkworm, although of great value as a commercial product, are so coarse and rough compared with the silk of the spider that they can not be used in such instruments.

Platinum wires are made sufficiently fine, and make most excellent cross wires for instruments where low magnifying powers are used, yet as the power increases they become rough and imperfect.

Spider lines, although of but a fraction of a thousandth of an inch in diameter, are made up of several thousands of microscopic streams of fluid, which unite and form a single line, and it is because of this that they remain true and round under the highest magnifying power.

An instance of the durability of the spider lines is found at the Allegheny Observatory, where the same set of lines in the micrometer of the transit instrument has been in use since 1859.

The placing of the spider lines in the micrometer is a work of great delicacy, and in some micrometers there are as many as thirty, which form a reticule, with lines two one-thousandths of an inch apart and parallel with each other under the highest magnifying power,

Step by step, from the methods of the Arabian astronomers to the time of Tycho Brahe and on down to the present day, improvements in the instruments and methods for the measurement of angles have been going on, until astronomers can measure double stars with a separation of one second of arc, and within less than one second they can define their positions in the heavens.

In the realm of the measurements of minute linear distances and the perfection of curved and flat surfaces the refinements are even greater than those pertaining to the measurement of time and of angles.

Most important in the linear dividing engine is the screw, and although much had been accomplished in bringing such engines to a high degree of excellence, it was for Professor Rowland to make an engine which has a practically perfect screw; and without doubt it is in all respects the nearest perfect of all the mechanisms that have been employed for ruling lines exactly parallel and equally spaced.

The Rowland engine was made especially for ruling diffraction gratings which are made of speculum metal, and with it a metal surface has been ruled with 160,000 lines, there being about 29,000 to the inch, and as many as 43,000 lines to the inch have been ruled.

The gratings mostly used have from 14,000 to 20,000 lines to the inch, and with such exactness is the cutting tool moved by the screw that the greatest error in the ruling does not exceed one-millionth of an inch.

The production of these gratings, which has enabled the physicist in his study of the spectrum to enter fields of research before unknown, has not only called for the highest degree of perfection ever attained in the spacing of linear distances, but it has also called for

a refinement most difficult in the optical surfaces upon which the lines are ruled. To Mr. Brashear was given the problem of producing such surfaces, and notwithstanding the many difficulties encountered in working and refining the speculum metal plates, he has made many hundred plates with surfaces either flat or curved with an error not to exceed one-tenth of a wave length of light, or one four-hundred-thousandth of an inch.

As the established standards of length, which are the yard of Great Britain and the meter of France, are made of metal and liable to destruction or damage, Professor Michelson conceived the idea of determining the lengths of these standards in wave lengths of light, which would be a basis of value unalterable and indestructible.

For the purpose of carrying out these experiments the Interferometer was constructed—an instrument which required the highest order of workmanship and the greatest skill of the optician. Again Mr. Brashear proved equal to the occasion, and made for the instrument a series of refracting plates, the surfaces of which were flat within one-twentieth of a wave length of light, with sides parallel within one second. This was the most difficult work ever attempted in the refinement of optical surfaces.

Professors Michelson and Morley devised a method for using the Interferometer to make the wave length of some definite light an actual and practical standard of length. So satisfactory was the result that Professor Michelson was invited to continue the experiments at the bureau of weights and measures at Sèvres, France, where the standard meter, which is kept in an underground vault and inspected only at long intervals, was used for that important work. The final result of the experiments, which occupied nearly a year, shows that there are 1,553,164.5 wave lengths of red cadmium light in the French standard meter at 15° C. So great is the accuracy of these experiments that they can be repeated within one part in two millions. Should the material standard of length be damaged or destroyed the standard wave length of light will remain unaltered as a basis from which an exact duplicate of the original standard can be made. These two marvelous instruments, the Rowland dividing engine and the Michelson Interferometer, show the possibilities in the perfection of linear divisions and the standards of length.

We have recounted some steps of the progress that has been made in the measurement of time, of angles, and of length, together with some of the refinements in these measurements, but we are confronted with the fact that notwithstanding all that has been accomplished from centuries past down to the present time there are, as ever before, many imperfections requiring new problems in mechanical science to be worked out for the further enlightenment and welfare of mankind.

PROGRESS IN RADIOGRAPHY.[a]

By L. Gastine.

The X rays were discovered during the closing months of the year 1895, so that but a brief time has been available for the study of their use, though these few years have been fruitful ones.

We must recognize at the start that the subject has been greatly favored by its element of the marvelous, which appeals so keenly to the public at large. Scientific men know well that prior work of numerous physicists had already prepared the way for Roentgen's half-accidental discovery, but these advances had been cheerfully ignored by the masses, and even by most physicians and surgeons throughout the world.

Very naturally, then, when it became positively known that with the X rays the skeleton of the hand could be photographed there was excitement everywhere, for it will be recalled that the bones of the hand were the first invisible solid bodies reproduced by Roentgen. The image thus obtained demonstrated an important fact, the permeability of opaque bodies by the new rays, and on account of the uncertainty as to their character they were christened "X rays."

With this new process objects were photographed incased in wood (as a compass in its box), money in a purse, the wheels of a watch through its case, and what not; and these amazing experiments served incidentally to demonstrate that the permeability of solid bodies varies with the character of the substance. It was learned, for instance, that wood, plaster, cloth, paper, are easily traversed by these rays, while metals are less penetrable, especially glass and lead.

While investigators were establishing empirically by rather trifling experiments the comparative permeability of different substances, the medical world was amusing itself making attempts to radiograph various parts of the human skeleton. In every civilized country experiments showed the power of the rays to penetrate the hands, the feet, the arms, the legs; and decided it was hardly possible to go further; the head forming a recalcitrant mass, the torso and abdomen

[a] An abridged translation, by permission, from articles in La Photographie Française, Paris, 1905.

giving only uninteresting and indistinct images. This together with the fact that only imperfect silhouettes at best could be obtained, calmed somewhat the zeal of a majority of curious practitioners. Most of those who for a moment had anticipated finding in the new discovery a valuable method of research were disappointed, and condemned it utterly.

The excess of curiosity and anticipation naturally resulted in a reaction, which was accentuated by the organization of enterprises for public exhibition, where for a few cents or even for nothing, anyone was shown whatever part of his body he wished to see, or he was given a picture of such part of his skeleton as could be easily radiographed.

Although this commercial exploitation did little for the good name of radiography, and in some cases resulted in personal injury by burning the patient, yet it served at least to advertise it widely. Happily, however, while this popularization of Roentgen's discovery was going on, truly scientific research occupied the attention of many serious and competent persons. Students took up the application of radiography to anatomy, then to medicine and surgery, and to some of them it seemed to be a simple operation. Apparently all that was necessary was an electric current, a Ruhmkorff coil, a Crookes tube, and some ordinary photographic plates with the simple chemicals for developing them. Such was the reasoning with the advent of radiography. It has not yet greatly improved, though, despite misapprehensions and misuses, radiography has continued its progress. Physicists like Villars perfected the Crookes tube; technicians like Contremoulins devised exact instruments for their practical application. Indistinct images were superseded by radiographs of admirable clearness in which the most delicate details of the bone structure were exactly reproduced.

The radiograph was in time applied to the skeletons of mice, fish, snakes, frogs, to small mummies, fossils, and shells. Finally a successful attempt was made to penetrate the more bulky parts of the human body. As early as 1896 investigators had obtained silhouettes not only of the bones but also of the more or less penetrable parts of the organism, like the heart and the lungs. These successes encouraged more vigorous attacks on other portions, and with special methods they finally overcame obstacles and rendered possible radiographs of parts of the skull, the muscles, and even of the arterial system in the hand. It is only fair, however, to state that most of this progress was made in the laboratory of the Faculty of Medicine, at Paris, and the results were scarcely known by the majority of those busily engaged in making radiographic researches by less scientific methods. Anxious merely to get good pictures, and without accurate knowledge of the physical, geometrical, and anatomical conditions which must

REPRODUCTION, REDUCED, OF ONE OF THE FIRST RADIOGRAPHS OF THE HAND, MADE EARLY IN 1896.

RADIOGRAPH OF HAND, MADE BY M. G. CONTREMOULINS, 1897.

necessarily be taken into consideration, these operators groped their way to an ability to make radiographs, more or less clear to be sure, but often deplorable as indications of actual conditions, for the pictures failed to show what ought to be shown, and sometimes even showed what was not existent.

The experimenters could of course make nothing of these deceptive errors, for in the medical world particularly, questions of pure physics and geometry are by no means clearly understood. An eminent member of the Academy of Medicine voiced, therefore, the sentiments of a great number of his confreres when he declared that the radiograph was likely to err gravely and that its indications were of little value. He even went so far as to say that no two radiographers could take similar radiographs of the same fracture. That this last statement is true in practice, although theoretically erroneous, has been demonstrated experimentally before another learned assembly by the production of radiographs of a fracture, taken at various angles, in some of which the incidence was normal, in others oblique. To understand the real fallacy of the case in question it is only necessary to realize that since the radiograph is only a conic projection of certain shadows these shadows will necessarily vary according to the angle at which they are projected, a fact which makes all radiographic deformations and exaggerations easily appreciable. For instance, when walking along the street in the evening your shadow from some gaslight grows longer and longer as you increase your distance from the lamp-post. About noon, shadows are short; as the sun sinks toward the horizon the rays strike objects more obliquely and the shadows are elongated. These elongations are due to the angle of the rays of light; they illustrate exactly how two fragments of fractured bone radiographed at too oblique an angle may unite to form a single silhouette, the elongation of the shadows making a continuous image, and thus hiding the fracture.

The distance between the fractured member and the photographic plate, and between the member and the Crookes tube, also plays an important part in the formation of the radiographic image. In throwing "Chinese shadows" on the wall with the hands it is quickly evident that the silhouette is very small when the hand is close to the wall, and that it grows rapidly when the hand is moved toward the light. The same principle is true in radiography. If, as often happens, the ends of the fracture are far apart, the fragment nearer the light gives an exaggerated shadow in the radiograph, which joins the normal shadows of the more distant portion and effectually conceals the break. Or if, as they more frequently do, the two ends overlap, the radiograph will, of course, should the fracture have been reproduced from a position beneath which the bones over-

lap, give an image without a break; but, on the other hand, should the fracture be reproduced from a point at right angles from the first position, the break in the bone will show plainly. In other words, taken from in front, the fracture will be hidden, if the ends overlap in that position, while it will appear clearly if the fracture is radiographed from the side, because the broken ends will then be one beside the other.

These theoretical and experimental demonstrations determined clearly the technique for this kind of radiography. It is: (1) To take not one but two radiographs of every fracture or suspected fracture, these radiographs to be taken at different points about 90 degrees apart; (2) to place the fractured bone as close as practicable to the photographic plate, and the Crookes tube perpendicularly above as far as possible from the fracture and thus avoid distortion. This is the method of procedure which obtains in all laboratories worthy of the name, and radiographs taken in accordance with it give little basis for the statements of the belittlers of the process.

If the rays employed are not penetrating enough for the case in hand, the imperfection of the image will be so great as to prevent the suspected break being seen as it should, and if, on the contrary, the rays be too penetrating, the sensitive plate will not produce a good image. Too many interruptions in a given time for a given case will destroy the shading of the image, and, reciprocally, the image will be too feeble if the number of interruptions is insufficient. And each case requires an appreciation of its peculiar factors of penetration and quantity. I will not even mention the problems regarding the sensitiveness of the emulsions for the plate, the thickness of the films, the qualities and faults of the developers, fixers, printing papers, or of the difficulties in developing and printing.

You have already surmised, no doubt, from the points we have just touched upon that mere ability to get an image does not constitute a radiographer. A perfect knowledge of the geometric laws governing the formation of shadows is indispensable; not a theoretical knowledge, but a practical acquaintance which will enable one to operate rationally and to interpret logically the images obtained under carefully observed conditions. Moreover, the skillful practitioner must have a perfect knowledge of the forms and exact proportions of the bones or other parts to be observed, so as to be able to recognize and appreciate the almost inevitable radiographic deformation, and to distinguish it from real malformation in the parts themselves.

Besides this exact knowledge of geometry and anatomy, the radiographer must be a clever electrician to understand the complex physical phenomena which govern the formation of X rays in the Crookes tubes. A Crookes tube emits X rays of greater or less penetration in proportion to its state of vacuum, and according to the

number of interruptions per second in the current which forms the electric discharges in the tube, the image is quickly or slowly formed on the photographic plate.

To make a radiograph when one has the proper materials at hand is a physical experiment which any college student can perform as easily as he can bring about a simple chemical reaction. But as this student would be utterly incapable of making a quantitative or qualitative chemical analysis, no more can he carry out a rational radiographic research to determine even the simplest fracture. This comparison is not an idle one, for just as a man is not a full-fledged chemist when he knows how to make a single kind of analysis, a man is by no means a really competent radiographer because he can get a good radiograph of a fracture of the arm or leg.

There are as many different methods of radiographing as there are different cases to be treated, and the processes vary with the nature of the subject. A broken bone in the hand is not approached in the same way as is a fracture in the foot; the thigh is a good deal more difficult to radiograph than the forearm; and a break in the neck of the femur, for instance, is one particularly difficult to determine. Certain simple fractures almost reproduce themselves—that is to say, despite the incompetence of the operator—while others, where the bone is not much displaced, are exceedingly elusive.

Radiography, however, does not concern itself entirely with broken bones; it reveals innumerable other organic alterations. Before taking up any of its principal applications in surgery and medicine, let us glance for a moment at its utilization in locating foreign substances in the body.

The human body would seem to be in little danger of accidental penetration by extraneous substances, but as a matter of fact these penetrations are not uncommon, especially in the larger cities. In Paris, for instance, hundreds of people have needles, pins, bullets, grains of lead, pieces of money, or metallic splinters extracted from their muscular tissues, intestines, stomach, œsophagus, eyes, and even from the brain itself, which is, contrary to the general opinion, easily explored by modern methods without fatal results.

All searches for foreign substances in these various parts of the body require a most exact localization, for it is necessary to know just where the object is before operating with scalpel and forceps. To understand the complexity, let us imagine the patient is the victim of a footpad, brought unconscious to the hospital. He has been shot in the chest; the wound is plain enough. In the hope that the ball has not penetrated far the surgeon probes, but finds nothing. The bullet has gone deep; possibly it is near the heart or some other vital organ. In such a case it would be dangerous to grope blindly with the proble, and a radiograph localization becomes necessary.

Or, in another instance, a victim of despair has turned his weapon on his own heart. The probe moves cautiously, for its direction seems to indicate that the attempt was successful. But no; the ball has turned aside; the probe encounters some unbroken tissues not far from the surface. Here again the radiograph is necessary.

The direction of entry of a projectile is too frequently but little indication of its direction in the body. A ball aimed at the heart may be found in the intestines or the lower back, or a bullet entering the right temple is lodged on the left, after having rebounded into the interior of the cranial cavity.

When an undesirable object has been swallowed, it is, of course, not very difficult to foretell the road it will travel, but to know the position of these capricious tourists at any given moment is difficult. Many of them halt en route; and these are just the ones it is necessary to look after. The radiograph must be called into service.

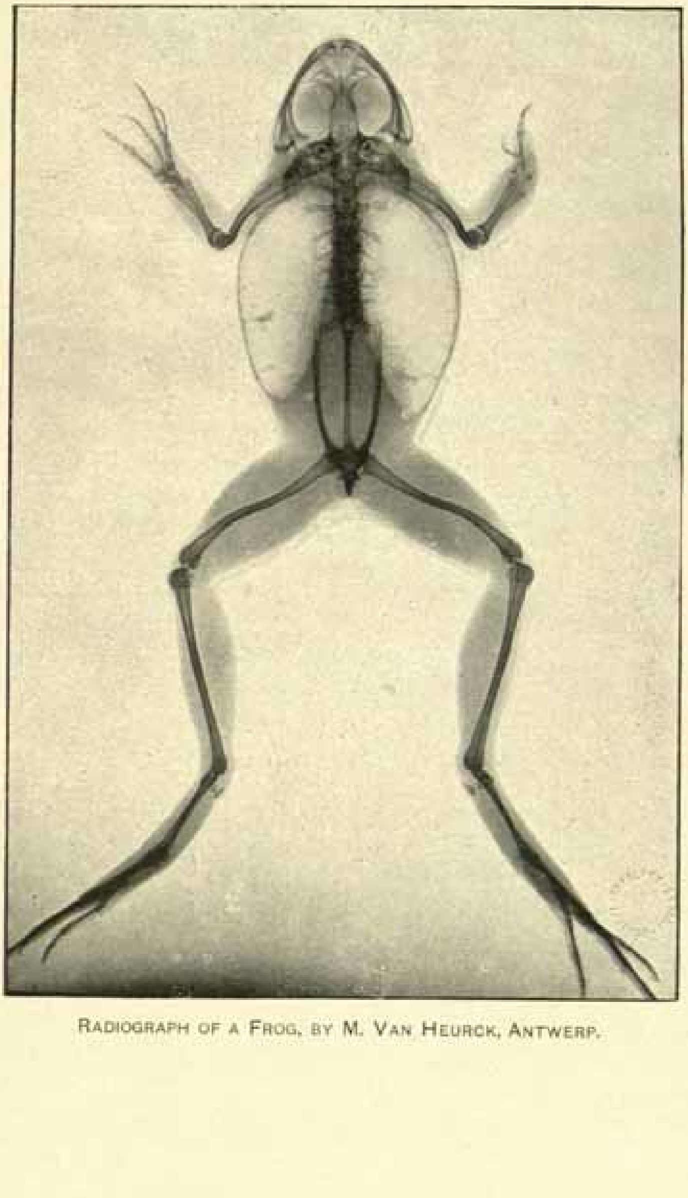
The treacherous needle, entire or broken, enters the muscular tissues. You think it can not be far from the surface. It is a great mistake. Try if you will to extract it; the needle travels. Let us examine this strange game of hide and seek; whether broken or not the needle has at one end a very sharp point and at the other a blunter extremity which penetrates with more difficulty. If it be a broken end, it will not penetrate at all save in the softest tissues. Therefore each movement, each muscular contraction, drives the sharp point deeper and deeper, and as its blunt end will permit no retreat the needle advances, traveling ceaselessly in most unexpected directions. To remove it, a most exact localization is necessary, since a needle is a small object to begin with, and when embedded in a heavy muscle a surgeon has the utmost difficulty in discovering it with ordinary instruments.

The extraction of any foreign body calls likewise for a most precise localization; only the exact knowledge of the whereabouts of such a body will reduce the operative interference to a minimum.

The method of locating projectiles lodged in the skull, devised in 1897 by Monsieur Contremoulins, has solved with a marvellous degree of precision the question of exact localization. The principles of this method are explained by the inventor in an article published by the Revue Internationale d'Électrothérapie et de Radiographie (pl. VIII, fig. 1):

Given a head containing a projectile "x," we begin our determination of the exact position of the bullet with reference to the skull. On any three points of the face we apply the extremities of the three branches of a compass (*a*, *b*, *c*), which are attached to *a'*, *b'*, *c'*. On the right of the head is the photographic plate E E'; on the left the two Crookes tubes *L L'*, held constantly in the same relation to the head and the plate.

Now, if we operate successively the two tubes we will have the shadow of the projectile "x" on two different points on the plate *E E'*. (These points



RADIOGRAPH OF A FROG, BY M. VAN HEURCK, ANTWERP.

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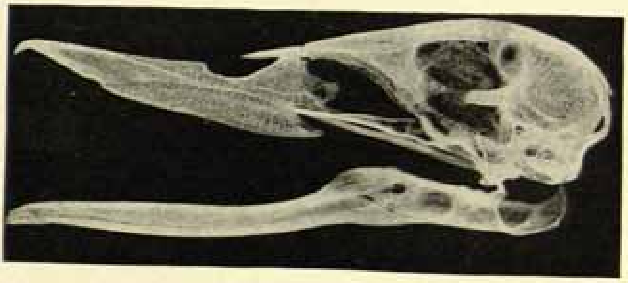

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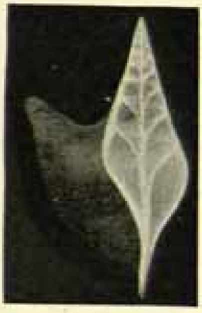

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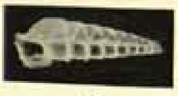


7

ZOOLOGICAL AND PALEONTOLOGICAL APPLICATIONS OF THE RADIOGRAPH, MADE BY M. G. CONTREMOULINS.

1. Head of Parroquet.
2. Head of petit rongeur (note details of teeth in the maxillaries).
3. Head of canard.

4-7. Fossil shells show the internal construction without destroying the specimen.

are designated in the illustration by the letters p p' for the tube L, and p'' p''' for tube L'.)

Then if we can determine exactly the position of the two sources of light on one hand, and, on the other, find the exact centers (l l') of the two shadows on the plate, we can stretch two lines—say, of fine wire—from the center of the lights to the center of the shadows; and these two lines will intersect at a point in space which represents exactly the center of the projectile.

Suppose, now, that the two radiographs are completed. We can withdraw the head of the subject without disturbing in the least the relations of the compass, the Crookes tubes, and the photographic plate. Then we may stretch our two wires from the tubes to the shadows and obtain with the most perfect exactness the position of the center of the projectile with reference to the face of the subject, or, what amounts to the same thing, with reference to the extremities of the three branches of the compass, which represent the position of the face in space while the radiographs were being taken.

Finally, if we attach to the body of the compass an adjustable needle which will exactly indicate the intersection of the two wires (the center of the ball) we will have all the elements necessary for finding the hidden missile.

Such is the theory. In practice it is, of course, necessary to have a special apparatus adapted to all heads, which through its perfect rigidity insures the maintenance of the relative positions of the branches of the compass, the Crookes tubes, and the photographic plate.

As this article is not a comprehensive treatise on radiography we will not attempt to explain any of the essential operations—the marking on the subject's face of the points touched by the compass, the exact determination of the center of light of the X rays in order to place the wires, or the adjustment of the articulated fourth branch of the compass with its needle end.

When all these operations are accomplished the compass, with its three stationary branches and its needle indicator, will, as we have said, show the exact position of the projectile. This instrument might be used to guide the operation of extraction, but in practice it is replaced by an almost exactly similar "compass of extraction," which may be sterilized and therefore more safely guide the surgeon in his work.

The patient is etherized, the operation compass is applied so that its three branches correspond exactly with the three points marked on his face. Then the needle indicator on the fourth arm shows to the surgeon (a) in what direction he must cut to find the projectile, (b) by the distance between the sliding adjustment and the needle point how deep he must go to extract it. To simplify the operation, the compass has two needles, one regulated by the other. This allows the surgeon to choose the most suitable point for an incision. This point decided, the scalp is cut away and the skull laid bare and opened by trepanning.

As many times as he may need its guidance the surgeon can place the sterilized compass on the subject's head; and, finally, when the

needle can glide to the extremity of its course *its point touches the projectile.* The surgeon has then only to draw it out with his forceps.

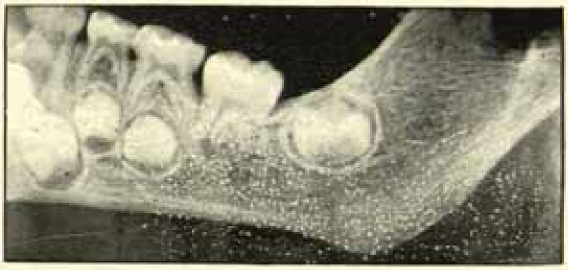
So precise is this method and so accurate are the instruments that fragments of grains of lead have been withdrawn from the brain. The localizations it achieves are rigorously exact—to the half millimeter. Altogether it renders so practicable intracranial operations formerly considered impossible that one of our most celebrated surgeons acknowledged it a guiding light which renders easy and safe the extraction of hidden projectiles.

By the same geometric method, somewhat simplified and with modified apparatus, the exact location of foreign bodies lodged in any part of the body may be discovered. Also, as will easily be seen, since this method gives a precise indication of a single point, it will do similar service for a series of points. A projectile encounters a bone and flies into fragments, a subject has been struck by several bullets, a bone is shattered into splinters; in any of these cases the various parts are located with as much precision as is the single ball.

The number of exact localizations that the radiograph can make is almost unlimited. In practical radiography this ability to take a number of observations is very valuable, especially in the case of malformation, for it permits an exact determination of the contour of the bony matter and of faults of conformation.

Thus metroradiography permits of exact measurements of all parts of the organism which give clear images under the X rays. It bears the same relation to simple radiography that quantitative chemical analysis does to qualitative; that is to say, in most cases in medicine, as well as in surgery, a knowledge of the nature of the case is as nothing compared with a knowledge of the importance of the case.

Early in the article we noticed that in spite of the disfavor into which radiography had fallen through misdirected activity, yet a few serious physicists continued their work and obtained now and then remarkable results, which have done much to redeem the good name of radiography. A great part of the progress must be attributed to two men, whose names should always be recognized—the physicist Villars, and Chabaud, the perfecter of the Crookes tubes. Among the radiographers themselves should be cited A. Londe, who, during the early years, did worthy work in his photographic studies at Salpêtrière. His efforts were directed toward the better selection and installation of radiographic material and then toward perfecting it and employing it with more method. To him we are indebted for the first practical treatise, which although superseded and discredited in part, was of much interest in its day. Unfortunately, however, after a few years of radiography, Monsieur Londe gave up his operations at the Salpêtrière.



LEFT SIDE OF LOWER MAXILLARY OF A CHILD OF 7 YEARS.

Radiograph by M. G. Contremoulins in 1896. The permanent teeth lodged in the maxillary appear below the milk teeth that they will replace.

RADIOGRAPH OF THE ARTERIES IN THE FINGERS.

RADIOGRAPH OF THE MUSCULAR SYSTEM OF THE HAND, MADE BY M. G. CONTREMOULINS, 1897.

From the very discovery of the X rays, Monsieur Contremoulins, at that time preparator to the Faculty of Medicine, has by the employment of reasonable and scientific methods attained the best results, which have been described in his numerous communications to the academies. He was the first to obtain clear images of the cranium, the thorax, and the pelvis. While studying with the late Dr. V. Lemoine on the possible applications of radiography to zoology and paleontology, he made marvelous images of bony structures and radiographs of fossils, which have never been surpassed. Applying the X rays to anatomical study, he obtained by injections of metal into the vessels clear radiographs of the arteries and their ramifications in the finger tips. Images of the muscles of the hand he got in a similar manner.

I do not wish to neglect in this article any of those who are working with radiography, and who, through their publications or their communications to the learned societies, are accredited with having created something good or interesting. If I fail to mention them, I will appear partial, which I am not; if, on the other hand, I do cite them by name, I must necessarily characterize with a word or so the value, defects, or insignificance of their work.

Doctor Béclère has written and spoken much on the X rays, especially on radioscopy, which must not be confounded with radiography. In this connection let us look for a moment at the principles of radioscopy. Under the action of X rays from a Crookes tube a screen treated with platinocyanide of barium is completely illuminated. Now, if a hand is interposed between the Crookes tube and this screen, the image of the hand will appear on the screen, not, however, as a mere silhouette, but with the flesh, muscles, nerves, and veins, and bones shadowed more or less deeply according to their resistance to the rays. Thus may be seen on the screen the bones of the thorax, and some of its organs, like the heart, whose movements may be discerned without difficulty.

Such a method of investigation and analysis is naturally seductive. Whether it is really as valuable as radiography is a many-sided question and one which I hardly care to discuss here; so I content myself for the present with a single statement. The radioscope in a limited number of cases, such as the study of the movements of the thoracic organs, is of incomparable value and in a few other cases is complementary to the radiograph.

Doctor Guilleminot is the author of a really original and thorough work on chronoradiography. The value of his method and its processes is another question I am unwilling to attempt to settle; facts are already beginning to indicate a lack of success, but time alone will determine its legitimate place.

Marie and Ribaut have given much study to a method of investigation and X ray analysis based upon stereoscopy. These experiments are by no means lacking in interest, their radioscope-stereoscope being particularly meritorious, though experience has demonstrated, especially in the case of extracting projectiles, that human vision, however perfect it may be, is a poor substitute for a mechanical guide to the location of the foreign body.

Doctor Bouchacourt is the author of a method of investigation with the X rays which he calls endodiascopie (ἐνδον, from within; διά, through; σκοπειν, to examine). He employs specially constructed Crookes tubes, which are introduced into the body through the natural apertures. The tube projects a silhouette on a screen (endodiascopy-radioscopy) or on a plate (endodiascopy-radiography) of the parts of the organism coming between it and the screen or the plate.

Marie and Cluzot, James Makenzie, Davidson and Hedley, Mergies, Leduc, Massiot, Maunory, and others are also engaged in endeavors to work out problems in various directions of research.

The science of the application of the properties of the X rays to the analysis of the human body is an admirable and valuable development, but one around which, unfortunately, harmful misapplications have clustered since its beginning.

In conclusion, the utilization of the X rays in medicine and surgery since its inception with Roentgen's discovery has developed into a science essentially exact, precise, and certain—a science with which you especially must sympathize because in its highest form radiography has borrowed so much from photography. Moreover, it is a science to interest us all, because it is constantly being called upon to play a more or less important rôle in the relief of those ills the flesh is heir to.

But learn how to discriminate between the good and the bad methods of applying the X rays; discover how to select the rational and valuable processes of analysis; begin this by noting that simple radiography and metroradiography are capable of meeting every exigency.

The skeleton is perhaps the part of the human organism that may best be studied with radiography and metroradiography. The radiograph pictures the bones of the infant as soon as they begin to form, before birth even. Although these observations during gestation may not be of any general interest, it is of great value to the parents to know that their child has a well-formed skeleton. While the bones of the infant are still soft a close watch on their development may permit the prevention or reduction of malformations which might be difficult to correct later. Parents anxious about their children's

health should have them radiographed systematically when very young and at various stages in their growth. These regular inspections will reveal, long before it becomes apparent otherwise, rickets, leprosy, tuberculosis, or syphilis of the bones, Paget's disease, osteomalacia, bony tumors, dislocations, arthritis, gout, flat foot, rheumatism, hip disease, spinal disease, and a score of other more or less common troubles.

At all ages the human being is exposed to the introduction of foreign substances into his body, either by natural entrances or through penetration of the skin. The infant swallows pieces of money or other small objects in his play; the adult accidentally swallows a variety of tiny things, and besides is very much more likely than is the infant to be struck by a projectile or to cut himself with bits of metal or of glass. The radiograph, and in special cases the radioscope, discovers these foreign bodies; metroradiography locates them exactly and insures their easy and safe extraction.

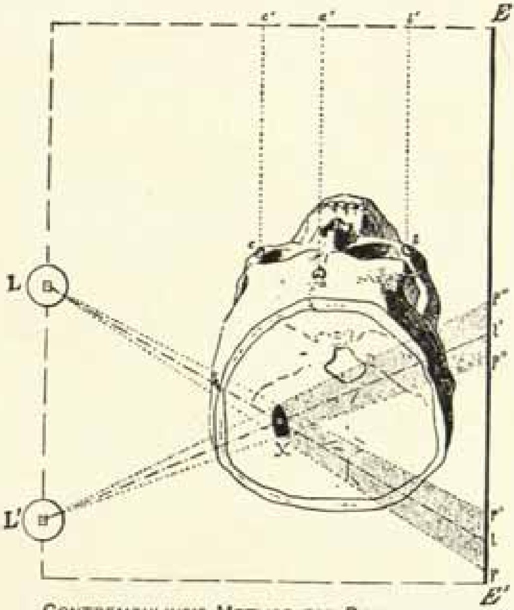
Splinters of bone, detached bits of cartilage and tendon, growths in the muscles, intestines, renal and other calculi may also be mentioned among foreign bodies that embarrass the human organism, and which can be located through the agency of the X rays.

In heart troubles radiography and metroradiography furnish most valuable indications. But in this case the radioscope, which allows the observer to follow the movements of the organ, has an exceptional and unequaled value. In examining the lungs, however, to discover tuberculosis, phthisis, pulmonary sclerosis, and pleuritic affections the radiograph alone gives delicate and certain indications. It reveals pulmonary tuberculosis long before any symptoms are seen, and often early enough to permit a cure.

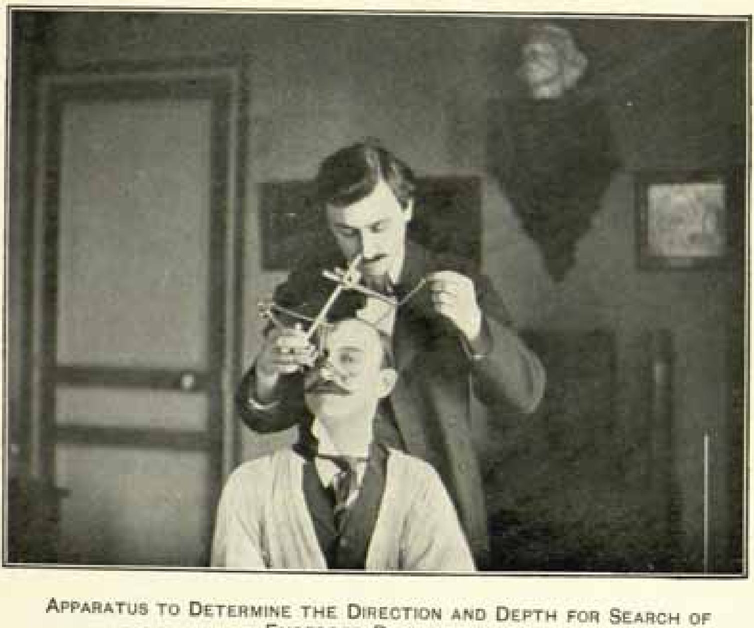
The radiograph gives clear images of certain abscesses, and shows exactly the extent and limits of any necessary operation. As to the state of the teeth and maxillary bones of children and adults it furnishes information of great importance, especially in cases of dental anomalies, abscess, abnormal growth, the cause of certain neuralgias, etc.

Finally, for several years past the X rays have been used in the treatment of certain maladies such as lupus, acne, cancer, and even of tuberculosis, and have generally seemed to have a helpful influence. But this last utilization, which naturally implies an exact appreciation of the character of the rays, is a matter to which physicians have not given enough care, since they have employed them without sufficient data as to their curative power.

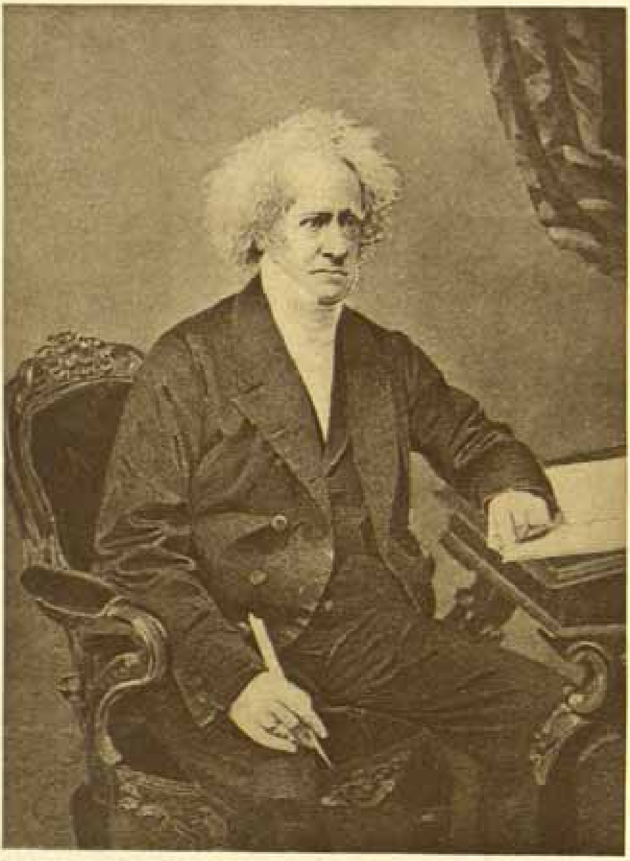
RADIOGRAPH OF THE ARTERIAL SYSTEM OF THE HAND, MADE BY M. G. CONTREMOULINS IN 1896.



CONTREMOULINS'S METHOD FOR DETERMINING LOCATION OF OBJECTS IN THE HEAD.



APPARATUS TO DETERMINE THE DIRECTION AND DEPTH FOR SEARCH OF EMBEDDED PROJECTILE.



SIR J. F. W. HERSCHEL.

Reproduced from Uranium print.

HISTORY OF PHOTOGRAPHY.[a]

By Robert Hunt.

I. The Photographic Processes on Paper of Sir John Herschel.

The researches of Sir John Herschel have been principally directed to the investigation of the physical laws which regulate the chemical changes we have been considering. His analyses of the prismatic spectrum have been most complete, and as far as they have been carried out go to prove the operation of forces other than those with which we are acquainted.

At the same time, however, as this philosopher has been engaged in investigations of this high order, he has from the multitude of his experiments been successful in producing several processes of great beauty. There are not any which are to be regarded as peculiarly sensitive—they are, indeed, for the most part rather slow—but the manipulation required is of the easiest character, and the results are most curious and instructive.

The philosophy which is forever united with the scientific investigations of Sir John Herschel is too valuable to be omitted from any description of the processes which he recommends. The following quotations are, therefore, taken from his communication to the Royal Society, and linked together by my own remarks in such a manner as it is hoped will be most easily understood by the unscientific amateur.

CYANOTYPE.

The processes in which cyanogen is employed are so called. Sir John Herschel makes the following remarks on the subject of his experiments with the cyanides:

> I shall conclude this part of my subject by remarking on the great number and variety of substances which, now that attention is drawn to the subject, appear to be photographically impressible. It is no longer an insulated and anomalous affection of certain salts of silver or gold, but one which doubtless, in

[a] Extracts from A Manual of Photography, by Robert Hunt, fourth edition, London and Glasgow, 1854.

a greater or less degree, pervades all nature and connects itself intimately with the mechanism by which chemical combination and decomposition is operated. The general instability of organic combinations might lead us to expect the occurrence of numerous and remarkable cases of this affection among bodies of that class, but among metallic and other elements inorganically arranged instances enough have already appeared and more are daily presenting themselves to justify its extension to all cases in which chemical elements may be supposed combined with a certain degree of laxity and, so to speak, in a *tottering equilibrium*. There can be no doubt that the process in a great majority, if not in all, cases which have been noticed among inorganic substances is a deoxidizing one so far as the more refrangible rays are concerned. It is obviously so in the cases of gold and silver. In that of the bichromate of potash it is most probable that an atom of oxygen is parted with, and so of many others. A beautiful example of such deoxidizing action on a nonargentine compound has lately occurred to me in the examination of that interesting salt, the ferrosesquicyanuret of potassium, described by Mr. Smee in the Philosophical Magazine, No. 109, September, 1840, and which he has shown how to manufacture in abundance and purity by voltaic action on the common or yellow ferrocyanuret. In this process nascent oxygen is absorbed, hydrogen given off, and the characters of the resulting compound in respect of the oxides of iron forming, as it does, Prussian blue with protosalts of that metal, but producing no precipitate with its persalts, indicate an excess of electro-negative energy, a disposition to part with oxygen, or, which is the same thing, to absorb hydrogen (in the presence of moisture) and thereby to return to its pristine state under circumstances of moderate solicitation, such as the affinity of protoxide of iron, for instance, for an additional dose of oxygen, etc.

Paper simply washed with a solution of this salt is highly sensitive to the action of light. Prussian blue is deposited (the base being necessarily supplied by the destruction of one portion of the acid and the acid by decomposition of another). After half an hour or an hour's exposure to sunshine a very beautiful negative photograph is the result, to fix which all that is necessary is to soak it in water in which a little sulphate of soda is dissolved to insure the fixity of the Prussian blue deposited. While dry the impression is dove color or lavender blue, which has a curious and striking effect on the greenish-yellow ground of the paper, produced by the saline solution. After washing the ground color disappears and the photograph becomes bright blue on a white ground. If too long exposed it gets "over sunned" and the tint has a brownish or yellowish tendency, which, however, is removed in fixing, but no increase of intensity beyond a certain point is obtained by continuance of exposure.

If paper be washed with a solution of ammonio-citrate of iron and dried, and then a wash passed over it of the yellow ferrocyanuret of potassium, there is no immediate formation of true Prussian blue, but the paper rapidly acquires a violet-purple color, which deepens after a few minutes, as it dries, to almost absolute blackness. In this state it is a positive photographic paper of high sensibility and gives pictures of great depth and sharpness, but with this peculiarity, that they darken again spontaneously on exposure to the air in darkness and are soon obliterated. The paper, however, remains susceptible to light and capable of receiving other pictures, which in their turn fade, without any possibility (so far as I can see) of arresting them, which is to be regretted, as they are very beautiful and the paper of such easy preparation. If washed with ammonia or its carbonate, they are for a few moments entirely obliterated, *but presently reappear with reversed lights and shades*. In this state they are fixed, and the ammonia, with all that it will dissolve, being removed

by washing in water, their color becomes a pure Prussian blue, which deepens much by keeping. If the solution be mixed, there results a very dark violet-colored ink, which may be kept uninjured in an opaque bottle, and will readily furnish by a single wash at a moment's notice the positive paper in question, which is most sensitive when wet.

It seems at first sight natural to refer these curious and complex changes to the instability of the cyanic compounds, and that this opinion is to a certain extent correct is proved by the photographic impressions obtained on papers to which no iron has been added beyond what exists in the ferrocyanic salts themselves. Nevertheless, the following experiments abundantly prove that in several of the changes above described the *immediate action* of the solar rays is not exerted on these salts, but on the iron contained in the ferruginous solution added to them, which it deoxidizes or otherwise alters, thereby presenting it to the ferrocyanic salts in such a form as to precipitate the acids in combination with the peroxide or protoxide of iron, as the case may be. To make this evident, all that is necessary is *simply to leave out the ferrocyanate* in the preparation of the paper, which thus becomes reduced to a simple washing over with the ammonia-citric solution. Paper so washed is of a bright yellow color and is apparently little, but in reality highly, sensitive to photographic action. Exposed to strong sunshine, for some time indeed, its bright yellow tint is dulled into an ochery hue or even to gray, but the change altogether amounts to a moderate percentage of the total light reflected and in short exposures is such as would easily escape notice. Nevertheless, if a slip of this paper be held for only four or five seconds in the sun (the effect of which is quite imperceptible to the eye, and, when withdrawn into the shade, be washed over with the ferrosesquicyanate of potash, a considerable deposit of Prussian blue takes place on the part sunned and none whatever on the rest, so that on washing the whole with water a pretty strong blue impression is left, demonstrating the reduction of iron in that portion of the paper to the state of protoxide. The effect in question is not, it should be observed, peculiar to the ammonio-citrate of iron. The ammonio and potassia-tartrate fully possess and the perchloride, *exactly neutralized*, partakes of the same property, but the experiment is far more neatly made and succeeds better with the other salts.

In further development of these most interesting processes Sir John Herschel says:

The varieties of cyanotype processes seem to be innumerable, but that which I shall now describe deserves particular notice, not only for its preeminent beauty while in progress, but as illustrating the peculiar power of the ammoniacal and other persalts of iron above mentioned to receive a latent picture, susceptible of development by a great variety of stimuli. This process consists in simply passing over the ammonia-citrated paper on which such a latent picture has been impressed, *very sparingly and evenly*, a wash of the solution of the common yellow ferrocyanate (prussiate) of potash. The latent picture, if not so faint as to be quite invisible (and for this purpose should not be so), is negative. As soon as the liquid is applied, which can not be in too thin a film, the negative picture vanishes, and by very slow degrees is replaced by a positive one of a violet-blue color on a greenish-yellow ground, which at a certain moment possesses a high degree of sharpness and singular beauty and delicacy of tint. If at this instant it be thrown into water, it passes immediately to Prussian blue, losing at the same time, however, much of its sharpness, and sometimes, indeed, becoming quite blotty and confused. But if this be delayed, the picture, after attaining a certain maximum of distinctness,

grows rapidly confused, especially if the quantity of liquid applied be more than the paper can easily and completely absorb, or if the brush in applying it be allowed to rest on or to be passed twice over any part. The effect then becomes that of a coarse and ill-printed wood cut, all the strong shades being run together, and a total absence prevailing of half lights.

To prevent this confusion, gum arabic may be added to the prussiated solution, by which it is hindered from spreading unmanageably within the pores of the paper, and the precipitated Prussian blue allowed time to agglomerate and fix itself on the fibers. By the use of this ingredient also a much thinner and more equable film may be spread over the surface; and *when perfectly dry*, if not sufficiently developed, the application may be repeated. By operating thus I have occasionally (though rarely) succeeded in producing pictures of great beauty and richness of effect, which they retain (if not thrown into water) between the leaves of a portfolio, and have even a certain degree of fixity—fading in a strong light, and recovering their tone in the dark. The manipulations of this process are, however, delicate, and complete success is comparatively rare.

If sulphocyanate of potash be added to the ammonio-citrate or ammonio-tartrate of iron, the peculiar red color which that test induces on persalts of the metal is not produced, but it appears at once on adding a drop or two of dilute sulphuric or nitric acid. This circumstance, joined to the perfect neutrality of these salts, and their power, in such neutral solution, of enduring, undecomposed, a boiling heat, contrary to the usual habitudes of the peroxide of iron, together with their singular transformation by the action of light to proto-salts, in apparent opposition to a very strong affinity, has, I confess, inclined me to speculate on the possibility of their ferruginous base existing in them, not in the ordinary form of peroxide, but in one isomeric with it. The nonformation of Prussian blue, when their solutions are mixed with prussiate of potash, and the formation in its place of a deep violet-colored liquid of singular instability under the action of light, seem to favor this idea. Nor is it altogether impossible that the peculiar "prepared" state superficially assumed by iron under the influence of nitric acid, first noticed by Keir, and since made the subject of experiment by M. Schönbein and myself, may depend on a change superficially operated on the *iron itself* into a new metallic body isomeric with iron, unoxidable by nitric acid, and which may be considered as the radical of that peroxide which exists in the salts in question, and possibly also of an isomeric protoxide. A combination of the common protoxide with the isomeric peroxide, rather than with the same metal in a simply higher stage of oxidation, would afford a not unplausible notion of the chemical nature of that peculiar intermediate oxide to which the name of "Ferrosoferric" has been given by Berzelius. If (to render my meaning more clear) we for a moment consent to designate such an isomeric form of iron by the name *siderium*, the oxide in question might be regarded as a sideriate of iron. Both phosphorus and arsenic (bodies remarkable for sequi combinations) admit isomeric forms in their oxides and acids. But to return from this digression.

If to a mixture of ammonio-citrate of iron and sulphocyanate of potash a small dose of nitric acid be added, the resulting red liquid, spread on paper, spontaneously whitens in the dark. If more acid be added till the point is attained when the discoloration begins to relax, and the paper when dry retains a considerable degree of color, it is powerfully affected by light, and receives a positive picture with great rapidity, which appears at the back of the paper with even more distinctness than on its face. The impression, however, is pallid, fades on keeping, nor am I acquainted at present with any mode of fixing it.

If paper be washed with a mixture of the solution of ammonio-citrate of iron and ferrosesquicyanate of potash, so as to contain the two salts in about equal proportions, and, being then impressed with a picture, be thrown into water and dried, a negative blue image will be produced. This picture I have found to be susceptible of a very curious transformation, preceded by total obliteration. To effect this it must be washed with solution of proto-nitrate of mercury, which in a little time entirely discharges it. The nitrate being thoroughly washed out and the picture dried, a smooth iron is to be passed over it, somewhat hotter than is used for ironing linen, but not sufficiently so to scorch or injure the paper. The obliterated picture immediately reappears, not blue, but brown. If kept for some weeks in this state between the leaves of a portfolio, in complete darkness, it fades and at length almost entirely disappears. But, what is very singular, a fresh application of the heat revives and restores it to its full intensity.

This curious transformation is instructive in another way. It is not operated by light; at least not by light alone. *A certain temperature* must be attained, and that temperature suffices in total darkness. Nevertheless, I find that on exposing to a very concentrated spectrum (collected by a lens of short focus) a slip of paper duly prepared as above—that is to say, by washing with the mixed solutions, exposure to sunshine, washing, and discharging the uniform blue color so induced, as in the last article—its whiteness is changed to brown over the whole region of the red and orange rays, *but not beyond* the luminous spectrum. Three conclusions seem unavoidable: First, that it is the heat of these rays, not their light, which operates the change; second, that this heat possesses a peculiar chemical quality which is not possessed by the purely calorific rays outside of the visible spectrum, though far more intense; and, third, that the heat radiated from obscurely hot iron abounds especially in rays analogous to those of the region of the spectrum above indicated.

Sir John Herschel then proceeds to show that, whatever be the state of the iron in the double salts in question, its reduction by blue light to the state of protoxide is indicated by many other reagents. Thus, for example, if a slip of paper prepared with the ammonio-citrate of iron be exposed partially to sunshine and then washed with the bichromate of potash, the bichromate is deoxidized and precipitated upon the sunned portion, just as it would be if directly exposed to the sun's rays.

I have proved this fact with a great number of preparations of cobalt, nickel, bismuth, platinum, and other salts which have been thought hitherto to be insensible to solar agency; but if they are partially sunned, and then washed with nitrate of silver and put aside in the dark the metallic silver is slowly reduced upon the sunned portion. In many instances days were required to produce the visible picture; and in one case paper, being washed with neutral chloride of platinum, were sunned, and then washed in the dark with nitrate of silver; it was some weeks before the image made its appearance, but it was eventually perfectly developed. This specimen has been kept for several years, and continues constantly to improve in clearness and definition.

CHRYSOTYPE.

A process of an analogous character to that which has just been described, and in which the chloride of gold is an agent, must be next described. This was discovered at the same time as the cyanotype, and has been termed the chrysotype.

In order to ascertain whether any portion of the iron in the double ammoniacal salt employed had really undergone deoxidation and become reduced to the state of protoxide, as supposed, I had recourse to a solution of gold exactly neutralized by carbonate of soda. The protosalts of iron, as is well-known to chemists, precipitate gold in the metallic state. The effect proved exceedingly striking, issuing in a process no wise inferior in the almost magical beauty of its effect to the calotype process of Mr. Talbot, which in some respects it nearly resembles; with this advantage, as a matter of experimental exhibition, that the disclosure of the dormant image does not require to be performed in the dark, being not interferred with by moderate daylight. As the experiment will probably be repeated by others, I shall here describe it ab initio. Paper is to be washed with a moderately concentrated solution of ammonio-citrate of iron and dried. The strength of the solution should be such as to dry into a good yellow color, not at all brown. In this state it is ready to receive a photographic image, which may be impressed on it either from nature in the camera obscura, or from an engraving on a frame in sunshine. The image so impressed, however, is very faint and sometimes hardly perceptible. The moment it is removed from the frame or camera it must be washed over with a neutral solution of gold of such strength as to have about the color of sherry wine. Instantly the picture appears, not, indeed, at once of its full intensity, but darkening with great rapidity up to a certain point, depending on the strength of the solution used, etc. At this point nothing can surpass the sharpness and perfection of detail of the resulting photograph. To arrest this process and to fix the picture (so far at least as the further agency of *light* is concerned), it is to be thrown into water very slightly acidulated with sulphuric acid and well soaked, dried, washed with hydrobromate of potash, rinsed, and dried again.

Such is the outline of a process to which I propose applying the name of *chrysotype* in order to recall by similarity of structure and termination the *calotype* process of Mr. Talbot, to which in its general effect it affords so close a parallel. Being very recent, I have not yet (June 10, 1842) obtained a complete command over all its details, but the termination of the session of the society being close at hand I have not thought it advisable to suppress its mention. In point of *direct* sensibility the chrysotype paper is certainly inferior to the calotype, but it is one of the most remarkable peculiarities of gold as a photographic ingredient that *extremely feeble impressions once made by light go on afterwards darkening spontaneously and very slowly, apparently without limit, so long as the least vestige of unreduced chloride of gold remains in the paper.* To illustrate this curious and (so far as applications go) highly important property, I shall mention incidentally the results of some experiments made during the late fine weather on the habitudes of gold in presence of oxalic acid. It is well known to chemists that this acid heated with solutions of gold precipitates the metal in its metallic state. It is upon this property that Berzelius has founded his determination of the atomic weight of gold. Light as well as heat also operates this precipitation, but to render it effectual several conditions are necessary: First, the solution of gold must be neutral, or at most *very* slightly acid; second, the oxalic acid must be added in the form of a neutral oxalate:

Reproduced from gold Crysotype print.

Reproduced from silver Crysotype print.

and third, it must be present in a certain considerable quantity, which quantity must be greater the greater the amount of free acid present in the chloride. Under these conditions the gold is precipitated by light as a black powder if the liquid be in any bulk, and if merely washed over paper a stain is produced, which, however feeble at first, under a certain dosage of the chloride, oxalate, and free acid, goes on increaseing from day to day and from week to week, when laid by in the dark, and especially in a damp atmosphere, till it acquires almost the blackness of ink, the unsunned portion of the paper remaining unaffected, or so slightly as to render it almost certain that what little action of the kind exists is due to the effect of casual dispersed light incident in the preparation of the paper. I have before me a specimen of paper so treated in which the effect of thirty seconds' exposure to sunshine was quite invisible at first and which is now of so intense a purple as may well be called black, while the unsunned portion has acquired comparatively but a very slight brown. And (which is not a little remarkable and indicates that in the time of exposure mentioned the *maximum* of effect was attained) other portions of the same paper exposed in graduated progression for longer times, viz. one minute, two minutes, and three minutes, are not in the least perceptible degree darker than the portion on which the light had acted during thirty seconds only.

If paper prepared as above recommended for the chrysotype, either with the ammonio-citrate or ammonio-tartrate of iron, and impressed, as in that process, with a latent picture, be washed with nitrate of silver instead of a solution of gold, a very sharp and beautiful picture is developed of great intensity. Its disclosure is not instantaneous; a few moments elapse without apparent effect. The dark shades are then first touched in, and by degrees the details appear, but much more slowly than in the case of gold. In two or three minutes, however, the maximum of distinctness will not fail to be attained. The picture may be fixed by the hyposulphite of soda, which alone, I believe, can be fully depended on for fixing argentine photographs.

The best process for fixing any of the photographs prepared with gold is as follows: As soon as the picture is satisfactorily brought out by the auriferous liquid it is to be rinsed in spring water, which must be three times renewed, letting it remain in the third water five or ten minutes. It is then to be blotted off and dried, after which it is to be washed on both sides with a somewhat weak solution of hydriodate of potash (*iodide of potassium*). If there be any free chloride of gold present in the pores of paper, it will be discolored, the lights passing to a ruddy brown: but they speedily whiten again spontaneously, or at all events on throwing it (after lying a minute or two) into fresh water, in which, being again rinsed and dried, it is now perfectly fixed.

PHOTOGRAPHIC PROPERTIES OF MERCURY.

As an agent in the daguerreotype process, it is not, strictly speaking, photographically affected. It operates there only in virtue of its readiness to amalgamate with silver properly prepared to receive it. That it possesses *direct* photographic susceptibility, however, in a very eminent degree, is proved by the following experiment: Let a paper be washed over with a weak solution of periodide of iron, and, when dry, with a solution of proto-nitrate of mercury. A bright yellow paper is produced, which (if the right strength of the liquids be hit) is exceedingly sensitive while wet, darkening to a brown color in a very few seconds in the sunshine. Withdrawn, the impression fades rapidly, and the paper in a few hours recovers its original color. In operating this change of color the whole spectrum is affective, with the exception of the thermic rays beyond the red.

Proto-nitrate of mercury simply washed over paper is slowly and feebly blackened by exposure to sunshine. And if paper be impregnated with the ammonio-citrate of iron, already so often mentioned, partially sunned, and then washed with the proto-nitrate, a reduction of the latter salt, and consequently blackening of the paper, takes place very slowly in the dark over the sunned portion, to nearly the same amount as in the direct action of the light on the simply nitrated paper.

But if the mercurial salt be subjected to the action of light in contact with the ammonio-citrate or tartrate, the effect is far more powerful. Considering at present only the citric double salt, a paper prepared by washing first with that salt and then with the mercurial proto-nitrate (drying between) is endowed with considerable sensibility and darkens to a very deep brown, nay, to complete blackness, on a moderate exposure to good sun. Very sharp and intense photographs of a negative character may be thus taken. They are, however, difficult to *fix*. The only method which I have found at all to succeed has been by washing them with bichromate of potash and soaking them for twenty-four hours in water, which *dissolves out* the chromate of mercury for the most part, leaving, however, a yellow tint on the ground, which resists obstinately. But though pretty effectually fixed in this way against *light*, they are not so against *time*, as they fade considerably on keeping.

When the proto-nitrate of mercury is mixed in solution with either of the ammoniacal double salts it forms a precipitate, which, worked up with a brush to the consistence of cream and spread upon paper, produces very fine pictures, the intensity of which it is almost impossible to go beyond. Most unfortunately they can not be preserved. Every attempt to fix them has resulted in the destruction of their beauty and force; and even when kept from light they fade with more or less rapidity, some disappearing almost entirely in three or four days, while others have resisted tolerably well for a fortnight or even a month. It is to an overdose of tartaric acid that their more rapid deterioration seems to be due, and of course it is important to keep down the proportion of this ingredient as low as possible. But without it I have never succeeded in producing that peculiar velvety aspect on which the charm of these pictures chiefly depends, nor anything like the same intensity of color without over-sunning.

FERROTARTRATE OF SILVER.

Extending his inquiries still further into these very remarkable changes, the following process presented itself to Sir J. Herschel, which is in many respects remarkable:

If nitrate of silver, specific gravity 1·200, be added to ferro-tartaric acid, specific gravity 1·023, a precipitate falls which is in great measure redissolved by a gentle heat, leaving a black sediment, which, being cleared by subsidence, a liquid of a pale yellow color is obtained, in which a further addition of the nitrate causes no turbidness. When the total quantity of the nitrated solution amounts to about half the bulk of the ferrotartaric acid it is enough. The liquid so prepared does not alter by keeping in the dark.

Spread on paper and exposed wet to the sunshine (partly shaded) for a few seconds no impression seems to have been made; but by degrees (although withdrawn from the action of the light) it de-

velops itself spontaneously, and at length becomes very intense. But if the paper be thoroughly dried in the dark (in which state it is of a very pale greenish-yellow color) it possesses the singular property of receiving a dormant or invisible picture, to produce which (if it be, for instance, an engraving that is to be copied), from thirty seconds' to a minute's exposure in the sunshine is requisite. It should not be continued too long, as not only is the ultimate effect less striking, but a picture begins to be visibly produced, which darkens spontaneously after it is withdrawn. But if the exposure be discontinued before this effect comes on an invisible impression is the result, to develop which all that is necessary is to breathe upon it, when it immediately appears, and very speedily acquires an extraordinary intensity and sharpness as if by magic. Instead of the breath it may be subjected to the regulated action of aqueous vapor by laying it in a blotting-paper book of which some of the outer leaves on both sides have been dampened, or by holding it over warm water.

Many preparations, both of silver and gold, possess a similar property in an inferior degree, but none that I have yet met with to anything like the extent of that above described.

These pictures do not admit of being permanently fixed; they are so against the action of light, but not against the operations of time. They slowly fade out even in the dark, and in some examples which I have prepared the remarkable phenomenon of a restoration after fading, but with reversed lights and shades, has taken place.

THE AMPHITYPE.

The following very remarkable process was communicated by Sir John Herschel at the meeting of the British Association at York. The process can not be regarded as perfect, but from its beauty when success is obtained and the curious nature of all its phenomena it is deemed important to include it in the hope of inducing some investigator to take it up.

Sir John Herschel says, alluding to the processes just described:

I had hoped to have perfected this process so far as to have reduced it to a a definite statement of manipulations which would insure success. But capricious as photographic processes notoriously are, this has proved so even beyond the ordinary measure of such caprice. * * * Paper proper for producing an amphitype picture may be prepared either with the ferrotartrate or the ferrocitrate of the protoxide or the peroxide of mercury, or of the protoxide of lead, by using creams of these salts, or by successive applications of the nitrates of the respective oxides, singly or in mixture, to the paper, alternating with solutions of the ammonio-tartrate or ammonio-citrate of iron, the latter solution being last applied and in more or less excess. * * * Paper so prepared and dried takes a negative picture in time varying from half an hour to five or six hours, according to the intensity of the light; and the impression produced varies in apparent force from a faint and hardly perceptible picture to one of

the highest conceivable fullness and richness both of tint and detail, the color in this case being a superb velvety brown. This extreme richness of effect is not produced except lead be present either in the ingredients used or *in the paper itself*. It is not, as I originally supposed, due to the presence of free tartaric acid. The pictures in this state are not permanent. They fade in the dark, though with very different degrees of rapidity, some (especially if free tartaric or citric acid be present) in a few days, while others remain for weeks unimpaired and require whole years for their total obliteration. But, though entirely faded out in appearance the picture is only rendered dormant, and may be restored, changing its character from negative to positive and its color from brown to black (in the shadows), by the following process: A bath being prepared by pouring a small quantity of solution of pernitrate of mercury into a large quantity of water and letting the subnitrated precipitate subside, the picture must be immersed in it (carefully and repeatedly clearing off the air bubbles) and allowed to remain till the picture (if anywhere visible) is entirely destroyed, or, if faded, till it is judged sufficient from previous experience, a term which is often marked by the appearance of a feeble positive picture of a bright yellow hue on the pale-yellow ground of the paper. A long time (several weeks) is often required for this, but heat accelerates the action, and it is often complete in a few hours. In this state the picture is to be very thoroughly rinsed and soaked in pure warm water and then dried. It is then to be well ironed with a smooth iron, heated so as barely not to injure the paper, placing it, for better security against scorching, between smooth clean papers. If, then, the process has been successful, a perfectly black positive picture is at once developed. At first it most commonly happens that the whole picture is sooty or dingy to such a degree that it is condemned as spoiled, but on keeping it between the leaves of a book, especially in a moist atmosphere, by extremely slow degrees this dinginess disappears, and the picture disengages itself with continually increasing sharpness and clearness, and acquires the exact effect of a copperplate engraving on a paper more or less tinted with pale yellow.

I ought to observe that the best and most uniform specimens which I have procured have been on paper previously washed with certain preparations of uric acid, which is a very remarkable and powerful photographic element. The intensity of the original negative picture is no criterion of what may be expected in the positive. It is from the production, by one and the same action of the light, of either a positive or a negative picture, according to the subsequent manipulations, that I have designated the process thus generally sketched out by the term "*Amphitype*," a name suggested by Mr. Talbot, to whom I communicated this singular result; and to this process or class of processes (which I can not doubt when pursued will lead to some very beautiful results) I propose to restrict the name in question, though it applies even more appropriately to the following exceedingly curious and remarkable one in which silver is concerned. At the last meeting I announced a mode of producing, by means of a solution of silver in conjunction with ferro-tartaric acid, a dormant picture brought out into a forcible negative impression by the breath or moist air. The solution then described, and which had at that time been prepared some weeks, I may here incidentally remark, has retained its limpidity and photographic properties quite unimpaired during the whole year since elapsed, and is now as sensitive as ever—a property of no small value. Now, when a picture (for example, an impression from an engraving) is taken on paper washed with this solution it shows no sign of a picture on its back, whether that on its face be developed or not; but if, while the actinic influence is still fresh upon the face (i. e., as soon as it is removed from the light), the *back* be exposed for a very few seconds to sunshine and then removed to a

gloomy place, a positive picture, *the exact complement of the negative one on the other side*, though wanting of course in sharpness if the paper be thick, *slowly and gradually makes its appearance* there, and in half an hour acquires considerable intensity. I ought to mention that the ferro-tartaric acid in question is prepared by precipitating the ferro-tartrate of ammonia by acetate of lead and decomposing the precipitate by dilute sulphuric acid.

THE COLORING MATTER OF FLOWERS.

The results obtained by Sir John Herschel on the coloring juices of flowers are too remarkable to be omitted in a treatise in which it is desirable that every point should be registered up to the date of publication, which connects itself with the phenomena of chemical change applied to photography:

In operating on the colors of flowers I have usually proceeded as follows: The petals of the fresh flowers, or rather such parts of them as possessed a uniform tint, were crushed to a pulp in a marble mortar, either alone or with addition of alcohol, and the juice expressed by squeezing the pulp in a clean linen or cotton cloth. It was then spread on paper with a flat brush and dried in the air without artificial heat, or, at most, with the gentle warmth which rises in the ascending current of air from an Arnott stove. If alcohol be not added, the application on paper must be performed immediately, since exposure to the air of the juices of most flowers (in some cases even but for a few minutes) irrecoverably changes or destroys their color. If alcohol be present, this change does not usually take place or is much retarded, for which reason, as well as on account of certain facilities afforded by its admixture in procuring an even tint (to be presently stated), this addition was commonly but not always made.

Most flowers give out their coloring matter readily enough either in alcohol or water. Some, however, as the Escholzias and Calceolarias, refuse to do so, and require the addition of alkalies; others of acids, etc. When alcohol is added, it should, however, be observed that the tint is often apparently much enfeebled or even discharged altogether, and that the tincture when spread on paper does not reappear of its blue intensity till after complete drying. The temporary destruction of the color of blue heartsease by alcohol is curious, nor is it by any means a singular instance. In some, but in very few cases, it is destroyed, so as neither to reappear on drying nor to be capable of revival by any means tried. And in all cases long keeping deteriorates the colors and alters the qualities of the alcoholic tinctures themselves, so that they should always be used as fresh as possible.

If papers tinged with vegetable colors are intended to be preserved, they must be kept perfectly dry and in darkness. A close tin vessel, the air of which is dried by quicklime carefully inclosed in double paper bags well pasted at the edges to prevent the dust escaping, is used for this purpose. Moisture, as already mentioned, especially assisted by heat, destroys them for the most part rapidly, though some, as the color of the *Senecio splendens*, resist obstinately. Their destructibility by this agency, however, seems to bear no distinct relation to their photographic properties.

This is also the place to observe that the color of a flower is by no means always or usually that which its expressed juice imparts to white paper. In many cases the tints so imparted have no resemblance to the original hue. Thus, to give only a few instances, the red damask rose, of that intense variety

of color commonly called by florists the black rose, gives a dark slate blue, as do also the clove carnation and the black hollyhock; a fine dark brown variety of sparaxis give a dull olive green, and a beautiful rose-colored tulip a dirty bluish-green; but perhaps the most striking case of the kind is that of a common sort of red poppy (*Papaver Rheum*), whose expressed juice imparts to paper a rich and most beautiful blue color, whose elegant properties as a photographic material will be further alluded to hereafter.[a]

This change of color is probably owing to different causes in different flowers. In some it undoubtedly arises from the escape of carbonic acid, but this, as a general cause for the change from red to blue, has, I am aware, been controverted. In some (as is the case with the yellow ranunculi) it seems to arise from a chemical alteration depending on absorption of oxygen; and in others, especially where the expressed juice coagulates on standing, to a loss of vitality or disorganization of the molecules. The fresh petal of a single flower, merely crushed by rubbing on dry paper and instantly dried, leaves a stain much more nearly approximating to the original hue. This, for example, is the only way in which the fine blue color of the common field veronica can be imparted to paper. Its expressed juice, however quickly prepared, when laid on with a brush, affords only a dirty neutral gray, and so of many others. But in this way no even tint can be had, which is a first requisite to the experiments now in question as well as to their application to photography.

To secure this desirable evenness of tint the following manipulation will generally be found successful: The paper should be moistened at the back by sponging and blotting off. It should then be pinned on a board, the moist side downward, so that two of its edges (suppose the right-hand and lower ones) shall project a little beyond those of the board. The board being then inclined twenty or thirty degrees to the horizon, the alcoholic tincture (mixed with a very little water, if the petals themselves be not very juicy) is to be applied with a brush in strokes from left to right, taking care *not to* go over the edges which rest on the board, but *to* pass clearly over those which project, and observing also to carry the tint from below upward by quick sweeping strokes, leaving no dry spaces between them, but keeping up a continuity of wet surface. When all is wet, cross them by another set of strokes from above downward, so managing the brush as to leave no floating liquid on the paper. It must then be dried as quickly as possible over a stove or in a current of warm air, avoiding, however, such heat as may injure the tint. The presence of alcohol prevents the solution of the gummy principle, which, when present, gives a smeary surface; but the evenness of tint given by this process results chiefly from that singular intestine movement which always takes place when alcohol is in the act of separation from water by evaporation a movement which disperses knots and blots in the film of liquid with great energy and spreads them over the surrounding surface.

Corchorus japonica.—The flowers of this common and hardy but highly ornamental plant are of a fine yellow, somewhat inclining to orange, and this is also the color which the expressed juice imparts to paper. As the flower begins to fade *the petals whiten*, an indication of their photographic sensibility which is amply verified on exposure of the stained paper to sunshine. I have hitherto met with no vegetable color so sensitive. If the flowers be gathered in the height of their season, paper so colored (which is of a very beautiful and even yellow) begins to discolor in ten or twelve minutes in clear sunshine and in

[a] A semicultivated variety was used having dark purple spots at the bases of the petals. The common red poppy of the chalk (*Papavier hybridum*) gives a purple color much less sensitive and beautiful.

half an hour is completely whitened. The color seems to resist the first impression of the light, as if by some remains of vitality, which, being overcome, the tint gives way at once, and the discoloration when commenced goes on rapidly. *It does not even cease in the dark when once begun.* Hence it happens that photographic impressions taken on such paper, which when fresh are very sharp and beautiful, fade by keeping, visibly from day to day, however carefully preserved from light. They require from half an hour to an hour to complete, according to the sunshine. Hydriodate of potash cautiously applied retards considerably, but does not untimately prevent this spontaneous discharge.

Common ten weeks' stocks; Mathiola annua.—Paper stained with the tincture of this flower is changed to a vivid scarlet by acids and to green by alkalies. If ammonia be used, the red color is restored as the ammonia evaporates, proving the absence of any acid quality in the coloring matter sufficiently energetic to coerce the elastic force of the alkaline gas. Sulphurous acid whitens it, as does the alkaline sulphites, but this effect is transient, and the red color is slowly restored by free exposure to air, especially with the aid of light, whose influence in this case is the more remarkable, being exactly the reverse of its ordinary action on this coloring principle, which it destroys irrecoverably, as above stated. The following experiments were made to trace and illustrate this curious change:

Two photographic copies of engravings taken on paper tinted with this color were placed in a jar of sulphurous-acid gas, by which they were completely whitened and all traces of the pictures obliterated. They were then exposed to free air, the one in the dark, the other in sunshine. Both recovered, but the former much more slowly than the latter. The restoration of the picture exposed to the sun was completed in twenty-four hours, that in the dark not till after a lapse of two or three days.

A slip of the stained paper was wetted with liquid sulphurous acid and laid on blotting paper similarly wetted. Being then crossed with a strip of black paper, it was laid between glass plates and (evaporation of the acid being thus prevented) was exposed to full sunshine. After some time the red color (in spite of the presence of the acid) was considerably restored in the portion exposed, while the whole of the portion covered by the black paper remained, of course, perfectly white.

Slips of paper stained as above were placed under a receiver beside a small capsule of liquid sulphurous acid. When completely discolored they were subjected (on various occasions and after various lengths of exposure to the acid fumes, from half an hour to many days) to the action of the spectrum, and it was found, as, indeed, I had expected, that *the restoration of color was operated by rays complementary to those which destroy it in the natural state of the paper*, the violet rays being chiefly active, the blue almost equally so, the green little, and the yellow, orange, and most refrangible red not at all. In one experiment a pretty well defined red solar image was developed by the *least* refrangible red rays also, being precisely those for which, in the unprepared paper, the discoloring action is abruptly cut off. But this spot I never succeeded in reproducing; and it ought also to be mentioned that, according to differences in the preparation not obvious, the degree of sensibility, generally, of the bleached paper to the restorative action of light differed greatly, in some cases a perceptible reddening being produced in ten seconds and a considerable streak in two minutes, while in others a very long time was required to produce any effect. The dormancy of this coloring principle under the influence of sulphurous acid is well shown by dropping a little weak sulphuric acid on the paper bleached by that gas, which immediately restores the red color in all its

vigor. In like manner alkalies restore the color, converting it at the same time into green.

Papaver orientale.—The chemical habitudes of the sulphurous acid render it highly probable that its action in including a dormant state of the colorific principle consists in a partial deoxidizement, unaccompanied, however, with disorganization of its molecules. And this view is corroborated by the similar action of alcohol already spoken of—similar, that is, in kind, though less complete in degree. Most commonly vegetable colors weakened by the action of alcohol are speedily restored on the total evaporation of the ingredient. But one remarkable instance of absolute dormancy induced by that agent has occurred to me in the case of *Papaver orientale*, a flower of a vivid orange color, bordering on scarlet, the coloring matter of which is not extractable otherwise than by alcohol, and then only in a state so completely masked as to impart no more than a faint yellowish or pinkish hue to paper, which it retains when thoroughly dry, and apparently during any length of time, without perceptible increase of tint. If at any time, however, a drop of weak acid be applied to paper prepared with this tincture a vivid scarlet color is immediately developed, thus demonstrating the continued though latent existence of the coloring principle. On observing this, it occurred to me to inquire whether, in its dormant state, that principle still retained its susceptibility of being acted on by light, since the same powerful and delicate agent which had been shown, in so many cases as to constitute a general law, capable of disorganizing and destroying vegetable colors actually developed might easily be presumed competent to destroy the capacity for assuming color, in such organic matter as might possess it, under the influence of their otherwise appropriate chemical stimuli. A strip of the paper was therefore exposed for an hour or two to the spectrum, but without any sensible effect, the whole surface being equally reddened by an acid. As this experiment sufficiently indicated the action of light, if any, to be very slow, I next placed a strip, partly covered, in a southeast window, where it remained from June 19 to August 19, receiving the few and scanty sunbeams which that interval of the deplorable summer of 1841 afforded. When removed, the part exposed could barely be distinguished from the part shaded as a trifle yellower. But on applying acid the exposed and shaded portions were at once distinguished by the assumption of a vivid red in the latter and the former remaining unchanged.

A mezzotinto picture was now pressed on a glazed frame over another portion of the same paper and abandoned on the upper shelf of a greenhouse to whatever sun might occur from August 19 to October 19. The interval proved one of almost uninterrupted storm, rain, and darkness. On removal no appearance whatever of any impressed picture could be discerned, nor was it even possible to tell the top of the picture from the bottom. It was then exposed in a glass jar to the fumes of muriatic acid, when, after a few minnutes, the development of the dormant picture commenced and slowly proceeded, disclosing the details in a soft and pleasing style. Being then laid by in a drawer, with free access of air, the picture again faded by very slow degrees, and on January 2, 1842, was found quite obliterated. Being then subjected to the acid vapor, the color was reproduced.

Viola odorata.—Chemists are familiar with the color of this flower as a test of acids and alkalies, for which, however, it seems by no means better adapted than many others; less so, indeed, than that of the *Viola tricolor*, the common purple iris, and many others which might be named. It offers, in fact, another and rather a striking instance of the simultaneous existence of two coloring ingredients in the same flower, comporting themsleves differently, not only in regard to light but to chemical agents. Extracted with alcohol, the juice of the

violet is of a rich blue color, which it imparts in high perfection to paper. Exposed to sunshine, a portion of this color gives way pretty readily, but a residual blue, rather inclining to greenish, resists obstinately and requires a very much longer exposure (for whole weeks, indeed) for its destruction, which is not even then complete. Photographic impressions, therefore, taken on this paper, though very pretty, are exceedingly tedious in their preparation if we would have the lights sharply made out.

Sparaxis tricolor?, var.—Stimulating effects of alkalies.—Among a great many hybrid varieties of this genus, lately forwarded to me from the Cape, occurred one of a very intense purplish brown color, nearly black. The alcoholic extract of this flower in its liquid state is rich crimson brown. Spread on paper, it imparted a dark olive-green color, which proved perfectly insensible to very prolonged action, either of sunshine or the spectrum. The addition of carbonate of soda changed the color of this tincture to a good green, slightly inclining to olive, and which imparted the same tint to paper. In this state, to my surprise, it manifested rather a high degree of photographic sensibility, and gave very pretty pictures with a day or two of exposure to sunshine. When prepared with the fresh juice there is hardly any residual tint, but if the paper be kept a great amount of indestructible yellow remains outstanding. The action is confined chiefly to the negative end of the spectrum; all but the first five or six parts beyond the yellow show little more than a trace of action. A photograph impressed on this paper is reddened by muriatic acid fumes. If then transferred to an atmosphere of ammonia, and when supersaturated the excess of alkali allowed to exhale, it is fixed, and of a dark-green color. Both the tint and sharpness of the picture, however, suffer in this process.

Red poppy: Papaver Rheum?.—Among the vegetable colors totally destroyed by light, or which leave no residual tint, at least when fresh prepared, perhaps the two most rich and beautiful are those of the red poppy and the double purple groundsel (*Senecio splendens*). The former owes its red color in all probability to free carbonic acid or some other, as the acetic, completely expelled by drying, for the color its tincture imparts to paper, instead of red is a fine blue, very slightly verging on slate blue. But it has by no means the ordinary chemical characters of blue vegetable colors. Carbonate of soda, for instance, does not in the least degree turn the expressed juice green, and when washed with the mixture a paper results of a light slate gray, hardly at all inclining to green. The blue tincture is considerably sensitive, and from the richness of its tone and the absence of residual tint, paper stained with it affords photographic impressions of great beauty and sharpness, some of which will be found among the collection submitted with this paper for inspection.

Senecio splendens.—This flower yields a rich purple juice in great abundance and of surprising intensity. Nothing can exceed the rich and velvety tint of paper tinted while it is fresh. It is, however, not very sensible to light, and many weeks are necessary to obtain a good photographic impression.

In the progress of my own researches on this subject I found that the green coloring matter of the leaves of herbaceous plants when spread upon paper changed with tolerable rapidity when exposed to sunshine. There are, however, some very curious points connected with the phenomena of these changes which demand a far more extensive investigation than they have yet received.

I find that the juices taken from the leaves in the spring change more rapidly than when expressed from the same plants in the

autumn, and the juices of those flowering plants which have been cultivated under the artificial circumstances of a storehouse or conservatory are more readily affected than such as are grown in the open air. Many of the experiments just described furnish very instructive examples of the operations of the solar rays upon organic bodies, from which we may deduce important truths connected with natural phenomena.

II. Miscellaneous Processes.

MR. PONTON'S PROCESS (BICHROMATE OF POTASH).

Under the general term of the chromatype I would propose to include all those processes which involve the use of any of the salts of chromium. It was originally introduced to distinguish a particular process which I discovered, and published at the meeting of the British Association at Cork, in August, 1843; but it appears very convenient to adopt the principle introduced by Sir John Herschel, of grouping the phenomena of photography under special terms derived from the most prominent chemical preparation employed.

There are many preparations which are affected by light in a similar manner to the salts of silver. Several have been tried as photographic materials, but as yet without much success, with the exception of the bichromate of potash, which was first announced as a useful photographic agent by Mr. Mungo Ponton in the Edinburgh New Philosophical Journal, from which I quote Mr. Ponton's own account:

When paper is immersed in the bichromate of potash it is powerfully and rapidly acted on by the sun's rays. When an object is laid in the usual way on this paper the portion exposed to the light speedily becomes tawny, passing more or less into a deep orange, according to the strength of the light. The portion covered by the objects retains the original bright yellow tint which it had before exposure, and the object is thus represented yellow upon an orange ground, there being several gradations of shade or tint, according to the greater or less degree of transparency in the different parts of the object.

In this state, of course, the drawing, though very beautiful, is evanescent. To fix it, all that is required is careful immersion in water, when it will be found that those portions of the salt which have not been acted on by the light are readily dissolved out, while those which have been exposed to the light are completely fixed on the paper. By the second process the object is obtained white upon an orange ground and quite permanent. If exposed for many hours together to strong sunshine, the color of the ground is apt to lose in depth, but not more so than most other coloring matters. This action of light on the bichromate of potash differs from that upon the salts of silver. Those of the latter which are blackened by light are of themselves insoluble in water, and it is difficult to impregnate paper with them in a uniform manner. The blackening seems to be caused by the formation of oxide of silver.

In the case of the bichromate of potash, again, that salt is exceedingly soluble, and paper can be easily saturated with it. The agency of light not only changes its color, but deprives it of solubility, thus rendering it fixed in the

paper. This action appears to consist in the disengagement of free chromic acid, which is of a deep red color and which seems to combine with the paper. This is rendered more probable from the circumstance that the neutral chromate exhibits no similar change. The best mode of preparing paper with bichromate of potash is to use a saturated solution of that salt, soak the paper well in it, and then dry it rapidly at a brisk fire, excluding it from daylight. Paper thus prepared acquires a deep orange tint on exposure to the sun. If the solution be less strong or the drying less rapid, the color will not be so deep. A pleasing variety may be made by using sulphate of indigo along with the bichromate of potash, the color of the object and of the paper being then different shades of green. In this way, also, the object may be represented of a darker shade than the ground.

Paper prepared with the bichromate of potash, though as sensitive as some of the papers prepared with the salts of silver, is much inferior to most of them and is not sufficiently sensitive for the camera obscura. This paper, however, answers quite well for taking drawings from dried plants or for copying prints. Its great recommendation is its cheapness and the facility with which it can be prepared. The price of the bichromate of potash is about 2 shillings per pound, while the nitrate of silver is 5 shillings an ounce.

As the deep orange ground of these pictures prevents the permeation of the chemical rays of light, it is very easy to procure any number of facsimiles of an engraving by transfer from the first negative photograph. The correct copies have a beautiful sharpness, and, if carefully managed, but little of the minute detail of the original engraving is lost.

A photographic paper prepared with the bichromate of potash of another kind is described by M. E. Becquerel. He states: It is sufficient to steep a paper prepared in Mr. Ponton's manner, and upon which there exists a faint copy of a drawing, in a solution of iodine in alcohol, to wash this paper in alcohol, and then dry it; then the parts which were white become blue, and those which were yellow remain more or less clear.

M. E. Becquerel has pursued his investigations into the action of the chromic acid on organic compounds, and has shown that the mode of sizing the papers influences their coloration by light, and that with unsized paper coloration is effected only after a long time. Perceiving that the principal reaction resulted from the chromic acid contained in the bichromate of potash on the starch in the size of the paper, it occurred to M. E. Becquerel that as starch has the property of forming with iodine a combination of a very fine blue color, it should produce deep shades of that tint, while the lights still remain an orange yellow.

His method of proceeding is to spread a size of starch very uniformly over the surface of the paper. It is then steeped in a weak alcoholic solution of iodine, and afterwards washed in a great

quantity of water. By this immersion it should take a very fine blue tint. If this is uniform, the paper is considered fit for the experiment; in the contrary case it is sized again. It is then steeped in a concentrated solution of bichromate of potash, and pressed between folds of blotting paper and dried near the fire. To be effective it should be very dry.

It is now fit for use. When the copy is effected, which requires in sunshine about five minutes, the photograph is washed and dried. When dry, it is steeped in a weak alcoholic solution of iodine, and afterwards, when it has remained in it some time, it is washed in water and carefully dried with blotting paper, but not at the fire, for at a little below 100° F. the combination of iodine and starch discolors.

If it be considered that the drawing is not sufficiently distinct, this immersion may be repeated several times, for by this means may be obtained the intensity of tone that is desired, which intensity can be changed at will by employing a more concentrated solution of iodine.

When the paper is damp the shades are of a very fine blue, but when it is dry the color becomes deep violet. If while the drawing is still wet it be covered with a layer of gum arabic the color of the drawing is greatly preserved and more beautiful when it is dry. When a paper is thus prepared it loses at first a little of its tone, but it afterwards preserves its violet tint.

THE CHROMATYPE.

This process, devised by the author, is a pleasing one in its results. It is exceedingly simple in its manipulatory details and produces very charming positive pictures by the first application. The chromatype is founded on the above process of Mr. Ponton's. One dram of sulphate of copper is dissolved in an ounce of distilled water to which is added half an ounce of a saturated solution of bichromate of potash. This solution is applied to the surface of the paper and when dry it is fit for use, and may be kept for any length of time without spoiling. When exposed to sunshine the first change is to a dull brown, and if checked in this stage of the process we get a negative picture, but if the action of the light is continued the browning gives way and we have a positive yellow picture on a white ground. In either case if the paper when removed from the sunshine is washed over with a solution of nitrate of silver a very beautiful positive picture results. In practice it will be found advantageous to allow the bleaching action to go on to some extent. The picture resulting from this will be clearer and more defined than that which is procured when the action is checked at the brown stage. To fix these pictures it is necessary to remove the nitrate of silver, which

Reproduced from Chromatype print.

is done by washing in *pure* water. If the water contains any muriates the picture suffers, and long soaking in such water obliterates it, or if a few grains of common salt are added to the water the apparent destruction is very rapid. The picture is, however, capable of restoration, all that is necessary being to expose it to sunshine for a quarter of an hour, when it revives, but instead of being of a red color it becomes lilac, the shades of color depending upon the quantity of salt used to decompose the chromate of silver which forms the shadow parts of the picture.

Mr. Bingham remarks on this process, that if we substitute sulphate of nickel for the sulphate of copper, the paper is more sensitive and the picture is more clearly developed by nitrate of silver.

The following modification of this process possesses some advantages. If to a solution of the sulphate of copper we add a solution of the neutral chromate of potash, a very copious brown precipitate falls, which is a true chromate of copper. If this precipitate, after being well washed, is added to water acidulated with sulphuric acid, it is dissolved and a dichromatic solution is formed, which when spread upon paper is of a pure yellow. A very short exposure of the paper washed with this solution is quite sufficient to discharge all the yellow from the paper and give it perfect whiteness. If an engraving is to be copied we proceed in the usual manner; and we may either bring out the picture by placing the paper in a solution of carbonate of soda or potash, by which all the shadows are represented by the chromate of copper, or by washing the paper with nitrate of silver. It may sometimes happen that, owing to deficient light, the photograph is darkened all over when the silver is applied; this color, by keeping, is gradually removed and the picture comes out clear and sharp.

If the chromate of copper is dissolved in ammonia, a beautiful green solution results, and if applied to paper acts similarly to those just described.

The chromatype pictures, under certain conditions afford a beautiful example of the changes which take place slowly in the dark from the combined operations of the materials employed.

If we take a chromatype picture after it has been developed by the agency of either nitrate of silver or of mercury and place it aside in the dark, it will be found after a few weeks to have darkened considerably both in the lights and shadows. This darkening slowly increases, until eventually the picture is obliterated beneath a film of metallic silver or mercury; but while the picture has been fading out on one side it has been developing itself on the other, and a very pleasing image is seen on the back. After some considerable time the metal on the front gives way again, the paper slowly whitens,

and eventually the image is presented on both sides of the paper of equal intensity, in a good neutral tint upon a gray ground. These results, it will be remembered, are of a very similar character to those already described as peculiar to the amphitype process of Sir John Herschel.

THE FERROTYPE.

This process, which is of remarkable sensibility, was discovered by the author and published in the Athenæum under the name of the "Energiatype;" from a desire to group all those pictures under a general head into which iron salts enter as an element the present name is preferred. The preparation of the paper is as follows: Good letter paper (Whatman's is the best) is washed over with the following solution, viz: Five grains of succinic acid (it is important that succinic free from any oil of amber or adventitious matter should be obtained) are to be dissolved in 1 fluid ounce of water, to which are added about 5 grains of common salt and half a dram of mucilage of gum arabic. When dry the paper is drawn over the surface of a solution of 60 grains of nitrate of silver in 1 ounce of distilled water. Allowed to dry in the dark, the paper is now fit for use, is of a pure white, retains its color, and may be preserved for a considerable time in a portfolio until wanted for use.

The preparation of this paper is by no means difficult, but requires care and attention. The solutions must be applied very equally over the paper, which should be immediately hung upon a frame or clotheshorse to dry. Extreme care must be taken that the paper be not exposed to light after the nitrate of silver solution has been applied until required for use. Many of the disappointments experienced by the experimenters on the energiatype are occasioned by a neglect of this precaution, as, although no apparent effect may have been produced by the exposure, the clearness of the subsequent picture will be seriously injured. The succinic acid must also be very pure. We shall now briefly describe the method of applying this process to the different purposes for which it is best adapted, premising that the varying circumstances of time, place, and light will render necessary such modifications of the following directions as the experience of the operator may suggest. As a general rule, an open situation, sunshine, and, if possible, the morning sun, should be preferred, as the image is sharper and the color produced more intense and less affected by the subsequent fixing process.

In the camera, for a building or statue, an exposure of half a minute in strong sunshine is usually sufficient; for a portrait, taken under ordinary conditions, two or three minutes are required.

When the paper is taken from the camera, nothing is visible upon it; but by attending to the following directions the latent picture will

quickly develop itself. Having mixed together about one dram of a saturated solution of *protosulphate of iron* and two or three drams of *mucilage of gum arabic*, pour a small quantity into a flat dish. Pass the prepared side of the paper taken from the camera rapidly over this mixture, taking care to insure complete contact in every part. If the paper has been sufficiently impressed, the picture will almost immediately appear, and the further action of the iron must be stopped by the application of a soft sponge and plenty of clear water. Should the image not appear immediately, or be imperfect in its details, the iron solution may be allowed to remain upon it a short time; but it must then be kept disturbed by rapidly but lightly brushing it up, otherwise numerous black specks will form and destroy the photograph. Great care should be taken that the iron solution does not touch the back of the picture, which it will inevitably stain, and, the picture being a negative one, be rendered useless as a copy. A slight degree of heat will assist the development of the image where the time of exposure has been too short.

The picture should be carefully washed to take off any superficial blackness, and may then be permanently fixed by being soaked in water to which a small quantity of ammonia, or, better still, hyposulphite of soda, has been added. The paper must again be well soaked in clean water, to clear it from the soluble salts, and may then be dried and pressed.

Exact copies of prints, feathers, leaves, etc., may be taken on the succinated paper by exposing them to the light in the copying frame, until the margin of the prepared paper, which should be left uncovered, begins to change color very slightly. If the object to be copied is thick, the surface must be allowed to assume a darker tint, or the light will not have penetrated to the paper.

Positive copies of the camera negatives are procured in the same manner as the copies of the prints, etc., just described. Instead, however, of using the iron solution, the paper must be exposed to the light, in the frame, a sufficient time to obtain perfect copies. The progress of the picture may be observed by turning up the corner of the paper, and, if not sufficiently done, replacing it exactly in the same position. They should be fixed with hyposulphite, as before directed.

At the meeting of the British Association at York in 1844 I showed by a series of photographs that the *protosulphate of iron* was most effective in developing any photographic images on whatever argentiferous preparation they may have been received. Every subsequent result has shown that with proper care it is the most energetic agent for developing with which we are acquainted. The difficulty of obtaining and of preserving the salt free of any peroxide,

or a basic salt which falls as a brownish-yellow powder, has been the principal cause why it has not been so generally employed as the gallic acid. This can be insured by adding a few drops of sulphuric acid and some iron filings to the solution of the protosulphate of iron.

THE CATALYSOTYPE.

This process of Doctor Wood's is capable of producing pictures of superior excellence. Owing to the inconstancy of the iodine compounds, it is a little uncertain, but, care being taken to insure the same degree of strength in the solutions, a very uniform good result may be obtained. The process and its modifications are thus described by the inventor:

Let well-glazed paper (I prefer that called wove post) be steeped in water to which hydrochloric acid has been added in the proportion of 2 drops to 3 ounces. When well wet, let it be washed over with a mixture of sirup of iodine of iron, half a dram; water, 2½ drams; tincture of iodine, 1 drop.

When this has remained on the paper for a few minutes, so as to be imbibed, dry it lightly with bibulous paper, and being removed to a dark room, let it be washed over evenly, by means of a camel-hair pencil, with a solution of nitrate of silver, 10 grains to the ounce of distilled water. The paper is now ready for the camera. The sooner it is used the better, as when the ingredients are not rightly mixed it is liable to spoil by keeping. The time I generally allow the paper to be exposed in the camera varies from two to thirty seconds; in clear weather, without sunshine, the medium is about fifteen seconds. With a bright light the picture obtained is of a rich brown color; with a faint light, or a bright light for a very short time continued, it is black. For portraits out of doors, in the shade on a clear day, the time for sitting is from ten to fifteen seconds.

If the light is strong and the view to be taken extensive, the operator should be cautious not to leave the paper exposed for a longer period than five or six seconds, as the picture will appear confused from all parts being equally acted on. In all cases the shorter the time in which the picture is taken the better.

When the paper is removed from the camera no picture is visible. However, when left in the dark, without any other preparation being used, for a period which varies with the length of time it was exposed and the strength of the light, a negative picture becomes gradually developed until it arrives at a state of perfection which is not attained, I think, by photography produced by any other process.[a] It would seem as if the salt of silver, being slightly affected by the light, though not in a degree to produce any visible effect on it if alone, sets up a catalytic action, which is extended to the salts of iron and which continues after the stimulus of the light is withdrawn. The catalysis which then takes place has induced me to name this process, for want of a

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[a] The picture when developed is not readily injured by exposure to moderate light. It ought, however, to be fixed, which may be done by washing it with a solution of bromide of potassium, 15 or 20 grains to the ounce, iodide of potassium, 5 grains to the ounce. It may either be applied with a camel's-hair pencil or by immersion. The picture must then be well washed in water to remove the fixing material, which would cause it to fade by exposure to light.

better word, the "catalysotype." Sir J. Herschel and Mr. Fox Talbot have remarked the same fact with regard to other salts of iron, but I do not know of any process being employed for photographic purposes which depends on this action for its development except my own.

My reason for using the muriatic solution previous to washing with the iodide of iron is this: I was for a long time tormented by seeing the pictures spoiled by yellow patches and could not remedy it until I observed that they presented an appearance as if that portion of the nitrate of silver which was not decomposed by the iodide of iron had flowed away from the part. I then recollected that Sir J. Herschel and Mr. Hunt had proved that iodide of silver is not very sensitive to light unless some free nitrate be present. I accordingly tried to keep both together on the paper, and after many plans had failed I succeeded by steeping it in the acid solution, which makes it freely and evenly imbibe whatever fluid is presented to it. I am sure that its utility is not confined to this effect, but it was for that purpose that I first employed it.

My reason for adding the tincture of iodine to the sirup is, that having in my first experiments made use of, with success, a sirup that had been for some time prepared, and afterwards remarking that fresh sirup did not answer so well, I examined both and found in the former a little free iodine. I therefore added a little tincture of iodine with much benefit, and now always use it in quantities proportioned to the age of the sirup.

The following hints will, I think, enable any experimenter to be successful in producing good pictures by this process: In the first place, the paper used should be that called "wove post," or well-glazed letter paper. When the solutions are applied to it, it should not immediately imbibe them thoroughly, as would happen with the thinner sorts of paper. If the acid solution is too strong, it produces the very effect it was originally intended to overcome—that is, it produces yellow patches, and the picture itself is a light brick color on a yellow ground. When the tincture of iodine is in excess, partly the same results occur; so that if this effect is visible it shows that the oxide of silver which is thrown down is partly redissolved by the excess of acid and iodine, and their quantities should be diminished. On the contrary, if the silver solution is too strong, the oxide is deposited in the dark or by an exceedingly weak light, and in this case blackens the yellow parts of the picture, which destroys it. When this effect of blackening all over takes place, the silver solution should be weakened. If it be too weak, the paper remains yellow after exposure to light. If the iodide of iron be used in too great quantity, the picture is dotted over with black spots, which afterwards change to white. If an excess of nitrate of silver be used, and a photograph immediately taken before the deposition of the oxide takes place, there will be often after some time a positive picture formed on the back of the negative one. The excess of the nitrate of silver makes the paper blacker where the light did not act on it, and this penetrates the paper, whereas the darkening produced by the light is confined to the surface. The maximum intensity of the spectrum on the paper when a prism of crown glass is used lies between the indigo and blue ray. The difference of effect of a strong and weak light is beautifully shown in the action of the spectrum; that part of the paper which is exposed to the indigo ray is colored a reddish brown, and this is gradually darkened toward either extremity until it becomes a deep black.

I have not had many opportunities of experimenting with the catalysotype, but it certainly promises to repay the trouble of further investigation. The simplicity of the process and the sensibility of the paper should cause it to be extensively used. It has all the beauty and quickness of the calotype, without

its trouble and very little of its uncertainty, and if the more frequent use of it by me, as compared with other processes, does not make me exaggerate its facility of operation I think it is likely to be practiced successfully by the most ordinary experimenters.

Doctor Woods subsequently made the following addition:

Since the preceding paper was written I have been experimenting with the catalysotype, and one day, having had many failures, which was before quite unusual with me, I am induced to mention the cause of them for the benefit of subsequent experimenters. The paper I used was very stiff and highly glazed, so that the solution first applied was not easily imbibed. The blotting paper was very dry and bibulous. When using the latter I removed nearly all the solution of iron from the first, and of course did not obtain the desired result.

While varying the process in endeavoring to find out the cause just mentioned, I discovered that the following proportions gave very fine negative pictures, from which good positive ones were obtained: Take of sirup of iodide of iron, distilled water, each 2 drams; tincture of iodine, 10 to 12 drops; mix. First brush this over the paper, and after the few minutes, having dried it with the blotting paper, wash it over in the dark (before exposure in the camera) with the following solution by means of a camel-hair pencil: Take of nitrate of silver 1 dram; pure water, 1 ounce; mix. This gives a darker picture than the original preparation, and consequently one better adapted for obtaining positive ones; it also requires no previous steeping in an acid solution. To fix the picture, let it be washed first in water, then allowed to remain for a few minutes in a solution of iodide of potassium (5 grains to the ounce of water) and washed in water again. The paper I use is the common unglazed copy paper, but such as has a good body. I have tried the same paper with the original preparation and find it to answer exceedingly well. It does not require in this case, either, an acid solution. The same precautions and hints apply to the amended as to the original process, such as when it blackens in the dark there is too much caustic used; when it remains yellow or that it is studded with yellow spots, too much iodine; when marked with black spots, too much iron. It is necessary to mention these on account of the varying strength of the materials employed.

FERROCYANIDE OF POTASSIUM.

At the meeting of the British Association at Plymouth in 1841 I first directed attention to the use of the ferrocyanide of potassium in combination with the iodide of silver. The process resulting from this being very important in many points, the abstract of the paper then read, as given in the Transactions of the Sections, is reprinted.

The author having been engaged in experiments on those varieties of photographic drawings which are formed by the action of the hydriodic salts on the darkened chloride of silver, and with a view to the removal of the iodide formed by the process from the paper, was led to observe some peculiar changes produced by the combined influences of sunshine and the ferrocyanide of potassium. It was found that the ordinary photographic paper, if allowed to darken in sunshine, and then slightly acted on by any hydriodic solution,

and when dry washed with a solution of the ferrocyanide of potassium, became extremely sensitive to light, changing from a light brown to a full black by a moment's exposure to sunshine. Following out this result, it was discovered that perfectly pure iodide of silver was acted on with even greater rapidity, and thus became easy to form an exquisitely sensitive photographic paper.

The method recommended is the following:

Highly glazed letter paper is washed over with a solution of 1 dram of nitrate of silver to an ounce of distilled water; it is quickly dried and a second time washed with the same solution. It is then, when dry, placed for a minute in a solution of 2 drams of the iodide of potassium in 6 ounces of water, placed on a smooth board, gently washed by allowing some water to flow over it, and dried in the dark at common temperatures. Papers thus prepared may be kept for any length of time, and are at any time rendered sensitive by simply washing them over with a solution formed of 1 dram of the ferrocyanide of potassium to an ounce of water.

These papers, washed with the ferrocyanide and dried in the dark, are, in this dry state, absolutely insensible, but they may at any moment be rendered sensitive by merely washing them with a little cold clean water.

Papers thus prepared are rendered quite insensible by being washed over with the above hydriotic solution. They are, however, best secured against the action of time by a solution of ammonia.

THE FLUOROTYPE.

The fluorotype, so called from the introduction of the salts of fluoric acid, consists of the following process of manipulation:

Bromide of potassium....	20 grains.
Distilled water	1 fluid ounce.
Fluoride of sodium.......	5 grains.
Distilled water	1 fluid ounce.

Mix a small quantity of these solutions together when the papers are to be prepared, and wash them once over with the mixture, and, when dry, apply a solution of nitrate of silver, 60 grains to the ounce of water. These papers keep for some weeks without injury and become impressed with good images in half a minute in the camera. The impression is not sufficiently strong when removed from the camera for producing positive pictures, but may be rendered so by a secondary process.

The photograph should first be soaked in water for a few minutes and then placed upon a slab of porcelain, and a weak solution of the protosulphate of iron brushed over it; the picture almost imme-

diately acquires an intense color, which should then be stopped directly by plunging it into water *slightly* acidulated with muriatic acid, or the blackening will extend all over the paper. It may be fixed by being soaked in water, and then dipped into a solution of hyposulphite of soda and again soaked in water as in the other processes.

Mr. Bingham has the following remarks on this process, and he gives a modified form, into which a new photographic element is introduced:

> We find it is better to add to the protosulphate of iron a little acetic or sulphuric acid; this will be found to prevent the darkening of the lights of the picture to a great extent, and it will be found better not to prepare the paper long before it is required for use, this being one reason why the picture often becomes dusky on application of the protosulphate.
>
> Reasoning upon the principle that the action of light is to reduce the salts of silver in the paper to the metallic state, and that any substance which would reduce silver would also quicken the action of light, we were led to the following experiment: The protochloride of tin possesses the property of reducing the salts both of silver and gold. A paper was prepared with the bromide of silver, and previously to exposing it to light it was washed over with a very weak solution of the chloride of tin. The action of light upon the paper was exceedingly energetic; it was almost instantaneously blackened, and a copy of a print was obtained in a few seconds.

The use of fluorides has been recently introduced as a novelty by some French photographers, but reference to the author's Researches on Light, published in 1844, will distinctly show that I was the first to employ these salts as photographic agents.

BROMIDE OF SILVER AND MERCURIAL VAPOR.

In my first publication on this subject, in Griffin's Scientific Miscellany, I introduced the following process, which, although it has never yet been properly worked out, involves many points of interest: Some extremely curious results led me to examine the effect of the mercurial vapor on the pure precipitated iodides and bromides. I was long perplexed with exceedingly anomalous results, but, being satisfied from particular experiments that these researches promised to lead to the discovery of a sensitive preparation, I persevered.

To prepare this sensitive paper we proceed as follows: Select the most perfect sheets of well-glazed satin post, quite free from specks of any kind. Placing the sheet carefully on some hard body, wash it over on one side by means of a very soft camel's-hair pencil with a solution of 60 grains of the bromide of potassium in 2 fluid ounces of distilled water and then dry it quickly by the fire. Being dry, it is again to be washed over with the same solution and dried as before. Now, a solution of nitrate of silver, 120 grains to the fluid ounce of distilled water, is to be applied over the same surface and the paper

quickly dried in the dark. In this state the papers may be kept for use. When they are required the above solution of silver is to be plentifully applied and the paper placed *wet* in the camera, the greatest care being taken that no daylight, not even the faintest gleam, falls upon it, until the moment when we are prepared, by removing the screen, to permit the light radiated from the objects we wish to copy to act in producing the picture. After a few seconds the light must be again shut off and the camera removed into a dark room. It will be found on taking the paper from the box that there is but a very slight outline, if any, as yet visible. Place it aside in *perfect darkness* until quite dry, then fix it in a mercurial vapor box and apply a very gentle heat to the mercury. The moment the mercury vaporizes the picture will begin to develop itself. The spirit lamp must now be removed for a short time, and when the action of the mercury appears to cease it is to be very carefully applied again until a well-defined picture is visible. The vaporization must now be suddenly stopped and the photograph removed from the box. The drawing will then be very beautiful and distinct, but much detail is still clouded, for the development of which it is only necessary to place it cautiously in the dark and allow it to remain undisturbed for some hours. There is now an inexpressible charm about the picture, equaling the delicate beauty of the daguerreotypes, but being still very susceptible of change it must be viewed by the light of a taper only. The nitrate of silver must now be removed from the paper by well washing in soft water. When the picture has been dried wash it quickly over with a soft brush dipped in a warm solution of the hyposulphite of soda and then well wash it for some time in the manner directed for the ordinary photographs in order that all the hyposulphite may be removed. The drawing is now fixed, and we may use it to procure positive pictures, many of which may be taken from one original.

* * * * * * *

III. Photographs on Glass Plates and Recent Improvements.

To Sir John Herschel we are indebted for the first use of glass plates to receive sensitive photographic films.

PRECIPITATES OF SILVER SALTS.

The interest which attaches to this is so great and there appear to be in the process recommended by the English experimentalist so many suggestive points from which future photographists may start that the passages are given in Sir John Herschel's own words:

With a view to ascertain how far organic matter is indispensable to the rapid discoloration of argentine compounds, a process was tried which it may not be

amiss to relate, as it issued in a new and very pretty variety of the photographic art. A solution of salt of extreme dilution was mixed with nitrate of silver so diluted as to form a liquid only slightly milky. This was poured into a somewhat deep vessel, at the bottom of which lay horizontally a very clean glass plate. After many days the greater part of the liquid was decanted off with a siphon tube and the last portions very slowly and cautiously drained away, drop by drop, by a siphon composed of a few fibers of hemp laid parallel and moistened without twisting. The glass was not moved till quite dry and was found coated with a pretty uniform film of chloride of silver of delicate tenuity and chemical purity, which adhered with considerable force and was very sensitive to light. On dropping on it a solution of nitrate of silver, however, and spreading it over by inclining the plate to and fro (which it bore without discharging the film of chloride) it became highly sensitive, although no organic matter could have been introduced with the nitrate, which was quite pure, nor could any indeed have been present, unless it be supposed to have emanated from the hempen filaments, which were barely in contact with the edge of the glass and which were constantly *abstracting* matter from its surface in place of introducing new.

Exposed in this state to the focus of a camera with the glass toward the incident light it became impressed with a remarkably well-defined negative picture which was direct or reversed, according as looked at from the front or the back. On pouring over this cautiously, by means of a pipette, a solution of hyposulphite of soda the picture disappeared, but this was only while wet, for on washing in pure water and drying it was restored and assumed much the air of a daguerreotype when laid on a black ground, and still more so when smoked at the back, the silvered portions reflecting most light, so that its characters had in fact changed from negative to positive. From such a picture (of course before smoking) I have found it practicable to take photographic copies, and although I did not in fact succeed in attempting to thicken the film of silver by connecting it under a weak solution of that metal with the reducing pole of a voltaic pile, the attempt afforded distinct indications of its practicability with patience and perseverance, as here and there over some small portions of the surface the lights had assumed a full metallic brilliancy under this process. I would only mention further to those who may think this experiment worth repeating that all my attempts to secure a good result by drying the nitrate in the film of chloride have failed, the crystallization of the salt disturbing the uniformity of the coating. To obtain delicate pictures the plate must be exposed wet, and when withdrawn must immediately be plunged into water. The nitrate being thus abstracted, the plate may then be dried, in which state it is half fixed, and it is then ready for the hyposulphite. Such details of manipulation may appear minute, but they can not be dispensed with in practice, and cost a great deal of time and trouble to discover.

This mode of coating glass with films of precipitated argentine or other compounds affords, it may be observed, the *only* effectual means of studying their habitudes on exposure to light, free from the powerful and ever-varying influence of the *size* in paper and other materials used in its manufacture, and estimating their degree of sensibility and other particulars of their deportment under the influence of reagents. I find, for example, that glass so coated with the iodide of silver is much more sensitive than if similarly covered with the chloride, and that if both be washed with one and the same solution of nitrate there is no comparison in respect of this valuable quality, the iodide being far superior, and, of course, to be adopted in preference for the use of the camera. It is, however, more difficult to fix, the action of the hyposulphites on this compound of silver being comparatively slow and feeble.

When the glass is coated with the bromide of silver, the action per se, is very slow, and the discoloration ultimately produced far short of blackness; but when moistened with nitrate of silver, sp. gr. 1·1, it is still more rapid than with the iodide, turning quite black in the course of a very few seconds' exposure to sunshine. Plates of glass thus coated may be easily preserved for the use of the camera, and have the advantage of being ready at a moment's notice, requiring nothing but a wash over with the nitrate of silver, which may be delayed until the image is actually thrown on the plate and adjusted to the correct focus with all deliberation. The sensitive wash being then applied with a soft, flat camel's-hair brush, the box may be closed and the picture impressed; after which it only requires to be thrown into water and dried in the dark to be rendered comparatively insensible, and may be finally fixed with hyposulphite of soda, which must be applied hot, its solvent power on the bromide being even less than on the iodide.

Sir John Herschel suggested a trial of the fluoride of silver upon glass, which, he says, if proved to be decomposable by light, might possibly effect an etching on the glass by the corroding property of the hydrofluoric acid.

The metallic fluorides have been found to be decomposable, and a very sensitive process on paper, called the fluorotype, will be described in the chapter on Miscellaneous Processes. I am not aware that any experiments have been made directly upon glass, but it is certainly worthy of a careful trial.

Herschel has remarked that we can not allow the wash of nitrate to dry upon the coating of the chloride or iodide of silver. If, however, we dip a glass which has one film of chloride upon it into a solution of common salt, and then spread upon it some nitrate of silver, we may very materially thicken the coating, and thus produce more intense effects. Mr. Towson employed glass plates prepared in this manner with much success. The mode adopted by that gentleman was to have a box the exact size of the glass plate, in the bottom of which was a small hole; the glass was placed over the bottom, and the mixed solution, just strong enough to be milky, of the salt and silver poured in. As the fluid finds its way slowly around the edges of the glass, it filters out; the peculiar surface action of the solid glass plate, probably a modified form of cohesive force, separating the fine precipitate which is left behind on the surface of the plate. By this means the operation of coating the glass is much quickened. Another method by which films of any of the salts of silver can be produced upon glass plates, is the following modification of the patent processes of Drayton and of Thompson for silvering glass: Take a very clear plate of glass, and having put around it an edging of wax about half an inch in depth, pour into it a solution of nitrate of silver made alkaline by a few drops of ammonia, taking care that no oxide of silver is precipitated; mix with this a small quantity of spirits of wine, and then add a mixture of the oils of lavender and cassia, or, which is perhaps the best process, a solution of grape sugar.

In a short time the glass will be covered with a very beautiful metallic coating. The solution is now poured off, the edging of wax removed, and the silver is exposed to the action of diluted chlorine, or to the vapor of iodine or bromide, until it is converted into a compound of one of these elements, after which we may proceed as recommended by Sir John Herschel.

ALBUMEN.

In the Technologiste for 1848, M. Niepce de Saint-Victor published his mode of applying *albumen* to glass plates. M. Blanquart Everard followed, and successively albumen, gelatine, and serum were employed. Messrs. Ross and Thomson, of Edinburgh, have been eminently successful operators with albumen on glass plates, many of their pictures leaving little to be desired. The manipulatory details of the albumen process will be found in the technical division of this work.

COLLODION.

The successful application of a solution of gun cotton in ether, to form the film for receiving the sensitive surface on glass, has been claimed respectively by Mr. Fry and Mr. Archer. There is some difficulty in fixing precisely this point, since there was no actual publication of the process until long after it was generally in use. Mr. Fry certainly introduced the use of gutta-percha in combination with collodion.

THE GENESIS OF THE DIAMOND.[a]

By Gardner F. Williams, Kimberley, South Africa.

Chemically the diamond is composed of the element carbon in its pure crystallized state. The diamond crystallizes in the isometric system and the most common forms are the octahedron and dodecahedron, while the (24-sided) tetrahexahedron is not uncommon. Cube diamonds with beveled edges, representing the combination ∞ 0 ∞ and ∞ 0 2 are occasionally found in the Bultfontein and Wesselton mines at Kimberley, South Africa. The diamonds from various mines have distinctive forms of crystallization, or variations of the same forms, so characteristic that those familiar with South African diamond mines and their products can determine positively from which mine any given parcel of diamonds has been obtained. It is not always possible to determine the source of each individual diamond, for similar stones are occasionally found in different mines; but these are exceptions to the rule. There is a difference in the luster, shape, or crystalline form of the diamonds from the various mines that gives each mine some distinctive characteristic. In one mine nearly all the crystals are sharp-edged octahedrons, while in another dodecahedrons with rounded faces predominate. One might give no end of peculiarities of the diamonds from the various mines, but it will suffice for the purposes of this paper to state the fact that such distinctive characteristics do occur.

From this observation it may be concluded that the diamonds in the mines of the Kimberley district, which occupies a small area (see fig. 1), did not have a common origin.

The diamond is the most impenetrable of all known substances and will scratch any other stone or the hardest steel. During his lecture[b] at Kimberley, Sir Wm. Crookes squeezed a diamond between

[a] Reprinted, with the author's revision and additions, from Transactions American Institute of Mining Engineers, 1905. Read at Lake Superior meeting, September, 1904.

[b] A lecture delivered before the British Association at Kimberley, September 5, 1905.

two blocks of steel until the blocks touched without injury to the stone in the slightest degree. The pressure is said to have been

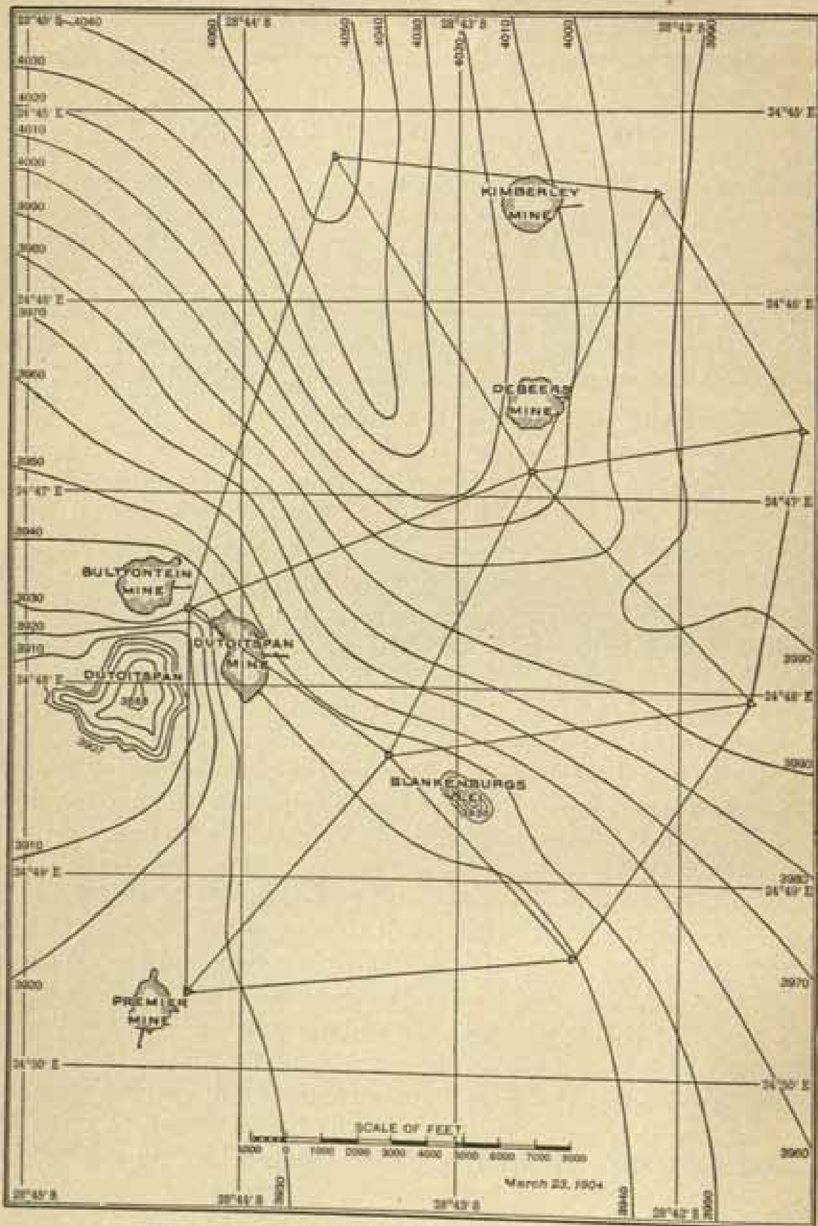

FIG. 1.—Diamond mines in the Kimberley District, South Africa.

170 tons to the square inch. It is a very strong reflector of light and refracts incident rays more than any other substance except crocoite.[a]

[a] Table of indices of refraction in Dufrenoy's Traité de Mineralogie.

While crocoite is the only mineral that exceeds the dispersive power of diamond to dissolve white light into rainbow tints, in its powers of reflection, refraction, and dispersion taken together the diamond is unmatched.[a] It is highly phosphorescent, and even the blackest diamond is transparent to the X ray. The diamond glows under the influence of the B rays from radium. Diamonds when subjected to the action of radium for several months assume a green color, but cut stones when treated in this manner seem to lose part of their brilliancy. It is insoluble in all acids, and can easily be burned and converted into carbon dioxide. It volatilizes at a temperature of about 3,600° C. and passes from the solid to the gaseous state without liquefying.

Sir William Crookes went through the process of producing diamonds before the eyes of his audience, but was only able to show them the result of this experiment by reproducing a lantern slide of microscopical diamonds which he had made in the same way previously, for it takes a fortnight to separate them from the iron and other substances in which they are embedded. The scientific principle upon which this experiment rests, according to Sir William Crookes, is that molten iron absorbs carbon, and as iron increases in volume as it passes from the liquid to the solid state, if the outer crust of the iron is suddenly cooled and the center remains in a liquid state, the enormous pressure caused by its expanding while cooling affords the two factors necessary for the crystallization of a diamond—heat and pressure.

Authorities differ somewhat as to the exact moment when molten iron expands on cooling, but it is the generally accepted theory that expansion takes place at the moment of solidification. It is also a well-known fact that shrinkage or contraction takes place as the solidified metal cools. It is therefore possible to obtain enormous pressure in the molten center of a casting by the contraction of the outer shell which has been rapidly cooled and the expansion of the inner mass just as it begins to solidify.[b]

It is noteworthy that the diamond is a nonconductor of electricity, while graphite and amorphous carbon, substances so closely allied to it in chemical composition, are good electrical conductors. By the application of friction the diamond can be positively electrified, but it very soon loses its electricity. The diamond is easily cleaved in planes parallel to the octahedral faces. Pieces may be easily broken from the facets of a cut stone by striking it with a hard substance.

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[a] Feuchtwanger's Treatise on Gems.

[b] American Society Mechanical Engineers, Vol. XVIII, pp. 419 and 431; Vol. XVII, pp. 126 and 1015.

So much, it may be claimed, is known about the physical properties of the diamond, but how the diamond has been formed or crystallized is a question still debated by scientists.

Upon the information at hand it may be assumed that all diamonds found prior to the discovery of the Kimberley pipes or craters came from alluvial deposits and had been washed down by the disintegration of the original matrix. Such was the character of the formation in which the noted diamonds of India were found, which is described as a layer of broken sandstone, quartz, jasper, flint, and granite, interspersed with masses of calcareous conglomerate, the whole being about 20 feet thick and covered with a few feet of black "cotton soil." Here were the great mines of Gani-Coulour and Gani-Parteal, whence came the Koh-i-nur (793 carats), the Great Mogul (787.5 carats), the Regent (410 carats), and many other historical stones.[a]

The India mines were noted more for the size and purity than for the quantity of the gems they produced. There had been no considerable production of diamonds outside of the Deccan fields until the discovery of diamonds in Brazil in the year 1728. Here, in the province of Minas Geraes, rich beds were opened in an alluvial deposit of clay, quartz pebbles, and sand, charged with iron oxide.[b] In many places the diamond-bearing strata were buried under 30 feet or more of alluvial detritus. These deposits occurred along the rivers, up the ravines to the ridges and plateaus, where conglomerate beds were reached from which the deposits in the rivers had been washed. The conglomerate was chiefly itacolumite, a micaceous sandstone. The sandstone, being a fragmental sedimentary rock, was not the original matrix of the diamond. Probably when the sandstone was being formed the diamonds were washed down with the detritus and became embedded in it.

Diamonds have also been found in alluvial deposits in Borneo; New South Wales; British Guiana; in the gold deposits of the Ural Mountains, Australia, and California; along the Vaal River in South Africa; and in many other localities.

Before the discovery of the mines at Jagersfontein and Kimberley, which occurred between August, 1870, and July, 1871, there is no record that diamonds had been discovered in volcanic pipes or craters, their occurrence having always been in alluvial or sedimentary deposits.

A few years ago diamonds were found in the battery mortar of a mill at Klerksdorp in the Transvaal which was crushing gold ore

[a] Voyages en Turquie, en Perse et aux Indes, Tavernier, Paris, 1676.

[b] The Diamond Fields of Brazil, Report of United States Minister Bryan, 1899, conveying report of Secretary of Legation Dawson. A Treatise on Gems, Lewis Feuchtwanger, M. D., 1867. An Account of Diamonds Found in Brazil, James Castro de Sarmento. Travels in South America, J. J. von Tschudi.

from a conglomerate reef similar to the Witwatersrand reefs. It had occurred to me that either the wash from a diamond-bearing pipe had been mixed with the detritus when the conglomerate beds were formed or that a diamond-bearing dike penetrated the conglomerate strata and its contents were mined and sent to the mill along with the gold ore. This remarkable occurrence of diamonds has been explained to me by an old Kimberley miner who was on the ground at the time the diamonds were found.

In his opinion some of the top soil or wash was mined with the gold-bearing conglomerate and the diamonds came from this alluvial deposit. The finding of these diamonds in the battery mortar, as above described, is well authenticated. The diamonds were of a greenish color.

In November, 1902, the Premier mine near Pretoria, Transvaal, was found. The surface area of the mine has 3,515 claims (a claim being 31 by 31 feet); 1,285 of these had been worked to an average depth of 38 feet at the end of 1905. This ground has proved to be of exceptional richness and has yielded 1,821,609 carats from 2,824,579 loads of 1,600 pounds each. It was in this mine that the Cullinan diamond, famous for being the largest diamond crystal known, was found January 26, 1905. This stone is of excellent quality and weighs 3,025¾ carats—9,586.5 grains (1.37 pounds).

During last year (1905) a piece of Brazilian boart or carbonado weighing 3,078 carats was broken up and sold in London.

Coming now to the occurrence of diamonds at Kimberley, I may preface my remarks by saying that my experience with the mines at Kimberley dates back nearly twenty-two years, about nineteen of which have been passed in the management of them.

The diamonds occur in a rock commonly known as "blue ground," filling the craters of extinct volcanoes. This rock was described by Prof. Henry Carvill Lewis as a porphyritic volcanic peridotite of basaltic structure[a], which he named "kimberlite." It must be designated as breccia. There is no doubt that the blue ground is of volcanic origin, and was forced up from below; it consists of olivine with fragments of other rocks. I am of the opinion that the craters were filled by aqueous rather than igneous agencies, possibly by something in the nature of mud volcanoes.

It is a noteworthy fact that all the craters were filled just even with the surface of the surrounding country. Would this have been the case if the pipes were of igneous origin? I think not.

It may be claimed that the surface of the country, as it existed when the craters were filled with the diamond-bearing breccia, was

[a] The Matrix of the Diamond, Henry Carvill Lewis, M. A., F. R. S., at a meeting of the British Association at Manchester, August and September, 1887.

not the same as at present, but that it has been denuded or washed away, or has been removed by glacial action. There is, however, not the least possible evidence to bear out such a contention. If the country rock and diamond-bearing ground had become decomposed and been washed away, then diamonds would have been found in the "wash" or in ravines and water courses in the vicinity of the mines. Such is not the case, and no diamonds have been found in alluvial soil nearer than the Vaal River, about 20 miles distant, and these diamonds are totally different in character from the "mine" stones.

The Kimberley mines lie in basins from which no water flows into any stream, but runs into pans or vleis, where it evaporates or is used for mining purposes.

In this connection it may be stated that Dutoitspan mine is situate within a few hundred feet of Du Toit's pan, a pond, which is fed by small water courses during the rainy season. The bottom of the pan was probably 30 feet lower than the edge of the mine, where the yellow diamond-bearing ground joined the basalt, yet it is a significant fact that no diamonds have been found in the pan.

Bultfontein mine is also quite as near this pan and lies at a considerable elevation above it.

At Kimberley and De Beers mines the same conditions exist, but the drainage from these mines is to the north into Diebel's vlei, which is 100 or more feet below the mines and nearly 4 miles distant therefrom. No diamonds have been found between the mines and the vlei nor in the vlei itself, and I repeat that this is a significant fact. By what laws of nature would it be possible to obliterate a large section of these mines and leave no diamonds behind in these depressions? In case the depressions have been made since the formation of the pipes, would it not be reasonable to expect that the forces that made them would have washed a portion of the diamond pipes into them?

I have given these facts at considerable length because my contention that these are the craters and not simply the necks of mud volcanoes has been questioned. It is contended that the craters have been washed away, but this is hardly borne out by local observations. The tops of these craters are bell-shaped, as is the case of ordinary volcanoes. I can not conceive how these craters could have been just filled to the level of the surface of the surrounding country, except that the material which filled them came up as mud highly charged with gases which escaped in the air on nearing the surface and allowed the mass of mud to subside. There must have been some process to incorporate the shales, which lie near the surface, so thoroughly with the eruptive mass.

Any denudation of the tops of these craters would have left behind some trace, even more than a trace, some concentration of diamonds

and the heavy minerals which are associated with them. In the machines in use on the diamond fields we imitate nature in concentrating the heavy minerals. The light particles are washed away, leaving the concentrates behind.

The Vaal River diamonds did not have their origin in the Kimberley mines. The occurrence of well rounded and at times polished bowlders and small pieces of rock in these mines is proof that other than igneous action was necessary to produce them.

Professor Bonney says that "the idea that they have been rounded by a sort of cup-and-ball game played by a volcano may be dismissed as practically impossible."[a] He refers to the Dwyka conglomerate bed as a possible source of these bowlders. A conglomerate bed composed of fragments of quartz, feldspar, chert, shale, quartzite, quartz porphyry, and other rocks exists in the Kimberley strata between the shale and the melaphyre (or olivine-diabase of Stelzner), and is between 300 and 400 feet below the surface. This conglomerate is from 3 to 10 feet thick, as determined in the various shafts in the Kimberley mines. The rounded stones in the mines did not come from this bed, and are wholly unlike the stones in the conglomerate. Personally I do not favor the cup-and-ball theory, and would not give it a second thought were it not for the fact that the diamond-bearing ground as it is found in the mines shows such a mixture with the country rock (shale) that some process of nature must have stirred up and thoroughly mixed the contents of these great craters. I can not comprehend how this result could have been brought about in an igneous volcano. There would have been overflows of the diamond-bearing rock which would have been found in the vicinity of the mines. No such deposits have been found, and I do not believe that they exist.

It is much easier to reconcile existing conditions to the aqueous or mud-volcano theory (especially if the mud was accompanied by large quantities of gases which, on nearing the surface, escaped while the mud receded) than to an igneous theory.

There must have been innumerable eruptions and explosions to account for the inclusion of the surface shales and fragments of the country rock in the diamond-bearing peridotite. The frequent occurrence of these eruptions would, in a measure, solve the problem as to the manner in which the fragments of rocks varying in size from pebbles to bowlders, some with polished surfaces, became, as it were, waterworn.

The evidence of the movement of the diamond-bearing rock after solidifying is indicated by the slickensides and striated surfaces of the country rocks at their junctions or contacts with the kimberlite.

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[a] Proceedings of the Royal Society, vol. lxv., 1899.

Large sheets of calcite are frequently found at the junction of these rocks, which have taken the form of the striæ. Beautiful calcite crystals and transparent pieces of doubly refracting, or Iceland spar, are of frequent occurrence.

There is conclusive proof that the diamonds in the South African mines are not found in their original place of crystallization, as is shown by the frequent occurrence of broken crystals embedded in the hard kimberlite. The geological strata of the rocks which surround the diamond-bearing pipes of the Kimberley district are shown in figure 2.

Concerning the discussion of the genesis of the diamond, Sir Isaac Newton's opinion was that it was of vegetable origin and combustible; but it was not until 1694 that the combustibility of the diamond was actually proved by the famous burning-glass experiment of the academicians of Cimento.

Lavoisier, Guyton de Morveau, and others determined that the diamond was converted into carbonic dioxide by burning. The experiments of Sir Humphry Davy, in 1816, showed that the diamond was almost pure carbon. These experiments have been confirmed by Dumas, Stas, Friedel, Roscoe, and other eminent chemists, who have fixed with extreme precision the composition of the diamond to be pure carbon in crystalline form. The late Dr. W. Guybon Atherstone was one of the first scientists to deal with the occurrence and genesis of the diamond in the Kimberley mines. Being a resident of the Cape Colony, he made frequent visits to the diamond fields and made personal investigations.[a]

"For a substance to crystallize," he says, 'its molecules must be free to move. * * * The diamond, we know, is neither soluble nor fusible. It is the element carbon crystallized, and is consumed by heat. How, then, could it survive as a crystal in the center of a volcano? The key to solve this mystery was placed in my hands over half a century ago by one of the greatest philosophers of the age, whose lectures I had the privilege of attending. * * * 'Hold out your hand,' said Faraday, at the close of the lecture that fairly electrified the world of science, as with a loud hiss a snowy substance, burning like a coal, but in reality intensely cold, escaped into the palm of my hand from the strong iron vessel, in which, with a pressure of fifty atmospheres, he had liquified carbonic acid gas—the very gas resulting from the combustion of the diamond. * * * In the carbonic acid gas generated from the carbonaceous shales by heat and interspersed as gas bubbles in the cavities of the viscid, ferruginous amygdaloid and in the admixture of steam, lava, and ashes known as the 'Kimberley blue,' reduced to the liquid state by the enormous

[a] Geological Magazine, Vol. VI, p. 208, May, 1889.

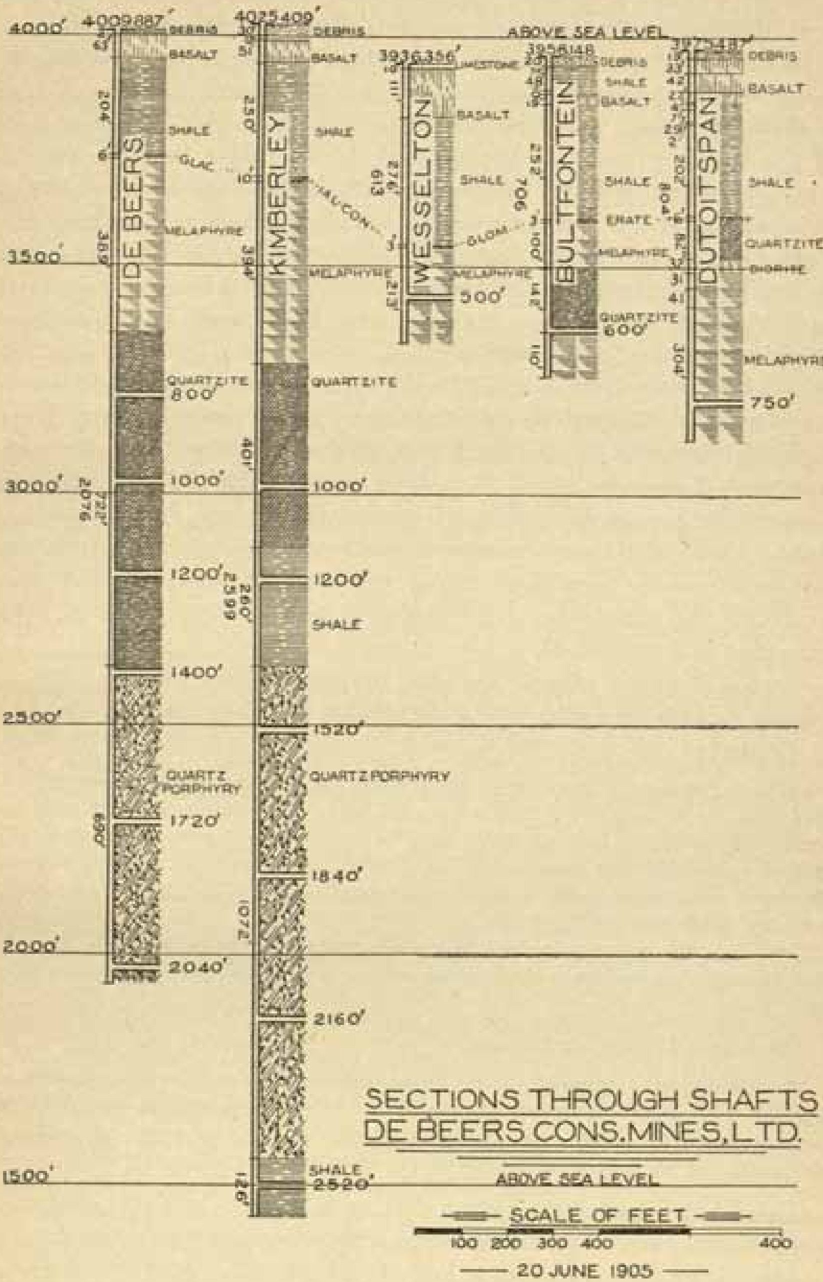

Fig. 2.—Geological strata of Kimberley District.

pressure in the subaqueous volcano, we have the constituents of the diamond in a form admitting of crystallization and the subsequent absorption of its oxygen by the iron always present in its containing walls during long intermittent periods of volcanic inactivity."

In this presentation Doctor Atherstone dogmatically puts the carbonic acid gas evolved from the carbonaceous shales into the cavities of the amygdaloid (presumably the melaphyre, which is the only one of the incasing rocks of the volcanic pipes that is amygdaloidal). This gas is then reduced by pressure to a liquid state, in which form, as he thought, the carbon admitted of crystallization. He then absorbed the oxygen of the carbonic acid by the iron in the containing walls of the craters. As the melaphyre existed before the volcanoes burst through it, it is more than probable that the cavities, which existed in it at the time it was erupted, were filled with agate and calcite, which they now contain, before the diamond-bearing ground was forced up through it. If the theory above given had any foundation in fact, one of two results must have happened, viz, either the resultant diamonds would have been inclosed in the amygdaloidal rock or the diamonds must be formed in the "blue" in their perfect state. Both of these assumptions are contrary to facts. As to the derivation of the necessary carbon from the carbonaceous shales surrounding the mines, it will be made clear subsequently that this assumption is not justified.

Professor Lewis alleged that the diamond is the result of the intrusion of igneous rocks into and through the carbonaceous shales. He says:[a]

Perhaps the most interesting chemical observation concerning the blue ground was that made by Sir H. E. Roscoe. He found that on treating it with hot water an aromatic hydrocarbon could be extracted. By digesting the blue ground with ether and allowing the solution to evaporate, this hydrocarbon was separated and found to be crystalline, strongly aromatic, volatile, burning with a smoky flame and melting at 50° C.

That the rock was a true lava and not a mud or ash is indicated by the fact that the minerals and their associations are those characteristic of eruptive ultrabasic rocks.

Professor Lewis further says:

The kimberlite is shared by no other terrestrial rock. In structure it resembles meteorites of similar composition. If the groundmass of kimberlite were replaced by native iron, it would be nearly allied in both structure and composition with meteorites known as chondrites.

The "Ava" meteorite, which fell in Hungary in 1846, contained graphite in cubic crystalline form which Gustav Rose thought was produced by the transformation of diamonds. Later Weinschenk found transparent crystals (diamonds) in the Ava meteorite. Mi-

[a] The Matrix of the Diamond, Prof. Henry Carvill Lewis, p. 52.

nute diamond crystals and graphite have been found in the meteorites from Cañon Diablo, Arizona.

Professor Lewis advanced the theory that probably the diamonds came from the hydrocarbon which was contained in the fragments of carbonaceous shales distributed through the blue ground, but the inclusion of carbonaceous shales in the blue ground can hardly be reconciled with Professor Lewis's conclusion "that the rock was a true lava."

If the diamond is the result of the intrusion of igneous rocks into and through the carbonaceous shales, why do not all pipes composed of kimberlite contain diamonds? And why do diamonds exist in some mines, such as those in the Pretoria district, where no carbonaceous shales are to be found?

Professor Molengraaff, formerly state mineralogist to the South African Republic, discusses[a] the genesis of the diamond, and says that the theory of the formation of diamonds during the ascension of the blue ground from carbon borrowed from the carbonaceous shales was, in his opinion, weak.

> In the Pretorian beds, as well as in the formations underlying these, strata containing any notable quantities of carbon were nowhere to be found in the Transvaal; so that the conclusion might safely be drawn that the igneous blue ground, in forcing its way from great depths toward the place where it was found, could not borrow any carbon from the surrounding strata in order to convert it into diamonds.

In Bohemia a rock occurs which contains every mineral known in the blue ground of Kimberley except diamonds. On my visit to the Mining Academy at Freiberg, Saxony, a few years ago, Doctor Stelzner, professor of geology, showed me two cases containing these minerals, and in every instance the Bohemian minerals corresponded with those from Kimberley, except that the case of Kimberley minerals contained a few small diamonds which I had presented to the academy.

Both the aqueous and igneous theories of the origin of the kimberlite have had able supporters, among those of the former being Stanislas Meunier,[b] M. Chaper,[c] and later Professor Garnier and Sir William Crookes.[d] The igneous theory is strongly supported by

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[a] A Monograph on the Diamonds at Rietfontein, near Pretoria, in the Transvaal.

[b] Composition et origine du sable diamantifère du Du Toits Pan, Afrique Australe—Comptes rendus de l'Academie des Sciences de Paris, Vol. LXXXIV, No. 6, p. 250. Examen mineralogique des roches qui accompagnent la diamant dans les mines du Cap de Bonne Esperance—Bulletins de l'Academie Royale de Belgique, 3d series, Vol. III, No. 4.

[c] Note sur la région diamantifère de l'Afrique Australe, Paris, 1880.

[d] A lecture before the Royal Institution of Great Britain, June 11, 1897.

Professors Lewis,[a] Molengraaff,[b] and Stelzner.[c] My own opinion is that the aqueous theory is the less assailable.

Concerning the origin of the blue ground, assuming that it is not the original matrix of the diamond, I find the following weak points in the igneous theory:

1. As already observed, it is impossible to account by the igneous theory for the water-worn bowlders found in the blue ground.

2. The experiments of Herr W. Luzi,[d] of Leipsic, in the production of artificial figures of corrosion upon the surfaces of rough diamonds, are most interesting in the light which they throw on the crystallization and the probable matrix and genesis of the diamond. Until lately the only appearance of corrosion upon the surface of rough diamonds was the regular, triangular, negative pyramids which were produced through heating the diamond in the open air or under the oxygen flame.

Herr Luzi discovered that the breccia (kimberlite) from the South African mines when in a molten condition possesses the property of absorbing the diamond or of changing its shape.

The following is a translation of the description of his experiment:

> A small quantity of blue ground was melted in a crucible placed in a Fourquinon-Leclerq furnace at a temperature of 1,770°, which was the highest temperature attainable. A diamond with perfectly smooth natural faces was submerged in this molten mass. A further quantity of blue ground was added to the contents of the crucible until it was completely filled. A tightly fitting cover was placed on the crucible, which was again exposed for thirty minutes to the greatest heat attainable. When the crucible was cooled the diamond was removed and found to be covered with irregular oval and half-round grooves of various depths. In one experiment the diamond was found to be deeply eaten away on one side.

Some of these partly absorbed diamonds upon which Herr Luzi experimented are deposited in the mineralogical museum of the Leipsic University.

Owing to the cost of the material to be experimented upon, however, Herr Luzi was unable to determine positively what chemical action took place during the time the diamonds were heated in the complicated silica-flux. The fact that diamonds can be absorbed by being placed in molten blue ground tends to prove that the blue ground was not thrust up through the earth's crust in a molten state.

If the diamond is unable to withstand the corroding influence of

[a] The Matrix of the Diamond, Henry Cavill Lewis, at a metting of the British Association at Manchester, August, 1887.

[b] The Occurrence of Diamonds at Rietfontein, G. A. P. Molengraaff.

[c] A lecture by A. W. Stelzner before the Isis Society, in Dresden, Saxony, April 20, 1893.

[d] Ueber künstliche Corrosionsfiguren an Diamanten, Berichte der Deutschen Chemischen Gesellschaft, XXV, p. 2470 (1892).

the silica-magma at the comparatively low temperature given above, how could it possibly have retained its forms of crystallization and perfect faces at the far higher temperature and pressure which must have existed under the igneous theory?

It seems a pity that Herr Luzi did not state the exact weight of the diamonds upon which he experimented, both before and after his experiments. The burning or absorption of the diamond in its matrix is a strong argument against the contention that the blue ground was once a molten lava. If a diamond placed in a graphite crucible containing melted blue ground, which is subjected to a temperature of only 1,770° R., changes its shape, could diamonds be found perfect in shape, without a flaw, and with clear transparent faces, so smooth that they have the appearance of having been polished?

3. Some years ago a diamond weighing 28.5 carats, found at Kimberley, attracted the attention of the valuator. Its external surface was smooth and crystallized, showing no other mineral except the diamond itself, but the interior was white and not transparent. Noticing this peculiar appearance, the valuator broke the stone in order to satisfy his curiosity and found that a small perfect octahedral diamond was inclosed in the center of the larger stone. Nor was this all. There were flakes of a white mineral, not diamond, attached to the fragments of the broken diamond. In appearance the flakes were white, translucent, and crystalline, and about as hard as steel. When heated in a closed tube, moisture was given off. It fused readily on platinum wire to a white bead. A few grains of this white mineral were collected, and by analysis it proved to be apophyllite, a silicate of lime and potash with 16 per cent of water.

If a mineral which is fusible at the ordinary temperature obtained with a blowpipe, and which contains 16 per cent of water, was formed at the same time that the diamond crystallized, it is certain that this did not take place under an enormously high temperature. How, then, one may ask, did the apophyllite become a part of this diamond?

Herr von Tschudi[a] describes a beautiful crystallized Brazilian diamond in the center of which was a leaf of gold. He obtained the information from Dr. Mills Franco, who claimed that there was no doubt or deception as to the identification of the gold.

Occurrences of this nature tend to veil in additional mystery the genesis of the diamond.

4. Professor T. G. Bonney[b] obtained from the Newlands mines, 40 miles northwest of Kimberley, specimens of a coarsely crystalline rock studded with garnets, technically called holocrystalline

[a] Travels in South America, by J. J. von Tschudi.

[b] The Parent Rock of the Diamond in South Africa, by Prof. T. G. Bonney.

and allied to eclogites. At a meeting of the Royal Society[a] he presented his conclusions:

> The blue ground is not the birthplace either of the diamond or of the garnets, pyroxenes, olivine, and other minerals, more or less fragmental, which it incorporates. The diamond is a constituent of the eclogite, just as much as a zircon may be a constituent of a granite or a syenite. * * * I had always expected a peridotite (as supposed by Professor Lewis), if not a material yet more basic, would prove to be the birthplace of the diamond.
>
> Can it possibly be a derivative mineral, even in the eclogite? Had it crystallized out of a more basic magma, which, however, was still molten when one acid more was injected and the mixture became such as to form eclogite? But I content myself with indicating a difficulty and suggesting a possibility; the fact itself is indisputable that the diamond occurs, though rather sporadically, as a constituent of an eclogite, which rock, according to the ordinary rules of inference, would be regarded as its birthplace.

Professor Bonney's statement that diamonds occur in the eclogite of the Newlands mine caused me to examine the eclogite which is found in all the mines at Kimberley and has always been treated as waste rock and thrown away. There are tons of it lying about the Kimberley mines. I have examined hundreds of pieces of this rock, but never found a diamond, nor have I ever heard of a diamond being found in it by anyone during the many years that these fields have been worked. I caused about 20 tons to be collected and sent to a test plant, where it was crushed and afterwards jigged, but it contained no diamonds. Surely if one could find diamonds in the eclogites of a poor mine like the Newlands, the total diamond yield of which was only a few hundred carats, one would naturally expect to find them in the eclogites from mines in the vicinity of Kimberley, which are so rich.

Mr. Waldemar Lindgren, who is connected with the United States Geological Survey, has had an opportunity of studying the blue ground and the minerals contained therein from samples supplied by the writer from which 45 slides were made. His conclusions are as follows:

> In looking over the literature [on diamonds], especially the papers by Profs. A. W. Stelzner and T. G. Bonney, it seems to me that the connection of the diamond with the garnet in the peridotite and pyroxenite has been satisfactorily proved. It is not possible to regard it as formed in the "blue ground." On the contrary, it was evidently contained in the peridotite magma and crystallized with it.

A specimen of the rock, which I presume to be similar to the eclogite spoken of by Professor Bonney, taken from Dutoitspan mine, was handed to Dr. G. F. Becker, who had a slide made from it. He determined the rock to be lherzolite, and says:

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[a] Proceedings of the Royal Society, Vol. LXV, July 27, 1899.

This composition shows that the rock is extremely analogous to kimberlite; in fact, probably a subvariety of it. Zirkel considers kimberlite as closely allied to lherzolite, while Rosenbush appears uncertain how to classify it.

Doctor Becker is still of the opinion that diamonds ought to be found in the lherzolite in spite of the result of the test of 20 tons.

Quite a number of specimens of diamonds and garnets cemented together have been found, but in most specimens which have come under my observation the diamond has grown into the garnet. A diamond was found (January 9, 1904) in Wesselton mine, Kimberley, which had a small garnet embedded in it. The diamond weighed 114 carats, and the garnet was estimated to weigh about half a carat. It appeared to fill the hole in which it was embedded. The diamond was of cubic crystallization with nearly half of the cube wanting. The part of the diamond in which the garnet was buried had numerous depressions similar to the one containing the garnet, and one is led to think that these depressions were also once filled with small garnets, or, in other words, the diamond crystallized upon a nest of garnets. It was of a peculiar plumbago color and semitransparent. All of the diamonds crystallized in cubic form which have been found of late in Wesselton mine were of this peculiar color. Specimens have also been found where the diamond was embedded in olivine.

5. Sir William Crookes and others have mentioned diamonds which burst or explode on being brought to the surface; and Sir William says it has been "conclusively proved that the diamond's genesis must have taken place at great depths under enormous pressure. The explosion of large diamonds on coming to the surface shows extreme tension."

Professor Lewis says that Kimberley diamonds have been found sometimes to have optical anomalies due to strain. Fizzan thought this strain to have been caused by the unequal distribution of heat during cooling; but Jannettaz [a] holds that the strain is due to compressed gas in the interior of the crystal.

I have found that the light-brown smoky diamonds frequently crack when brought from the mine to the surface; but even these remain intact if kept in a moist place. In the days of open-cut working, when a smoky or light-brown diamond was found, the digger placed it in his mouth, where he kept it until he offered it for sale. The buyer placed it in a raw potato, in which it was shipped to Europe. The temperature of the ground in which the stone was found would, as a rule, not exceed 70° F. The temperature of the diamond would be raised to 98° F. while in the digger's mouth. If, however, the stone was kept in a dry place, even at a lower tempera-

[a] Bulletin de la Société Minerale de France, II, 1879, p. 124.

ture, it would crack in all directions. One might argue from this that it was not the expansion of gases by heat alone which caused the fractures. If these fractures were due to compressed gas, as contended by Jannettaz, one might expect this cracking to have occurred while the diamond and its contained gas were exposed to the enormous heat to which, according to the igneous theory, diamonds must have been subjected.

I had been led to believe that only light-brown or smoky stones crack on being exposed to dry air, but I have lately been informed by one of the old diamond miners that he had seen white stones which showed the same phenomenon. There are innumerable fragments of diamonds in the Kimberley pipes, and it is a question how the original crystals became fractured.

6. Sir William Crookes says that the ash left after burning a diamond invariably contains iron as its chief constituent, and the most common colors of diamonds, when most perfectly pellucid, show various shades of brown and yellow from the palest "offcolor" to almost black. These variations, he declares, accord with the theory that the diamond has separated from molten iron.

I have made exhaustive tests in order to ascertain whether diamonds contain iron, oxidized or metallic. The experiments were made with a magnetic separating machine, the field magnets of which attracted any mineral containing iron or iron oxides except pyrites. Although some of these diamonds had the appearance of being coated with iron, and others were colored dark brown and deep yellow, they were in no way attracted by the magnet, even when excited by a strong electric current. These experiments do not, perhaps, disprove the existence of iron in the diamond, but they do establish the fact that the quantity is infinitesimally small. Further experiments in this direction ought to be made by those who have better facilities for such work than are at our disposal here in Kimberley. The experiments of Messrs. Hannay, Moissan, Friedel, Sir William Crookes, and others all show that microscopic diamonds can be produced artificially; but they throw very little light upon the question how the diamonds in the South African craters crystallized.

7. From what is known of the theory of crystallization, one is inclined to the old Indian idea that diamonds grow like onions, though much less quickly. It is hardly conceivable that diamonds, such as the Koh-i-nur, the Great Mogul, the Excelsior (a Jagersfontein South African stone of 971 carats), the two largest De Beers diamonds (respectively of 503 and 428.5 carats), and the Cullinan from the Premier mine (3,025¾ carats), were formed, as the microscopic diamonds have been, in a moment of time during the sudden cooling of molten iron.

Is it not more reasonable to suppose that these enormous crystals grew little by little, and that nature has followed the same laws of crystallization in the diamond as in other minerals?

In March, 1904, a diamond of 228 carats was found in the Kimberley mine, which contained two red spots in the center of the stone. One of these was bright red, and, under a magnifying glass, was found to be a small diamond with crystalline faces easily distinguishable. The large diamond was cracked in all directions around the small crystal for a distance of about one-sixteenth of an inch.

I have been frequently asked "What is your theory of the original crystallization of the diamond?" and the answer has always been "I have none, for after nineteen years of thoughtful study, coupled with practical research, I find that it is easier to 'drive a coach and four' through most theories that have been propounded than to suggest one which would be based on any nonassailable data." All that can be said is that in some unknown manner carbon, which existed deep down in the internal regions of the earth, was changed from its black and uninviting appearance to the most beautiful gem which ever saw the light of day.

THE CULLINAN DIAMOND.—A DESCRIPTION OF THE BIG DIAMOND RECENTLY FOUND IN THE PREMIER MINE, TRANSVAAL.[a]

By F. H. HATCH, Ph. D., F. G. S., and G. S. CORSTORPHINE, Ph. D., F. G. S.

Great interest has been excited, not only in the Transvaal, but throughout the world, by the discovery at the Premier mine, on Wednesday, the 25th of January, 1905, of the largest diamond hitherto known. The stone was found by Mr. Wells, surface manager, in the yellow ground about 18 feet from the surface, a brilliant flash of light from a projecting corner having caught his attention. After a preliminary cleaning it weighs 3,024¾ carats. According to Gardner Williams the South African carat is equivalent to 3·174 grains; consequently the diamond weighs 9,600·5 grains troy, or 1·37 pounds avoirdupois. Through the courtesy of the directors of the company, we have been enabled to make an examination of the stone, with the following result: Roughly speaking, it measures 4 by 2½ by 2 inches; but its size and shape will be best realized by reference to the photographs reproduced on Plates I and II, which represent the diamond from four different points of view and its actual size. These beautiful photographs were taken by Mr. E. H. V. Melvill for the purposes of this description. The stone is bounded by eight surfaces, four of which are faces of the original crystal, and will be referred to in this description under the letters A, B, C, D, and four are cleavage surfaces, the cleavage being of course parallel to the face of the octahedron. In the following description these cleavage surfaces are referred to under the letters E, F, G, H. They are distinguished from the original octahedral faces by greater regularity and smoothness. The shape and relative position of these various surfaces can be seen in the diagrammatic projection depicted in the text figure, which has been drawn in the mineralogical laboratory of the Oxford University Museum, by the kind permission of Professor Miers, F. R. S. The drawing is to half scale.

[a] Reprinted by permission from the Geological Magazine (London), Decade V, Vol. II, No. 490, April, 1905.

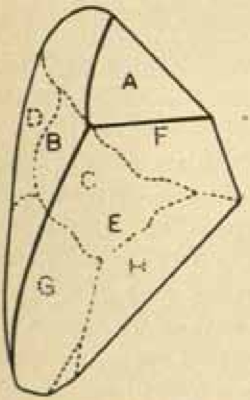
DESCRIPTION OF THE SURFACES.

A is an original octahedral face showing typical striations, the bands varying from 0·1 to 0·4 centimeter, and running parallel to the edge AE.

B is a large surface slightly curved showing partial striations, which, however, are interrupted by the slightly mammillary character of the surface.

C is also a natural surface showing a few striations parallel to the edge CE.

D. Between B and F, C, G there is an irregular octahedral face, D, showing distinct equilateral triangular indentations which resemble etched figures, except in regard to their comparatively large size, the largest having a side measuring 0·7 centimeter. D is parallel to E.



Diagrammatic projection (to half scale).

E, F, G, H are cleavage planes.

E is the largest of these, and is a very perfect cleavage plane. Parallel to it within the crystal there is a small air layer between two internal cleavages, producing a "rainbow," or Newton's rings.

F is the second largest of the cleavage planes and shows a small spot within the crystal.

G is an irregularly shaped cleavage plane.

H is another cleavage face showing series of cleavages in the corner bounded by E and G. Two spots are visible, one actually on the surface, the other about 1 centimeter within the crystal.

Of the faces given, A and G, H and B, and E and D are parallel. In the case of B and H the parallelism is imperfect owing to the curvature of B.

The purity of the crystal is best seen on looking into face E, and the luster is well seen on the irregular natural face B, the broken cleavage on H causing a good deal of refraction, which affects B to some extent as the facets of a cut gem would. For a large stone the crystal is of remarkable purity, and the color approximates to that of a blue-white.

The large size of the cleavage planes E and F indicates that a very considerable portion of the crystal is wanting. From the shape of B, D, and G, one can say that the entire crystal was irregular in shape, but A and D being octahedral faces, the presumption is that the complete crystal was a distorted octahedron, probably with dodecahedral faces developed on the edges. The portions missing probably amount to more than half of the original crystal.

The Cullinan diamond, as it has been named, after the chairman of the Premier company, is more than three times the weight of the largest diamond previously known—the famous stone found in 1893 at Jagersfontein, in the Orange River Colony, which weighed 972 carats.

EXPLANATION OF PLATES.

Plate I.

Fig. 1. The cleavage plane F, which, on account of its favorable position relative to the camera, appears as a brilliantly illuminated surface; the irregular original faces C and D also appear in this view.

Fig. 2. The crystal resting on the cleavage plane E with the faces B and D exposed to view. The sharp bounding edges are formed as follows: At the bottom by E, on the right by A, and on the left by G.

Plate II.

Fig. 3. View of the diamond set up to show the largest cleavage surface E, and the best developed octahedral face A above. The left-hand side of this figure consists of the large irregular natural surface B.

Fig. 4. Comparison of the Cullinan diamond with one of 334 carats, also from the Premier mine. On the large stone the cleavage surface H forms the lower left-hand corner, the natural surface C is to the right of H, and at the top the cleavage surface F. The markings apparently on F are really at the back and are photographed through the crystal. The face on the extreme left, in perspective, is the large cleavage surface E.

Fig. 1.

Fig. 2.

THE CULLINAN DIAMOND, ACTUAL SIZE.

Fig. 3.

Fig. 4.

THE CULLINAN DIAMOND, ACTUAL SIZE.

GOLD IN SCIENCE AND IN INDUSTRY.[a]

By G. T. Beilby, F. R. S., President of Chemical Section of the British Association.[b]

In scanning the list of the elements with which we are thoughtfully supplied every year by the international committee on atomic weights, the direction in which our thoughts are led will depend on the particular aspect of chemical study which happens to interest us at the time. Putting from our minds on the present occasion the attractive speculations on atomic constitution and disintegration with which we have all become at least superficially familiar during the past few years, let us try to scan this list from the point of view of the "plain man" rather than from that of the expert chemist. Even a rudimentary knowledge will be sufficient to enable our "plain man" to divide the elements broadly into two groups—the actually useful and the doubtfully useful or useless. Without going into detail we may take it that about two-thirds would be admitted into the first group and one-third into the second. It must, I think, be regarded as a very remarkable fact that of the 80 elements which have had the intrinsic stability to enable them to survive the prodigious forces which must have been concerned in the evolution of the physical universe, so large a proportion are endowed with characteristic properties which could ill have been spared either from the laboratories of nature or from those of the arts and sciences. Even if one-third of the elements are to be regarded as waste products or failures, there is here no counterpart to the reckless prodigality of nature in the processes of organic evolution.

If we exclude those elements which participate directly and indirectly in the structure and functions of the organic world, there are

[a] Address to the Chemical Section of the British Association for the Advancement of Science, South Africa, 1905.

[b] Reprinted, by permission, from The Chemical News, London, vol. 92, No. 2387, August 25, 1905. The illustrations referred to were not reproduced in the printed address.

two elements which stand out conspicuously because of the supreme influence they have exercised over the trend of human effort and ambition. I refer, of course, to the metals gold and iron.

From the early beginnings of civilization gold has been highly prized and eagerly sought after. Human life has been freely sacrificed in its acquirement from natural sources, as well as in its forcible seizure from those who already possessed it. The "Age of Gold" was not necessarily the "Golden Age," for the noble metal in its unique and barbaric splendor has symbolized much that has been unworthy in national and individual aims and ideals.

We have accustomed ourselves to think of the present as the Age of Iron, as indeed it is, for we see in the dull, gray metal the plastic medium out of which the engineer has modeled the machines and structures which play so large a part in the active life of to-day. Had iron not been at once plentiful and cheap, had it not brought into the hands of the engineer and artificer its marvelous qualities of hardness and softness, of rigidity and toughness, and to the electrician its mysterious and unique magnetic qualities, it is not difficult to conceive that man's control over the forces of nature might have been delayed for centuries, or perhaps for ages. For iron has been man's chief material instrument in the conquest of nature; without it the energy alike of the waterfall and of the coal field would have remained uncontrolled and unused. In this conquest of the resources of nature for the service of man are we not entitled to say that the intellectual and social gains have equaled, if they have not exceeded, in value the purely material gains; and may we not then regard iron as the symbol of a beneficent conquest of nature?

With the advent of the industrial age gold was destined to take a new place in the world's history as the great medium of exchange, the great promoter of industry and commerce. While individual gain still remained the propelling power toward its discovery and acquisition, every fresh discovery led directly or indirectly to the freer interchange of the products of industry, and thus reacted favorably on the industrial and social conditions of the time.

So long as the chief supplies of gold were obtained from alluvial deposits by the simple process of washing, the winning of gold almost necessarily continued to be pursued by individuals, or by small groups of workers, who were mainly attracted by the highly speculative nature of the occupation. These workers endured the greatest hardships and ran the most serious personal risks, drawn on from day to day by the hope that some special stroke of good fortune would be theirs. This condition prevailed also in fields in which the reef gold occurred near the surface, where it was easily accessible without

costly mining appliances, and where the precious metal was loosely associated with a weathered matrix. These free-milling ores could be readily handled by crushing and amalgamation with mercury, so that here also no elaborate organization and no great expenditure of capital were necessary. A third stage was reached when the more easily worked deposits above the water line had been worked out. Not only were more costly appliances and more elaborately organized efforts required to bring the ore to the surface, but the ore when obtained contained less of its gold in the easily recovered, and more in the refractory or combined form. The problem of recovery had now to be attacked by improved mechanical and chemical methods. The sulphides or tellurides with which the gold was associated or combined had to be reduced to a state of minute subdivision by more perfect stamping or grinding, and elaborate precautions were necessary to insure metallic contact between the particles of gold and the solvent mercury. In many cases the amalgamation process failed to extract more than a very moderate proportion of the gold, and the quartz sand or "tailings" which still contained the remainder found its way into creeks and rivers or remained in heaps on the ground around the batteries. In neighborhoods where fuel was available a preliminary roasting of the ore was resorted to, to oxidize or volatilize the baser metals and set free the gold; or the sulphides, tellurides, etc., were concentrated by washing, and the concentrates were taken to smelting or chlorinating works in some favorable situation where the more elaborate metallurgical methods could be economically applied. Many efforts were also made to apply the solvent action of chlorine directly to the unconcentrated unroasted ores; but unfortunately chlorine is an excellent solvent for other substances besides gold, and in practice it was found that its solvent energy was mainly exercised on the base metals and metalloids and on the materials of which the apparatus itself was constructed.

This to the best of my knowledge is a correct, if rather sketchy, description of the state of matters in 1889 when the use of a dilute solution of cyanide of potassium was first seriously proposed for the extraction of gold from its ores. Those of us who can recall the time will remember that the proposal was far from favorably regarded from a chemical point of view. The cost of the reagent, its extremely poisonous nature, the instability of its solutions, its slow action—such were the difficulties that naturally presented themselves to our minds. And, even granting that these difficulties might be overcome, there still remained the serious problem of how to recover the gold in metallic form from the extremely dilute solutions of the cyanide of gold and potassium. How each and all of these difficulties have been swept aside, how within little more than a decade this method of

gold extraction has spread over the gold-producing countries of the world, now absorbing and now replacing the older processes, but ever carrying all before it—all this is already a twice-told tale which I should feel hardly justified in alluding to were it not for the fact that we are to-day meeting on the Rand where the infant process made its début nearly fourteen years ago. The Rand to-day is the richest of the world's gold fields, not only in its present capacity, but in its potentialities for the future; twenty years ago its wonderful possibilities were quite unsuspected even by experts.

It is not for me to describe in detail how the change has been accomplished; this task will, we know, be far better accomplished by representative chemists who are now actively engaged in the work. But for the chemists of the British Association it is a fact of great significance that they are here in the presence of the most truly industrial development of gold production which the world has yet seen—a development moreover that is founded on a purely chemical process which for its continuance requires not only skilled chemists to superintend its operation, but equally skilled chemists to supply the reagent on which the industry depends.

In 1889 the world's consumption of cyanide of potassium did not exceed 50 tons per annum. This was produced by melting ferrocyanide with carbonate of potassium, the clear fused cyanide so obtained being decanted from the carbide of iron which had separated. The resulting salt was a mixture of cyanide, cyanate, and carbonate, which was sometimes called cyanide of potassium for the hardly sufficient reason that it contained 30 per cent of that salt. When the demand for gold extraction arose, it was at first entirely met by this process, the requisite ferrocyanide being obtained by the old fusion process from the nitrogen of horns, leather, etc. In 1891 the first successful process for the synthetic production of cyanide without the intervention of ferrocyanide was perfected, and the increasing demand from the gold mines was largely met by its use. At present the entire consumption of cyanide is not much short of 10,000 tons a year, of which the Transvaal gold field consumes about one-third. Large cyanide works exist in Great Britain, Germany, France, and America, so that a steady and sure supply of the reagent has been amply provided. In 1894 the price of cyanide in the Transvaal was 2 shillings per pound; to-day it is one-third of that, or 8 pence. During the prevalence of the high prices of earlier years the manufacture was a highly speculative one, and new processes appeared and disappeared with surprising suddenness, the disappearance being generally marked by the simultaneous vanishing of large sums of money. To-day the manufacture is entirely carried out in large works scientifically organized and supervised, and, both

industrially and commercially, the speculative element has been eliminated.

Chemistry has so often been called on to play the part of the humble and unrecognized handmaiden to the industrial arts that we may perhaps be pardoned if in this case we call public attention to our Cinderella as she shines in her rightful position as the genius of industrial initiation and direction.

To this essentially chemical development of metallurgy we owe it that in a community whose age can only be counted by decades we find ourselves surrounded by chemists of high scientific skill and attainments who have already organized for their mutual aid and scientific enlightenment "The Johannesburg Society of Chemistry, Metallurgy, and Mining," whose published proceedings amply testify to the atmosphere of intellectual vigor in which the work of this great industry is carried on.

It appears, then, that while gold still maintains its position of influence in the affairs of men, the nature of that influence has undergone an important change. Not only has its widespread use as the chief medium of exchange exercised far-reaching effects on the commerce of the world, but the vastly increased demand for this purpose has in its turn altered the methods of production. These methods have become more highly organized and scientific, and gold production is now fairly established as a progressive industry, in which scope is found for the best chemical and engineering skill and talent.

The experience of more highly evolved industries in the older countries has shown that the truly scientific organization of industry includes in its scope a full and just consideration for the social and intellectual needs of its workers from highest to lowest. It augurs well, therefore, for the future of the gold industry, from the humane and social points of view, that its control should be more and more under the influence of men of scientific spirit and intellectual culture, who, we may feel assured, will not forget the best traditions of their class.

The application of science to industry requires on the part of the pioneers and organizers keen and persistent concentration on certain well-defined aims. Any wavering in these aims or any relaxation of this concentration may lead to failure or to only a qualified success. This necessary but narrow concentration may be a danger to the intellectual development of the worker, who may thereby readily fall into a groove and so may become even less efficient in his own particular work. It certainly requires some mental strength to hold fast to the well-defined practical aim while allowing to the attention occasional intervals of liberty to browse over the wide and pleasant fields of science. But I am certain that the acquirement of this

double power is well worth an effort. The mental stimulus, as well as the new experiences garnered during the excursion, will sooner or later react favorably on the practical problems, while the earnest wrestling with these problems may develop powers and intuitions which will lend their own charm to the wider problems of science.

GOLD AND SCIENCE.

If we reperuse the table of the elements, not now in our capacity as "plain men," but as chemists, we shall certainly not select gold as of supreme interest chemically. Its position as chief among the noble metals, its patent of nobility, is based on its aloofness from common associations or attachments. Unlike the element nitrogen, it is mainly for itself and little, if at all, for its compounds, that gold is interesting. In it we can at our leisure study the *metal* rather than the *element*. Its color and transparence, its softness and its hardness, the density as well as the extreme tenuity of some of its forms—such were the qualities which recommended it to Faraday when he desired to study the action of material particles on light. I should like to repeat to you in his own words the reasons he gave for this choice:

> Because of its comparative opacity among bodies and yet possession of a real transparency; because of its development of color both in the reflected and transmitted rays; because of the state of tenuity and division which it permitted with the preservation of its integrity as a metallic body; because of its supposed simplicity of character, and because known phenomena appeared to indicate that a mere variation in the size of its particles gave rise to a variety of resultant colors. Besides the waves of light are so large compared to the dimensions of the particles of gold which in various conditions can be subjected to a ray, that it seemed probable that the particles might come into effective relations to the much smaller vibrations of the other particles.

I may remind you that Faraday came to the conclusion that the variety in the colors presented by gold under various conditions is due to the size of its particles and their state of aggregation. Ruby glass or ruby solutions he proved are not true solutions, nor are they molecular diffusions of gold, but they contain the metal in aggregates sufficiently large to give a sensible reflection under an incident beam of light. Through the kindness of Sir Henry Roscoe I am able to exhibit to you some of the original ruby-gold preparations obtained during this research, which were afterwards presented to him by Faraday at the Royal Institution some years before his death.

By means of refined and ingenious optical methods Zigsimondy and Siedentopf have succeeded in making these ultramicroscopic particles visible in the microscope as diffraction disks; they have, further, counted the number of particles per unit area and have from the intensity of their reflection calculated their size. In ruby glass

the size of the particles in different specimens was found to vary from 4 to 791 millionths of a millimeter. No relation was found to hold between the color of the particles and their absolute size. This conclusion is in direct contradiction of Faraday's belief, already referred to. Mr. J. Maxwell Garnett has recently shown that the color of metallic glasses and films is determined, not only by the absolute size of the metal particles, but also by the proportion of the total volume they occupy in the medium in which they are diffused. The results of Mr. Garnett's calculations are in close agreement with a number of the observations on the color and microstructure of thin metal films which I had already recorded, and they appear to me to supply the explanation of much that had appeared puzzling before. My own observations lead me to think that the actual microscopic particles which are to be seen, and the larger of which can also be measured, in films and solutions or suspensions, do not in any way represent the ultimate units of structure which are required by Mr. Garnett's theory, but that these particles are aggregates of smaller units built up in more or less open formation.

That a relatively opaque substance, like gold, may be so attenuated that when disseminated in open formation it becomes transparent is contrary to all our associations with the same operation when performed on transparent substances like glass or crystalline salts. The familiar experiment of crushing a transparent crystal into a perfectly opaque powder would not prepare us for the effect of minute subdivision on the transparence of metals. At first it might be supposed that this difference is due to the very rough and incomplete subdivision of the crystal by crushing; but this is not the case, for the perfectly transparent oxide of magnesium may be obtained in a state of attenuation comparable with that of the gold by allowing the smoke from burning magnesium to deposit on a glass plate. The film of oxide obtained in this way is found to be built up of particles quite as minute as those of which the gold films are composed, yet the opacity of the oxide film is relatively much greater. The minute particles of the dielectric, magnesium oxide, scatter and dissipate the light waves by repeated reflection and refraction, while the similar particles of the metallic conductor, gold, act as electrical resonators which pass on some of the light waves while reflecting others. Specimens of films of gold and silver and of magnesium oxide are exhibited on the table and on the lantern screen. When the metallic particles are in this state of open formation and relative transparence, it was found that the electrical conductivity of the films had completely disappeared. Films of this description were found to have a resistance of over 1,000,000 megohms as compared with only 6 ohms in the metallic reflecting condition.

MOLECULES IN THE SOLID STATE.

My examination of gold films and surfaces has revealed the fact that during polishing the disturbed surface film behaves exactly like a liquid under the influence of surface tension. At temperatures far below the melting point molecular movement takes place under mechanical disturbance, and the molecules tend to heap up in minute mounds or flattened droplets. These minute mounds are often so shallow that they can only be detected when the surface is illuminated by an intense, obliquely incident beam of light. I have estimated that these minute mounds or spicules can be seen in this way in films which are not more than 5 to 10 micromillimeters in thickness. A film of this attenuation may contain so few as ten to twenty molecules in its thickness.

When moderately thin films of gold are supported on glass and heated at a temperature of 400 to 500° they become translucent, and the forms assumed under the influence of surface tension can be readily seen by transmitted light. It was in this way that the beautiful but puzzling spicular appearance by obliquely reflected light was first explained as due to the granulation of the surface under the influence of surface tension. Photo-micrographs of these films are exhibited.

Turning now to the mechanical properties of metals, we find that gold has proved itself of great value in the investigation of some of these. It has long been recognized as the most malleable and ductile of the metals, while its chemical indifference tends to preserve it in a state of metallic purity throughout any prolonged series of operations.

The artificers in gold must very early have learned that its malleability and ductility are not qualities which indefinitely survive the operations of hammering and wire drawing. A piece of soft gold beaten into a thin plate does not remain equally soft throughout the process, but spreads with increasing difficulty under the hammer. If carelessly beaten, it may even develop cracks round its edges. We may assume that the artificers in gold very soon discovered that by heating, the hardened metal might be restored to its former condition of softness.

In connection with the study of the micrometallurgy of iron and steel during recent years it has been recognized that heat annealing is as a rule associated with the growth and development of crystalline grains, and Professor Ewing and Mr. Rosenhain have shown that overstrain is often, if not invariably, associated with the deformation of these crystalline grains by slips occurring along one or more cleavage planes. This hypothesis, though well supported up to a point by microscopic observations on a variety of metals, offers no explanation of the natural arrest of malleability or duc-

tility which occurs when the overstrain has reached a point at which the crystalline grains are still, to all appearance, only slightly deformed. At this stage there is no obvious reason why the slipping of the crystalline lamellæ should not continue under the stresses which have initiated it. But far from this being the case, a relatively great increase of stress produces little or no further yielding till the breaking point is reached and rupture takes place.

The study of the surface effects of polishing, already referred to, had shown that the thin surface film retained no trace of crystalline structure, while it also gave the clearest indications that the metal had passed through a liquid condition before settling into the forms prescribed by surface tension. From this it was argued that the conditions which prevail at the outer surface might equally prevail at all inner surfaces where movement had occurred, so that every slip of one crystalline lamella over another would cause a thin film of the metal to pass through the liquid phase to a new and noncrystalline condition. By observations on the effects of beating pure gold foil it was found that the metal reached its hardest and least plastic condition only when all outward traces of crystalline structure had disappeared. It was also ascertained that this complete destruction of the crystalline lamellæ and units could only be accomplished in the layers near the surface, for the hardened substance produced by the flowing under the hammer appears to incase and protect the crystalline units after they become broken down to a certain size. By carefully etching the surface in stages by means of chlorine water or cold aqua regia the successive layers below the surface were disclosed. The surface itself was vitreous. Beneath this was a layer of minute granules, and lower still the distorted and broken-up remains of crystalline lamellæ and grains were embedded in a vitreous and granular matrix. The vitreous-looking surface layer represents the final stage in the passage from soft to hard, from crystalline to amorphous. By heating the beaten foil its softness was restored, and on etching the annealed metal it was found that the crystalline structure also was fully restored. Photomicrographs showing these appearances are exhibited. These microscopic observations were fully confirmed by finding well-marked thermo-electrical and electro-chemical distinctions between the two forms of metal, the hard and soft or the amorphous and the crystalline. The determination of a definite transition temperature at which the amorphous metal passes into the crystalline metal further confirms the phase view of hardening by overstrain and softening by annealing.

It was subsequently proved that *the property of passing from crystalline to amorphous by mechanical flow and from amorphous to crystalline by heat at a definite transition temperature is a general one which is possessed by all crystalline solids which do not decom-*

pose at or below their transition temperature. The significance of this fact, I venture to think, entitles it to more than a passing reference. It appears to me to mean that the transition from amorphous to crystalline is entitled to take its place with the other great changes of state, solid to liquid, liquid to gas, for like these, it marks a change in the molecular activity which occurs when a certain temperature is reached. It is entitled to take this place because there is every indication that the change is as general in its nature as the other changes of state. Compare it, for instance, with the allotropic changes with which chemists have been familiar. These are for the most part changes which are special to particular elements or compounds and are usually classed with the chemical properties by which the substances may be distinguished from each other. Very different is the amorphous crystalline change, for although in particular cases it may have been observed and associated with allotropic changes, yet the causes of its occurrence are more deeply founded in the relations between the molecules and the heat energy by which their manifold properties are successively unfolded as temperature is raised from the absolute zero. At this transition point we find ourselves face to face with the first stirrings of a specific directive force by which the blind cohesion of the molecules is ordered and directed to the building up of the most perfect geometric forms. It is hardly possible any longer to regard the stability of a crystal as static and inert and independent of temperature. Rather must its structure and symmetry be taken as the outward manifestation of a dynamic equilibrium between the primitive cohesion and the kinetic energy imparted by heat. Even before the discovery of a definite temperature of transition from the amorphous to the crystalline phase we had in our hands the proofs that in certain cases the crystalline state can be a state of dynamic rather than of static equilibrium. The transition of sulphur from the rhombic to the prismatic form supplies an example of crystalline stability which persists only between certain narrow limits of temperature. Within these limits the crystal is a "living crystal," if one may borrow an analogy from the organic world. It can still grow, and it will under proper conditions repair any damage it may receive.

The passage of the same substance through several crystalline phases, each only stable over a limited range of temperature, strongly supports the general conclusion drawn from the existence of a stability temperature between the amorphous and crystalline phases, namely, that the crystalline arrangement of the molecules requires for its active existence the particular kind or rate of vibration corresponding with a certain range of temperature. Below this point the crystal may become to all appearance a mere pseudomorph with no powers of active growth or repair. But these powers are not extinct—they are only in abeyance ready to be called forth under the

energizing influence of heat. This temporary abeyance of the more active properties of matter is strikingly illustrated by the early observations of Sir James Dewar at the boiling point of liquid air, and more recently at that of liquid hydrogen. At the latter temperature even chemical affinity becomes latent. In metals it was found that the changes in their physical properties brought about by these low temperatures are not permanent, but only persist so long as the low temperature is maintained. During the past year Mr. R. A. Hadfield has supplemented these earlier results by making a very complete series of observations on the effect of cooling on the mechanical properties of iron and its alloys. The tenacity and hardness of the pure metal and its alloys at the ordinary tempmerature and at —182° have been compared, and it has been found that these qualities are invariably enhanced at the lower temperature, but that they return exactly to their former value at the ordinary temperature. By the mere abstraction of heat between the temperatures of 18° and —182° the tensile strength of pure metals is raised 50 to 100 per cent. In pure iron the increase is from 23 tons per square inch at 18° C. to 52 tons at —182°; in gold from 15·1 tons to 22·4 tons; and in copper from 19·5 tons to 26·4. This increase is not, I think, due to the closer approximation of the molecules, for the coefficient of expansion of most metals below 0° is extremely small. Neither is it due to permanent changes of molecular arrangement or aggregation, for Mr. Hadfield has obtained a perfectly smooth and regular cooling curve for iron between 18° and —182°, and there appears to be no indication of the existence of any critical point between these temperatures. Further, the complete restoration of the original tenacity on the return to the higher temperature shows that no permanent or irreversible change has occurred during cooling. Everything therefore indicates that the increase of tenacity which occurs degree by degree as heat is removed is due to the reduction of the repulsive force of molecular vibration, so that the primary cohesive force can assert itself more and more completely as the absolute zero is approached.

The metals experimented with by Mr. Hadfield were all in the annealed or crystalline condition, so that the molecules must have exerted their mutual attractions along the directed axes proper to this state. It is to be expected that similar experiments with the metals in the amorphous state may throw light on the question whether and to what extent the crystalline state depends on a dynamic equilibrium between the forces of cohesion and repulsion, or whether a directed cohesion exists fully developed in the molecules at the absolute zero.[a]

[a] Since the above was written a series of observations has been made on the influence of low temperature on the tenacity of pure metals in the amorphous condition. These observations will form the subject of a separate communication to the chemical section.

The phenomena of the solid state throw an interesting light on the interplay of the two great forces, the primitive or blind cohesion which holds undisputed sway at the absolute zero, and the repulsion due to the molecular vibrations which is developed by heat. This interplay we know continues through the states which succeed each other as the temperature is raised, till a point is reached at which the molecular repulsions so far outweigh the cohesive force that the substance behaves like a perfect gas. The problems of molecular constitution are more likely to be elucidated by a study of the successive states between the absolute zero and the vaporizing temperature than at the upper ranges where the gaseous state alone prevails. The simplicity of the laws which govern the physical behavior of a perfect gas is very attractive, but we must not forget that this simplicity is only possible because repulsion has so nearly overcome cohesion that the latter may be practically ignored. The attractiveness of this simplicity should not blind us to the fact that it is in the middle region, where the opposing forces are more nearly equal, that the most interesting and illuminating phenomena are likely to abound. The application of the gas laws to the phenomena of solution and osmosis appears to be one of those cases in which an attractive appearance of simplicity in the apparent relations may prove very misleading.

Before passing from the specially metallic qualities of gold I will only remind you of the important part it has played in the researches on the diffusion of metals by the late Sir William Roberts-Austin, and in those of Mr. Haycock and Mr. Neville on the freezing points of solutions of gold in tin, which led to the recognition of the monatomic nature of the molecules of metals.

MOLECULES IN SOLUTION.

It has occurred to me that the practice of the cyanide process of gold extraction presents us with several new and interesting aspects of the problems of solution. As you are aware, the gold is first obtained from the ore in the form of a very dilute solution of cyanide of gold and potassium, from which the metal has to be separated, either by passing it through boxes filled with zinc shavings or by electrolysis in large cells.

The solution as it leaves the cyanide vats may contain gold equal to 100 grains or more per ton, and as it leaves the precipitating boxes it may contain as little as 1 or 2 grains and as much as 20 grains. In the treatment of slimes much larger volumes of solution have to be dealt with, and in this case solutions containing 18 grains per ton have been regularly passed through the precipitating boxes, their gold content being reduced to 1¼ grains per ton. In round numbers we may say that 1 gram of gold is recovered from 1 cubic meter of solution, while 0·1 gram is left in the solution. Even from the point

of view of the physical chemist we are here in presence of solutions of a very remarkable order of dilution. A solution containing 1 gram per cubic meter is in round numbers N/200,000, and the weaker solution containing 0·1 gram is N/2,000,000. It is convenient to remember that the latter contains a little more than $1\frac{1}{2}$ grains per ton. In experiments on the properties of dilute solutions the extreme point of dilution was reached by Kohlrausch, who employed solutions containing 1/100,000 of a gram molecule of solute per liter for his conductivity experiments. These solutions were therefore twice as strong as the gold solution with 1 gram per cubic meter and 20 times as strong as the more dilute solution. This fact must be my excuse for placing before you the results of a few simple calculations as to the molecular distribution in these solutions, which have certainly given me an entirely new view of what constitutes a really dilute solution from the molecular point of view.

In estimating the number of molecules in a given volume of solution the method adopted is to divide the space into minute cubical cells, each of which can exactly contain a sphere of the diameter of the molecule. In this way a form of piling for the molecules is assumed which, though not the closest possible, may quite probably represent the piling of water molecules. Taking the molecular diameter as $0{\cdot}2 \times 10^{-6}$ millimeters—a figure which is possibly too small for the water molecules and too large for the gold—it is found that a cubic millimeter of solution contains 125×10^{15} molecules, or 125 quadrillions. The head of an ordinary pin, if it were spherical, would have a volume of about 1 cubic millimeter.

If these water molecules could be arranged in a single row, each molecule just touching its two nearest neighbors, the length of the row would be 25,000,000 kilometers. A thread of these fairy beads, which contained the molecules of one very small drop of a volume of 6 cubic millimeters, would reach from the earth to the sun, a distance of about 150,000,000 kilometers.

In a solution containing $1\frac{1}{2}$ grains of gold per ton, or 1 decigram per cubic meter, the ratio of gold molecules to water molecules is as 1 : 193,000,000. Each cubic millimeter of the solution, therefore, contains 6,500,000,000 gold molecules. If these are uniformly distributed throughout the solution each will be about 400 micromillimeters, or 1/60,000 of an inch, from its nearest neighbors. This is not really very wide spacing, for the point of the finest sewing needle would cover about 1,500 gold molecules.

If a cubic meter of solution could be spread out in a sheet one molecule in thickness it would cover an area of 1,680 square miles, and nowhere in this area would it be possible to put down the point of the needle without touching some hundreds of gold molecules simultaneously.

According to Professor Liversidge, sea water contains on the average about 1 grain of gold per ton. If this is the case, then the above figures for the dilute cyanide solution apply with only a slight modification to sea water. No drop, however small it may be, can be removed from the ocean which will not contain many millions of gold molecules, and no point of its surface can be touched which is not thickly strewn with these. From this molecular point of view we must realize that our ships literally float on a gilded ocean!

From time to time adventurers arise who attempt to launch upon this gilded ocean unseaworthy ships freighted with the savings of the trusting investor. In order that nothing which has been said here may tempt anyone to contribute to the freighting of these ships, let me hasten to point out that the weakest of the cyanide solutions here referred to is richer in gold than sea water is reported to be. The practical conclusion from this comparison is sufficiently obvious. If the cyaniding expert, whose business it is to extract gold from dilute solutions, finds that it does not pay to carry this extraction beyond a concentration of 2 or 3 grains per ton, even when the solution is already in his hand, and when, therefore, the costs of treatment are at their minimum, how can it possibly pay to begin the work of extraction on sea water, a solution of one-half the richness, which would have to impounded and treated by methods which could not fail to be more costly in labor and materials than the simple process of zinc-box precipitation? It is generally unsafe to prophesy, but in this case I am rash enough to risk the prediction that if ever the gold mines of the Transvaal are shut up it will *not* be owing to the competition of the gold resources of the ocean.

In these calculations with reference to the dilute cyanide solutions it is assumed that the gold molecules are uniformly distributed—that they are practically equidistant from each other. There appears to me to be considerable doubt whether we have any right to make this assumption. Leaving out of account for the moment the action of the water molecules, it would appear that as long as the gold molecules are so numerous that a uniform distribution would bring them within the range of each other's attraction, we can imagine that all submerged molecules would be in equilibrium so far as the attractions of their own kind are concerned, being subjected to a uniform pull in all directions. This condition would certainly make for uniform distribution. But when the distance between them exceeds the range of the molecular forces, it is evident that an entirely new condition is introduced, and it seems not improbable that the widely distributed molecules would tend to drift into clouds in which they are brought back within the range of these forces. The range of the cohesive forces in water and aqueous liquids is usually taken from 50 to 100 micromillimeters, and I am disposed to think that ten times this

amount would not be an excessive estimate of the range in the case of gold. If the range for gold be taken as 500 micromillimeters, then the gold molecules of the dilute gold solution, which are spaced at 400 micromillimeters apart, are just within the range of each other's attraction, and their distribution is, therefore, likely to be uniform. But by a further dilution to half concentration, the equilibrium would be liable to be disturbed, and denser clouds of gold molecules would be formed, with less dense intervals between them.

In preparing the zinc boxes through which the gold solution is passed, very great care has to be exercised to insure that the contact surface of the zinc is used to the best advantage. With this object the packing of the zinc shavings is so managed that the solution is spread over the zinc surface in as thin sheets as possible. The object, of course, is to bring as many of the gold molecules as possible into actual contact with the zinc. The gold molecules found in the solution leaving the boxes are those which have not been in contact with the zinc. Yet we have seen that these molecules are still so numerous that they are within $\frac{1}{60000}$ of an inch of each other. If these molecules are in a state analogous to the gaseous state, with diffusive energy of the same order as that of the gas molecule, it is difficult to imagine how they can escape without coming in contact with the zinc surface during their tortuous passage through the boxes and being deposited there. Yet they do escape, even when the velocity of the solution in passing over the zinc surfaces is so slow as 10 centimenters per minute, or 1·6 millimeters per second.

We may regard the condition of these isolated gold molecules, or the more complex auricyanide of potassium molecules, as typical of that of the solute molecules in a dilute solution of any nonvolatile solid. They are *solid* molecules sparsely distributed among a multitude of intensely active solvent molecules, the temperature of the solution being many hundred degrees below that at which they could of themselves assume the greater freedom of the liquid or gaseous state. These solute molecules have to a great extent been set free from the constraining effect of their cohesive forces, *but it is important to remember that this freedom has not been attained by the increase of their own kinetic energy as in liquefaction by heat.* Their freedom and the extra kinetic energy they have acquired have in some way been imparted to them by the more active solvent molecules; for, if the solvent could be suddenly removed, leaving the solute molecules still similarly distributed in a vacuous space, they would eventually condense into a solid aggregate. This must be the case, for the nonvolatile solute has no measurable vapor pressure at the temperature of the solution. The kinetic energy of the solute molecules is of itself quite insufficient to endow them with the properties of the

gaseous or even of the liquid molecule, even when their cohesive forces have been weakened or overcome by separation.

If the energy employed in this separation is not intrinsic to the solute molecule then it must in some way have been imparted by the solvent molecules. It therefore becomes important to compare the energy endowment of one set of molecules with that of the other.

Compared with other solids, ice at is freezing point has very little hardness or tenacity: the cohesion of its molecules has been much relaxed by the great absorption of heat energy between the absolute zero and the freezing point. If an average specific heat of 0·5 over the whole range be assumed, the heat absorption of one gram amounts to 136·5 calories. In the transition to the liquid state at 0° a further absorption of 79 calories takes place, so that a gram of liquid water at the freezing point contains the heat energy of 215·5 calories. The fact that water has the high vapor pressure of 4·6 millimeters of mercury at the freezing point is probably a result of this enormous store of energy. As a liquid, therefore, it is natural to expect that its molecules will exhibit effects proportionate to this great store of energy. This expectation appears to be realized when we consider not only its properties as the universal solvent, but its osmotic and diffusive energy in solutions in which it is the solvent.

To complete the comparison it is only necessary to calculate the heat energy of gold at 0°. Taking its specific heat as 0·032, a gram of gold at 0° contains 8·7 calories. A gram molecule, therefore, contains in round numbers 1,700 calories as compared with 3,880 calories in a gram molecule of water.

Taking into consideration not only this greater store of energy, but also the much smaller cohesive force of water as compared with the majority of solid solutes, there can be no doubt that the active rôle in aqueous solutions of this type must be assigned to the solvent, not to the solute molecules.

This leads to the important conclusion that the energy of solution, of diffusion, and of osmosis is due, not to the imaginary gaseous energy of the solute, but to the actual liquid energy of the solvent molecules. When this conclusion is reached a new physical explanation of these phenomena is in our hands, and we are relieved from the strain to the imagination involved in the application of the gas theory to solutions of nonvolatile solids.

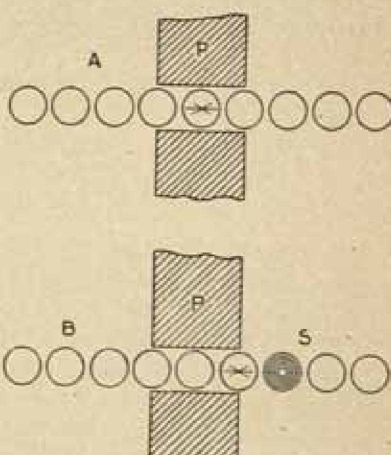
This transference of the active rôle to the solvent molecules does not in any way affect the well-established conclusions based on the laws of thermo-dynamics as to the energy relations in these phenomena, for it has always been recognized that these conclusions have reference to the average conditions prevailing in large collections of relatively minute units. Wherever the gas analogy has appeared to hold it has not necessarily involved more than this, that the observed

effects are in proportion to the number of these minute units in a given volume.

In applying the gas theory to the physical explanation of osmotic pressure it has been the custom to regard this pressure as directly due to the bombardment of the semipermeable membrane by the solute molecules. But this conception completely ignores the fact that the pressure developed is a hydrostatic, not a gaseous pressure, and that the hydrostatic pressure results directly from *the penetration of the solvent molecules from the other side of the partition.*

It appears to me more natural to abandon the gas analogy altogether, to regard the molecules as in the solid and liquid condition proper to their temperature, and to apportion to them their respective parts in the active changes according to their obvious endowment of energy.

Applying this view to the case of a solution and a solvent separated by a semipermeable membrane, it is seen that the pressure rises on the solution side, because the pure solvent molecules on the other side have some advantage for the display of their energy over the similar molecules in the solution. *This effect in its most general form may be attributed to the dilution of the solvent by the solute molecules.* In cases where the osmotic pressure appears to obey Boyle's law the effect is exactly measured by the number of solute molecules per unit volume. But the facts of this position are in no way changed if the effect is taken to be due to the activity of an equal number of solvent molecules, for we then see that each solute molecule by canceling the activity of one solvent molecule on the solution side permits a solvent molecule from the other side to enter the solution.



What the exact mechanism of this cancellation is there is at present no evidence to show, and the caution originally given by Lord Kelvin with reference to the undue forcing of the gas analogy must also be applied to the suggestion now put forward. But as a means of making the suggestion a little more clear I give here a simple diagram on which A represents a single perforation in a semipermeable membrane, P, on both sides of which there is only pure solvent. For the sake of clearness the molecules are shown only as a single row. Normally there will be no passage of solvent molecules from side to side, for the average kinetic energy of the molecules on both sides is equal.

This state of equilibrium is indicated on the diagram by marking with a cross the molecule which is exactly halfway through the partition.

At B a single solute molecule, S, has been introduced at the right side. If this molecule exactly cancels the energy of one solute molecule at its own end of the row, the equilibrium point will move one molecule to the right, the solvent molecules will move in the same direction, and one of their number will enter on the solution side. So long as the row includes one, and only one, solute molecule, the equilibrium will remain unchanged and no more solute molecules will pass in. If another solute molecule arrives on the scene, the equilibrium will again be disturbed in the same way as before, and another solvent molecule will pass into the solution.

This mechanism accomplishes to some extent the work of a "Maxwell demon," in so far at least as it takes advantage of the movement of *individual molecules* to raise one part of a system at a uniform temperature to a higher level or energy.

A MECHANICAL VIEW OF DISSOCIATION IN DILUTE SOLUTIONS.

The view that the phenomena of solution depend on the relative kinetic energy of the solvent and solute molecules appears to apply with special force to the phenomena of dissociation in dilute solutions. Under the gas theory there does not appear to be any reason why the solute molecules should dissociate into their ions. So obvious is this absence of any physical motive that Professor Armstrong has happily referred to the dissociation as "the suicide of the molecules." Others have proposed to ascribe the phenomenon to what might be called "the fickleness of the ions," thus supposing that the ions have an inherent love of changing partners. These may be picturesque ways of labeling certain views of the situation, but the views themselves do not appear to supply any clew to the physical nature of the phenomena. With the acceptance of the view that the phenomena of solution are largely due to the kinetic energy of the solvent molecules, the phenomena of dissociation also appear to take their place as a natural result of this activity. For consider the situation of an isolated molecule of cyanide of gold and potassium closely surrounded by and at the mercy of some millions of water molecules all in a state of intense activity. The rude mechanical jostling to which the complex molecule is subjected will naturally tend to break it up into simpler portions which are mechanically more stable. The mechanical analogy of a ball mill in which the balls are self-driven at an enormous velocity is probably rather crude, but it may at least help us to picture what, on the view now advanced, must be essentially a mechanical operation.

In importing this mechanical view of the breaking down of complex into simpler molecules we are not without some solid basis of facts to go upon. My own observations have shown that even in the solid state the crystalline molecule can be broken down by purely mechanical means into the simpler units of the amorphous state; and, further, that the water molecules of a crystal may by the same agency be broken away from their combination with the salt molecules. Since the publication of the earlier of these observations, Professor Spring has shown that the acid sulphates of the alkali metals may be mechanically decomposed into two portions, one of which contains more acid and the other more base than the original salt. It is important to recognize that in these three apparently short steps the transition has been made from the overcoming of the simple cohesion of similar molecules in contact with each other to the breaking asunder of the chemical union of dissimilar molecules. At each step the solid molecules appear, not as mere ethereal abstractions, but as substantial portions of matter which can be touched and handled mechanically.

The physical properties of a gas are primarily due to its being an assemblage of rapidly moving molecules. These simpler and more general properties can coexist with, and may be modified by, the more complex relations introduced by chemical affinity as it occurs in compound gases and mixtures.

It appears to me quite legitimate similarly to regard the physical properties of a *liquid* as due to its being an assemblage of rapidly moving molecules. The liquid system is highly condensed, and the motions of its molecules are controlled by the cohesive as well as by the repulsive forces. The closer approximation of the molecules may reduce their mean free path to an extremely small amount, or it may even cause their translatory motion to disappear, so that the whole kinetic energy of the liquid molecules may be in the form of rotation or vibration.

As we can imagine a perfect gas, so also may we imagine a perfect liquid, the physical properties of which are as simply related to the laws of dynamics as are those of the gas. But the conditions of the liquid state being also those most favorable to the play of chemical affinity, the internal equilibrium of solutions or of mixed liquids must be a resultant of this affinity, together with the primary forces of the ideal liquid state.

An ideally perfect solution—that is, a solution of the physical properties of which are determined solely by the number of molecules it contains in a given volume—must consist of a solvent and a solute which have no chemical affinity for each other, so that their molecules will neither associate nor dissociate in solution. Probably only

comparatively few solutions will be found which even approximate to this ideal perfection. But it appears to me that the study of the problems of the liquid and the dissolved states may be much simplified by the recognition (1) that the primary physical properties of liquids and solutions are due to the fact that they are assemblages of molecules endowed with the amount and the kind of kinetic energy which is proper to their temperature; and (2) that as these primary physical properties of the liquid and dissolved states may be masked and interfered with by chemical affinity, they should be studied as far as possible in examples where the influence of this force is either absent or at a minimum.

SUBMARINE NAVIGATION.[a]

By Sir William H. White, K. C. B., LL. D., D. Sc., F. R. S., M. Inst. C. E., M. R. I.[b]

Submarine navigation has engaged the attention of inventors and attracted general interest for a very long period. Its practical application to purposes of war was made about one hundred and thirty years ago. The main object of that application was to threaten, or if possible destroy, an enemy's battle ships engaged in blockade by means of under-water attacks, delivered by vessels of small dimensions and cost, which could dive and navigate when submerged. From the first, submarines were admittedly weapons favored by the weaker naval power, and as a consequence their construction found little favor with our naval authorities. Under the conditions which prevailed a century ago in regard to materials of construction, propelling apparatus and explosives, the construction of submarines necessarily proceeded on a limited scale, and the type practically died out of use almost at its birth. Enough had been done, however, to demonstrate its practicability and to make it a favorite field of investigation for inventors, some of whom contemplated wide extensions of submarine navigation. Every naval war gave fresh incentive to these proposals and led to the construction of experimental vessels. This was the case during the Crimean war, when the Admiralty had a submarine vessel secretly built and tried by a special committee, on which, among others, Mr. Scott-Russell and Sir Charles Fox served. Again, during the civil war in America the Confederates constructed a submarine vessel, and used it against the blockading squadron off Charleston. After several abortive attempts and a considerable loss of life they succeeded in destroying the Federal *Housatonic*, but their submarine, with all its crew, perished in the enterprise.

It is impossible to give even a summarized statement of other efforts made in this direction from 1860 onward to 1880, but one

[a] Reprinted by permission from author's printed copy.

[b] Read at weekly evening meeting of the Royal Institution of Great Britain, Friday, June 9, 1905, Sir William Crookes, D. Ss., F. R. S., honorary secretary and vice-president, in the chair.

can not leave unnoticed the work done in the United States by Mr. Holland, who devoted himself for a quarter of a century to continuous experiment on submarines and eventually achieved success. The Holland type was first adopted by the United States Navy, and was subsequently accepted by the British Admiralty as the point of departure for our subsequent construction of submarines. In France also successive designs for submarines were prepared by competent naval architects, and a few vessels were built and tried. The *Plongeur*, of 1860, was a submarine of large size, considerable cost, and well-considered design; but her limited radius of action and comparatively low speed left her for many years without a successor on the French navy list. The high relative standing attained by the French navy as compared with our own, in consequence of the vigorous action of the Emperor Napoleon III in developing steam propulsion and armor protection for seagoing ships, no doubt greatly influenced French policy at that time and delayed development of submarine construction. When conditions were altered in consequence of the Franco-German war of 1870, and the position of the French navy in relation to the British became less favorable, it was natural that the question of submarine construction should assume greater importance in France. In the interval, moreover, great advances had been made in materials of construction and in means of propulsion available for submarines. The extended use of steel and the practical applications of electricity gave to designers greater facilities than existed previously, and public interest in the construction of submarines and small, swift vessels was increased by the writings of the jeune école, who strongly condemned the continued construction of armored "mastodons."

The modern development of submarines for war purposes is chiefly due to French initiative. During the earlier stages of this development progress was extremely slow. The *Gymnote* was ordered in 1886 and the *Gustave Zédé* in 1888, and the trials continued over nearly eight years, large sums of money being spent thereon. In 1896 competitive designs for submarines were invited, but no great activity was displayed in this department of construction until the Fashoda incident two years later. Since that time remarkable developments have been made in France, considerable numbers of submarines have been laid down, rival types have been constructed, and many designers have been engaged in the work. Up to the present time about 70 submarines and submersibles have been ordered; in July, 1904, the total number of completed vessels was 28, and at the end of 1907 it is estimated that France will possess 60 completed submarines, with a total displacement of nearly 13,600 tons. The first French submarine of modern type, the *Gymnote*, was 56 feet long and of 30 tons displacement. The latest

types are nearly 150 feet long and of 420 tons displacement. The cost of a French submarine designed in 1898 was about £26,000. The estimated cost of the latest and largest vessels is about £70,000. The French have pursued no continuous policy in this development, but have alternated between vessels of comparatively large and others of much smaller displacement. This course had much to recommend it, no doubt, as it brought many accomplished naval architects into competition; but the lack of a continuous and progressive policy has resulted in dissatisfaction and difficulty, and this is frankly acknowledged by French authorities. Two years elapsed after the date when the French resolutely undertook the construction of submarines before the British Admiralty ordered five vessels of the Holland type from Messrs. Vickers, Maxim & Co., who had acquired the concession for the use of the Holland Company's patents. These first vessels in essentials were repetitions of the type which had been tried and officially approved by the authorities of the United States Navy. It was agreed that all improvements made by the Holland Company should be at the service of the British Admiralty through the English concessionaires. In this manner the royal navy at once acquired advantages attaching to the long experience and great skill of Mr. Holland, and with that advantage there was associated the possibility of utilizing their own technical resources and those of Messrs. Vickers, Maxim & Co. For five years a continuous policy has been followed in the development of our submarines, all of which have been constructed at Barrow-in-Furness. There has been a great development in size, speed, and general efficiency, resulting necessarily in correspondingly greater cost per vessel. Information of an official and authoritative character relating to submarines is freely published in France and the United States, but for British submarines corresponding official information is scanty. It has for years been the rule to give in the navy estimates full particulars of dimensions and costs for all other classes of British war ships, but for submarines a policy of secrecy is adopted that is most unreasonable and unnecessary.

From the best sources of information accessible it appears that the growth in size, with a correspondingly increased cost, has been even more rapid here than in France. Our first five submarines are 63 feet in length, 120 tons in displacement, with gasoline engines of 160 horsepower for surface propulsion, giving a speed of 8 to 9 knots. The electric motors for submerged propulsion are estimated to give a speed of about 7 knots. The contract price for each vessel in the United States was about £34,000, and that is about the price paid for our earliest vessels. The latest type of which particulars are available are said to be about 150 feet in length, 300 tons in displacement, and with gasolene engines of 850 horsepower for surface propulsion, giving a surface speed of 13 knots and a radius of action of 500 miles.

The underwater speed is 9 knots and the radius of action when submerged about 90 miles. No official particulars have been published as to the contract price for these vessels, which is certainly an undesirable course to adopt, seeing that for other and admittedly sufficient reasons these contracts have not been subject to competition as yet. It may be hoped that the Admiralty will reconsider this matter and treat submarines similarly to other vessels.

In French official classification a distinction is made between submarines and submersibles, and this terminology has been the cause of some confusion. Both classes are capable of diving when required and both can make passages at the surface. In this surface condition a considerable portion of the vessel lies above the water surface and constitutes what is technically called a "reserve of buoyancy." In the submersible this reserve of buoyancy and the accompanying freeboard is greater than in the submarine type, and in this respect lies the chief difference between the two types. The submersible has higher freeboard and greater reserve of buoyancy, which secures better seagoing qualities and greater habitability. The deck or platform is situated higher above water, and to it the crew can find access in ordinary weather when making passages and obtain exercise and fresh air. Recent exhaustive trials in France are reported to have established the great superiority of the submersible type when the service contemplated may involve sea passages of considerable length. The French policy, as recently announced, contemplates the construction of submersibles of about 400 tons displacement for such extended services and proposes to restrict the use of submarines to coast and harbor defense, for which vessels of about 100 tons displacement are to be employed. All recent British submarines would be ranked as submersibles according to the French classification, and it is satisfactory to know, as the result of French experiments, that our policy of construction proves to have distinct advantages. In addition to these two types of diving or submarine vessels, the French are once more discussing plans which have been repeatedly put forward and practically applied by M. Goubet, namely, the construction of small portable submarine vessels which could be lifted on board large ships and transported to any desired scene of operations. In the royal navy for many years past it has been the practice to similarly lift and carry second-class torpedo or vedette boats about 20 tons in weight. Lifting appliances for dealing with these heavy boats have been designed and fitted in all our large cruisers and in battle ships, and a few ships have been built as "boat carriers." The first of these special depot ships in the royal navy was the *Vulcan*, ordered in 1887–88, the design being in essentials that prepared by the writer at Elswick in 1883. The French have also built a special vessel, named the *Foudre*, which has been adapted for

transporting small submarines to Saigon and performed the service without difficulty. Whether this development of small portable submarines will take effect or not remains at present an open question, but there will be no mechanical difficulty either in the production of the vessels themselves or in the means for lifting and carrying them. M. Goubet worked out with complete success designs for vessels about 26 feet long and less than 10 tons displacement, with speeds of 5 to 6 knots, the trials of which have been very fully described, but French authorities have not adopted the type and no decision seems to have been taken to introduce it. In this country no similar action has been taken, and our smallest submarines, weighing 120 tons, can not be regarded as "portable." Indeed, some leading British authorities on submarines have indicated that experience is adverse to the construction of vessels in which not more than two or three men would form the crew, and on that ground have condemned the construction of these small submarines. They would necessarily be of slow speed and very limited radius of action, while their efficient working would depend upon the nerve and skill of only two or three men working in a very confined space.

Progress in mechanical engineering and in metallurgy has been great since Bushnell constructed and used his first submarine in 1776, during the war between the United States and this country. These advances have made it possible to increase the dimensions, speed, and radius of action of submarines; their offensive powers have been enlarged by the use of locomotive torpedoes, and superior optical arrangements have been devised for discovering the position of an enemy while they themselves remain submerged. But it can not be claimed that any new principle of design has been discovered or applied. From descriptions left on record by Bushnell and still extant it is certain that he appreciated and provided for the governing conditions of the design in regard to buoyancy, stability, and control of the depth reached by submarines. Indeed, Bushnell showed the way to his successors in nearly all these particulars, and, although alternative methods of fulfilling essential conditions have been introduced and practically tested, in the end Bushnell's plans have in substance been found the best. The laws which govern the flotation of submarines are, of course, identical with those applying to other floating bodies. When they are at rest and in equilibrium they must *displace* a weight of water equal to their own total weight. At the surface they float at a minimum draft and possess in this "awash" condition a sufficient free board and reserve of buoyancy to fit them for propulsion. When submarines are being prepared for "diving" water is admitted to special tanks, and the additional weight increases immersion and correspondingly reduces reserve of buoyancy. In some small submarines comparative success has been attained in

reaching and maintaining any desired depth below the surface simply by the admission of the amount of water required to secure a perfect balance between the weight of the vessel and all she contains and the weight of water which would fill the cavity occupied by the submarine when submerged. For all practical purposes and within the depths reached by submarines on service water may be regarded as *incompressible*. The submarine should, therefore, rest in equilibrium at any depth if her total weight is exactly balanced by the weight of water displaced. If the weight of the vessel exceeds by ever so small an amount the weight of water displaced, that excess constitutes an accelerating force tending to sink the vessel deeper. On the contrary, if the weight of water displaced exceeds by ever so small an amount the total weight of the vessel, a vertical force is produced tending to restore her to the surface. Under these circumstances it is obvious that if the admission or expulsion of water from internal tanks (or the extrusion or withdrawal of cylindrical plungers for the purpose of varying the displacement) were the only means of controlling vertical movement, it would be exceedingly difficult to reach or to maintain any desired depth. This difficulty was anticipated on theoretical grounds and has been verified on service—in some cases with considerable risks to the experimentalists—the submarines having reached the bottom before the vertical motion could be checked. It has consequently become the rule for all submarines to be left with a small reserve of buoyancy when brought into the diving condition. Submergence is then effected by the action of horizontal rudders controlled by operators within the vessels. Under these conditions submergence only continues as long as onward motion is maintained, since there is no effective pressure on the rudders when the vessel is at rest The smallest reserve of buoyancy should always bring a submarine to the surface if her onward motion ceases, and, as a matter of fact, in the diving condition that reserve is extremely small, amounting to only 300 pounds (equivalent to 30 gallons of water) in vessels of 120 tons total weight. This is obviously a narrow margin of safety and necessitates careful and skilled management on the part of those in charge of submarines. A small change in the density of the water, such as occurs in an estuary or in the lower reaches of a great river, would speedily obliterate the reserve of buoyancy and cause the vessel to sink if water was not expelled from the tanks. Moreover, variations in weight of the submarine (due to the consumption of fuel, the discharge of torpedoes, or other causes) must sensibly affect the reserve of buoyancy, and arrangements must be made to compensate for these variations by admitting equal weights of water in positions that will maintain the "trim" of the vessel. Additional safeguards against foundering have been provided in some submarines by fitting detachable ballast.

The more common plan is to make arrangements for rapidly expelling water from the tanks either by means of pumps or by the use of compressed air. In modern submarines with locomotive torpedoes compressed air is, of course, a necessity, and can be readily applied in the manner described if it is desired to increase their buoyancy.

The conditions of stability of submarines when diving are also special. At the surface, owing to their singular form, the longitudinal stability is usually much less than that of ordinary ships. When submerged their stability is the *same in all directions*, and it is essential that the center of gravity shall be kept below the center of buoyancy. This involves no difficulty, because water-ballast tanks can be readily built in the lower portions of the vessels. Small stability in the longitudinal sense, however, necessitates great care in the maintenance of trim and in the avoidance of serious movements of weights within the vessels. Moreover, when a vessel is diving under the action of her longitudinal rudders she is extremely sensitive to changes of trim and great skill is required on the part of operators in charge of working the rudders. As the underwater speed is increased the pressure on the rudders for a given angle increases as the *square* of the velocity, and sensitiveness to change of trim becomes greater. This fact makes the adoption of higher underwater speed a matter requiring very serious consideration. Some authorities who have given great attention to the construction of submarines have been opposed to the adoption of high speeds under water, because of the danger that vessels when diving quickly may reach much greater depths than are desirable. Causes of disturbance which might be of small importance when the underwater speed is moderate may have a greatly exaggerated effect when higher speeds are reached. Cases are on record where modern submarines in the hands of skilled crews have accidentally reached the bottom in great depths of water and have had no easy task to regain the surface. For these reasons it is probable that while speeds at the surface will be increased, underwater speeds will not grow correspondingly. Indeed, the tactics of submarines hardly appear to require high speed under water, seeing that it is an important element in successful attack to make the final dive at a moderate distance from the enemy. It is authoritatively stated that in our submarines complete control of vertical movements has been secured by means of skilled operators, and that a constant but moderate depth below the surface can be maintained. Proposals have been made and successfully applied to small submarines for automatically regulating the depth of submergence by apparatus similar to that used in locomotive torpedoes. For the larger submarines now used such automatic apparatus does not find favor, and better results are obtained with trained men.

The possibility of descending to considerable depths has to be kept in view when deciding on the form and structural arrangements of submarines, which may be subjected accidentally to very great external pressure. It is absolutely necessary to success that under the highest pressure likely to be endured there shall be rigidity of form, as local collapse of even a very limited amount might be accompanied by a diminution in displacement that would exceed the reserve of buoyancy. This condition is not difficult of fulfillment, and the approximately circular form usually adopted for the cross sections of submarines favors their resistence to external pressure.

Under former conditions there was difficulty in remaining long under water without serious inconvenience from the impurity of the air. Now, by suitable arrangements and chemical appliances, a supply of pure air can be obtained for considerable periods, sufficient indeed for any operations likely to be undertaken.

The use of gasoline engines for surface propulsion has many advantages. It favors increase in speed and radius of action, and enables submarines to be more independent and self-supporting. Storage batteries can be recharged, air compressed, and other auxiliary services performed independently of any "mother" ship. At the same time it is desirable to give to each group of submarines a supporting ship, serving as a base and store depot, and this has been arranged in this county as well as in France. With gasoline engines, care must be taken to secure thorough ventilation and to avoid the formation of explosive mixtures of gas and air, otherwise accidents must follow.

Little information is available as regards the success of "periscopes" and other optical instruments which have been devised for the purpose of enabling those in command of submarines to obtain information as to their surroundings when submerged. In this department secrecy is obviously desirable, and no one can complain of official reticence. From published accounts of experimental working abroad as well as in this country, it would appear that considerable success has been obtained with these optical instruments in comparatively smooth water. It is also asserted that when the lenses are subjected to thorough washing by wave water they remain efficient. On the other hand, the moderate height of the lenses above water must expose them to the danger of being wetted by spray even in a very moderate sea, and experience in torpedo boats and destroyers places it beyond doubt that the resultant conditions must greatly interfere with efficient vision. In heavier seas the comparatively small height of the lenses above water must often impose more serious limitations in the use of the periscopes and similar instruments. Improvements are certain to be made as the result of experience with these optical appliances, and we may be sure that in their

use officers and men of the royal navy will be as expert as any of their rivals. But when all that is possible has been done, it must remain true that increase in offensive power and in immunity from attack obtained by submergence will be accompanied by unavoidable limitations as well as by special risks resulting from the sacrifice of buoyancy and the great reduction in longitudinal stability which are unavoidable when diving. These considerations have led many persons to favor the construction of so-called *surface boats* rather than submarines. They would resemble submersibles in many respects, but the power of diving would be surrendered, although they would be so constructed that by admitting water by special tanks they could be deeply immersed and show only a small target above the surface when making an attack. There would be no necessity in such surface vessels to use electric motors and storage batteries, since internal combustion engines could be used under all circumstances. Hence it would be possible without increase of size to construct vessels of greater speed and radius of action and to simplify designs in other important features. It is not possible to predict whether this suggestion to adopt surface boats rather than submersibles will have a practical result, but it is unquestionable that improvements in or alternatives to internal combustion engines will favor the increase of power in relation to weight, and so will tend to the production of vessels of higher speed. The comparatively slow speed of existing submarines as compared with destroyers and torpedo boats of ordinary types admittedly involves serious limitations in their chances of successful attack on vessels under way, and higher surface speeds are desirable.

Concurrently with the construction of submarines, experiments have been made in this country and abroad to discover the best means of defense against this method of attack. Here, again, authentic details are necessarily wanting, since the various naval authorities naturally wish to keep discoveries to themselves. It is very probable, however, that published accounts of tests between swift destroyers, vedette boats, and submarines are not altogether inaccurate, and according to these accounts the periscopes of submarines have been found useful by assailants as the means of determining the position of the submarines and aiding their entanglement. Comparatively limited structural damage to a submarine in the diving condition may be accompanied by an inflow of water in a short period which will result in the loss of the vessel. The accident to Submarine A 1, which was struck by a passing mail steamer, illustrates this danger. It is reasonable to accept the published reports that large charges of high explosives exploded at a moderate distance may have a serious effect against submarines and cause them to founder. Their small reserve of buoyancy in the diving condition makes them specially liable to

risks of foundering rapidly, and little more than a crevice may practically fill the interior with water in a very short time when the vessel is submerged even to a moderate depth. On the other hand, reports which have appeared of the maneuvers in France and elsewhere, when attacks have been made by submarines on vessels at anchor or underway, show a considerable percentage of successes. Such exercises are valuable, no doubt, for purposes of training, but under peace conditions it is necessary to avoid the risks of damage to submarines, which might easily become serious if the defense were pressed home, as it would be in war. When the officers and crews of submarines know that they will be treated more considerately than in real warfare they will naturally take chances, and make attacks involving possible destruction under the conditions of a real action. In short, naval maneuvers in this department, while they may be useful in increasing the skill and confidence of officers and men in the management of submarines, can be no real test of fighting efficiency.

Submarines and air ships have certain points of resemblance, and proposals have been made repeatedly to associate the two types or to use air ships as a means of protection from submarine attacks. One French inventor seriously suggested that a captive balloon attached to a submarine should be the post of observation from which information should be telephoned to the submarine as to the position of an enemy. He evidently had little trust in periscopes and overlooked the dangers to which the observers in the car of the balloon would be exposed from an enemy's gun fire. Quite recently a proposal has been made by M. Santos Dumont to use air ships as a defense against submarines, his idea being that a dirigible air ship of large dimensions, and moving at a considerable height above the surface of the sea could discover the whereabouts of a submarine, even at some depth below the surface, and could effect its destruction by dropping high explosive charges upon the helpless vessel. Here, again, the inventor, in his eagerness to do mischief, has not appreciated adequately the risks which the air ship would run if employed in the manner proposed, as submarines are not likely to be used without supporting vessels. Hitherto submarines themselves have been armed only with torpedoes; but it has been proposed recently to add guns, and this can be done, if desired, in vessels possessing relatively large freeboard. No doubt if gun armaments are introduced, the tendency will be to further increase dimensions and cost, and the decision will be governed by the consideration of the gain in fighting power as compared with increased cost. As matters stand, submarines are practically helpless at the surface when attacked by small swift vessels, and it is natural that advocates of the type should desire to remedy this condition. Surface boats, if built, will undoubtedly carry guns as well as

torpedoes, and in them the gun fittings would be permanent, whereas in submarines certain portions of the armament would have to be removed when vessels were prepared for diving.

Apart from the use of submarine vessels for purposes of war, their adoption as a means of navigation has found favor in many quarters. Jules Verne, in his Twenty Thousand Leagues under the Sea, has drawn an attractive picture of what may be possible in this direction, and others have favored the idea of combining the supposed advantages of obtaining buoyancy from bodies floating at some depth below the surface with an airy promenade carried high above water. Not many years ago an eminent naval architect drew a picture of what might be accomplished by utilizing what he described as the "untroubled water below" in association with the freedom and pure air obtainable on a platform carried high above the waves. These suggestions, however, are not in accord with the accepted theory of wave motion, since they take no note of the great depths to which the disturbance due to wave motion penetrates the ocean. The problems of stability incidental to such plans are also of a character not easily dealt with, and consequently there is but a remote prospect of the use of these singular combinations of submarine and aerial superstructures. There is little likelihood of the displacement of ocean steamships at an early date by either navigable air ships or submarines, and the dreams of Jules Verne or Santos Dumont will not be realized until much further advance has been made in the design and construction of the vessels they contemplate.

LIBERIA.[a]

By Sir Harry Johnston, G. C. M. G., K. C. B.

Liberia is a portion of the West African coast lands which may be styled the end of Northern Guinea. Its southernmost promontory—Cape Palmas—of all the Guinea coast projects farthest southward, to scarcely more than 4° from the equator. The northern political boundary of Liberia meets the coast at the mouth of the river Mano in north latitude 7°. The actual boundary on the south, between Liberia and the French possessions on the Ivory coast, is the course of the river Kavalli, the mouth of which river lies about 13 miles to the east of Cape Palmas, in latitude 4° 22′. The northernmost extremity of Liberian territory on the coast lies just to the south of that marshy and densely forested portion of the Sierra Leone colony—the Sherbro district—which one might say, with a fairly accurate guess, was the farthest point reached by the Carthaginian explorer Hanno in his celebrated voyage of discovery along the northwest coast of Africa in about 520 B. C. It is probable that the "gorillas" which Hanno's expedition captured somewhere in the vicinity of the Sherbro River or of northern Liberia was the chimpanzees still found in these regions.

It will be seen on the map that Liberia occupies a most important strategic position on the west coast of Africa. The general trend of its coast is from northwest to southeast, parallel to the course taken by steamers plying across the Atlantic between Europe and South Africa. It might, in fact, in the hands of a strong naval power, exercise a very dominating influence over the eastern Atlantic, which is one reason, among many others, why Great Britain desires to see the independence of the Liberian Republic preserved and maintained.

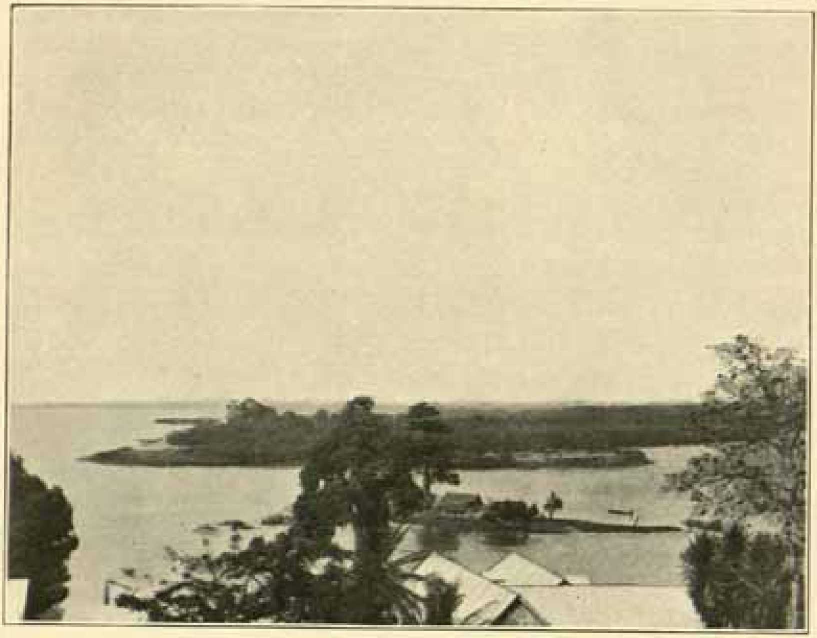
The country of Liberia as a whole is one dense forest. It is practically the culmination of the West African forest, the regions to the north, east, and west having been more extensively cleared by man in past times, or partaking more of the park-land, grass-grown char-

[a] Read at the Royal Geographical Society, March 27, 1905. Reprinted, by permission, from The Geographical Journal, London, Vol. XXVI, No. 2, August, 1905. See also "Liberia," by Sir Harry Johnston, New York, 1906, 2 vols., 8vo.

acter owing to their less copious rainfall. Now that two English companies, in conjunction with the Government of Liberia, are endeavoring to develop the resources of the interior and to accumulate knowledge regarding the climate and products, attempts are being made to record the rainfall, as to the extent of which at present only a guess can be made. It is probable that south of latitude 8° 30′ the average annual rainfall of Liberia is not less than 100 inches. Adjoining regions in Sierra Leone have a recorded rainfall of something like 130 inches, so that this is probably an under rather than an over estimate. North of latitude 8° 30′ the rainfall diminishes probably to 60 or 80 inches per annum, and in consequence the dense forest gives way to a pastoral country of savannas, grassy hills, or park lands of grass, with dense forest along the stream valleys. Mr. Alexander Whyte, well known by his many years' work as an official in charge of botanical departments in the British East African Protectorates, spent a good deal of 1904 in Libèria, and in the report which he drew up for my information he considers that this country, which has a seaboard of approximately 350 miles long (from northwest to southeast) and a total superficies of about 45,000 square miles, has two somewhat different climates, depending, no doubt, a good deal on the latitude. In the southern regions, below latitude 6°, the rainiest time of the year appears to be the months of March to June and August to December. North of this—round Monrovia, for example—the specially rainy months are April to the end of July, September, and October.

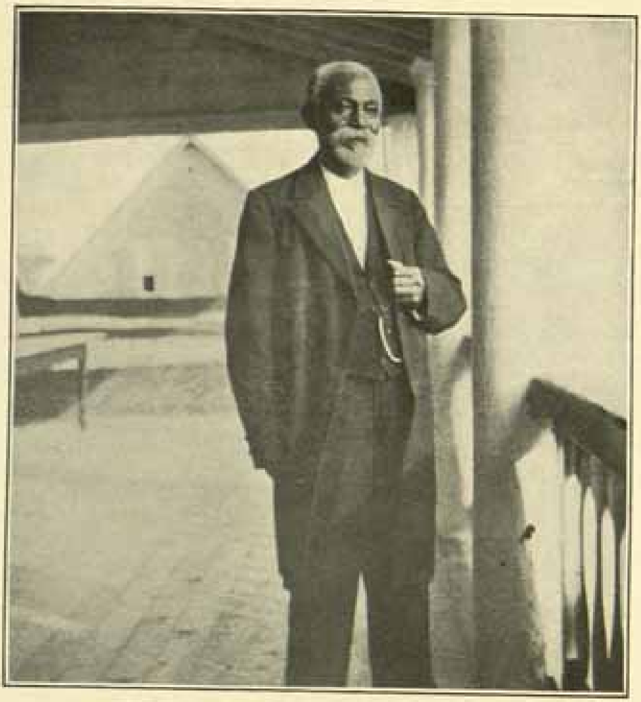
From my own experience of Liberia, I should say that the heavy rainy season begins in April and lasts till the end of July. Then there is a pause of a month or six weeks with less rain, the heavy rains beginning again in September and lasting till the middle of November. From mid-November till the end of March is the dry season, at any rate in the northern half of Liberia, but in the southern part this dry season is not much more marked than it is in the Niger Delta. Rain, in fact, may fall in any month of the year. Between November and April is the worst season for storms, some of which are very violent.

When I first visited the coast of Liberia, in 1882 and 1885, the primeval forest grew down to the sea along a great proportion of the coast; but when I revisited this country in the summer of 1904, and touched at a good many places at the coast where I had noted forest growing as late as 1888, much of this big-tree woodland had been swept away to make room for plantations or even for towns. In fact, with a few exceptions, the big-tree and rubber-producing forest does not usually begin in its most marked characteristics until a journey of at least 15 miles has been made inland from the coast. I have estimated, from the reports of the agents of the British com-



PROVIDENCE ISLAND IN MESURADO LAGOON (MONROVIA IN THE FOREGROUND), WHERE THE AMERICO-LIBERIAN COLONISTS FIRST SETTLED.

A STREET IN MONROVIA. AMERICAN LEGATION ON RIGHT HAND.



HON. G. W. GIBSON, AN EX-PRESIDENT OF LIBERIA.

PRESIDENT BARCLAY.

panies and from the accounts of Liberian, British, and French explorers, that out of the 45,000 square miles which may be approximately assigned as the area of the Liberian Republic, at least 25,000 square miles consist of dense, uncleared forest, penetrated, it may be, by narrow native paths, but as often as not only pierced by elephant-made tracks. About 3,500 square miles represent the plantations, gardens, towns, and settlements of the Americo-Liberians along the coast and 2,000 or 3,000 square miles the clearings made by the indigenous natives in the dense forest. The remainder of the territory—about 15,000 square miles—is grass or park land in the possession of the Mandingo tribes, who are great cattle breeders. This is the characteristic of the far interior of Liberia, where it borders on the French possessions of Upper Nigeria. From all accounts I can collect, as well as from the little I have seen myself, I do not think that much of the interior of Liberia can be described as marshy. It is, on the other hand, inclined to be hilly, and at distances of from 40 to 100 miles inland the ranges of hills reach altitudes which might almost be dignified by the name of mountains. Some of these mountains (the Nimba range) attain heights of over 6,000 feet—this, at any rate, is the height ascribed to them by certain French explorers; and from what I am told by Mr. Maitland Pye-Smith, one of the agents of the aforesaid British companies, I am inclined to think that 4,000 feet, at any rate, is reached or exceeded by peaks in the Satro range. If the reports of certain travelers are justified, however, it may well turn out that there are altitudes (such as Mount Druple) on the Franco-Liberian border of over 9,000 feet, and consequently higher than anything that is to be met in West Africa south of the upper Niger and west of the Kamerun. Some of these mountain sides are precipitous, with faces of bare rock. Others, again, are clothed with dense vegetation to their summits, and this continuance of dense and lofty forests for miles and miles and miles will be a terrible hindrance to surveying in the future, while at the present time it gives to Liberian exploration the same sad and somewhat dreary character that has been so powerfully described by Stanley in recording his adventures in the great Kongo forest. Much as the botanist may glory in the splendid vegetation, I really think that in the long run one wearies more quickly and easily of forest than of desert.

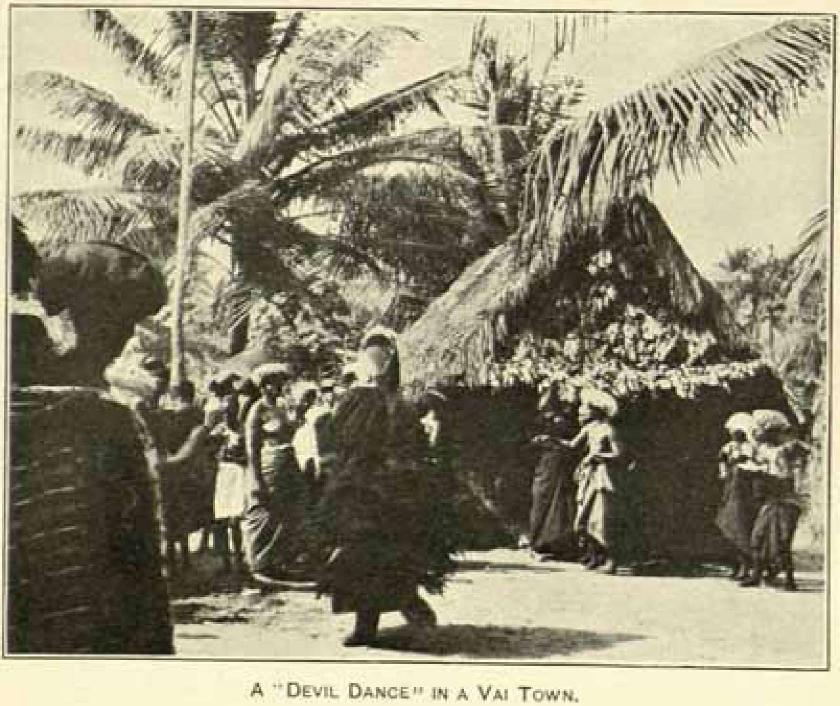
Forest, in fact, is the distinguishing feature of Liberia as a country; it is the climax of the forest region of West Africa. In and from the forest will be derived the great future wealth of this country. The geologic formation would appear to be mainly Archean, and the rocks are mostly granite and quartz, with here and there indications of volcanic tuff. The rocks near the seacoast and in the coast ranges of hills are much impregnated with iron, and are consequently very red

in color. The appearance of this rock, especially where it is revealed by the roads which the Americo-Liberians have cleared in the coast region, is curiously pitted and honeycombed. It is hard, becoming especially indurated on exposure, and this makes it a good surface for road making, as it does not degenerate into mud. Very little is known about the possible mineral wealth of Liberia up to the present time, as the extremely dense forest of the interior is a great obstacle to a rapid survey of the country. Apart from hematite iron, which appears to exist nearly everywhere, there are traces of gold in the mud of the rivers, and native stories assert the existence of alluvial gold in the Mandingo uplands beyond the forest region. Lead has been discovered recently in the Kelipo country in eastern Liberia, and zinc ore in the vicinity of Monrovia. In the Kavalli region there is a great deal of corundum in the rocks. It has been alleged that a diamond was discovered in the hills behind Grand Basa by a Liberian, but as yet no confirmation of this discovery has reached me; nor have I been able to ascertain where the copper comes from which is used to a limited extent in some of the Mandingo weapons from the far interior.

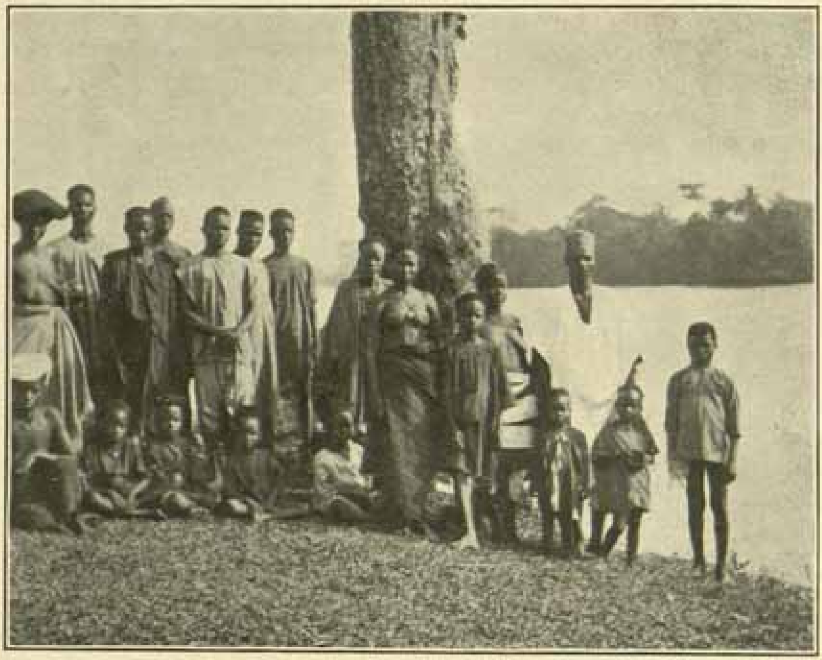
The Liberian forests contain most of the West African timber trees. Such ebony as is exported, however, does not seem to be so good as that which is derived from the genus *Diospyros*. It is very probably derived from a papilionaceous tree belonging to the botanical genus of *Dalbergia*.[a] The wealth of this forest in india-rubber-producing trees, vines, and bushes is without parallel in any other part of Africa, unless it be one or two small areas of the Kongo basin. Counting the four rubber-producing figs, there appear to be at least twenty-two trees, plants, or vines which produce saleable rubber. These species include the well-known and widespread *Landolphia owariensis* and the magnificent *Funtumia elastica*, the rubber tree once so abundant in Lagos colony. The *Funtumia elastica* is stated to grow to over 200 feet in height. It closely resembles in appearance the allied species *Funtumia africana*, but there is a very considerable difference in the price of the rubber yielded by the one and the other—the rubber derived from *Funtumia africana* may, perhaps, be sold for 18 pence a pound, but the well-prepared rubber of *Funtumia elastica* ranges in value from 3 to 4 shillings. The distinctive features of the leaves, flowers, and fruit, which enable the observer to decide whether he is tapping the valuable or the valueless *Funtumia*, will shortly be illustrated in my book on Liberia. The range of the *Funtumia elastica* appears to extend from the middle of Liberia eastward as far as western Uganda. It is found in a portion of the Bahr-al-Ghazal region and in the northern

[a] There are two species of ebony-producing *Dalbergia* in Liberia, one of which has just been discovered by an agent of the Monrovian Rubber Company—*Dalbergia liberica*.

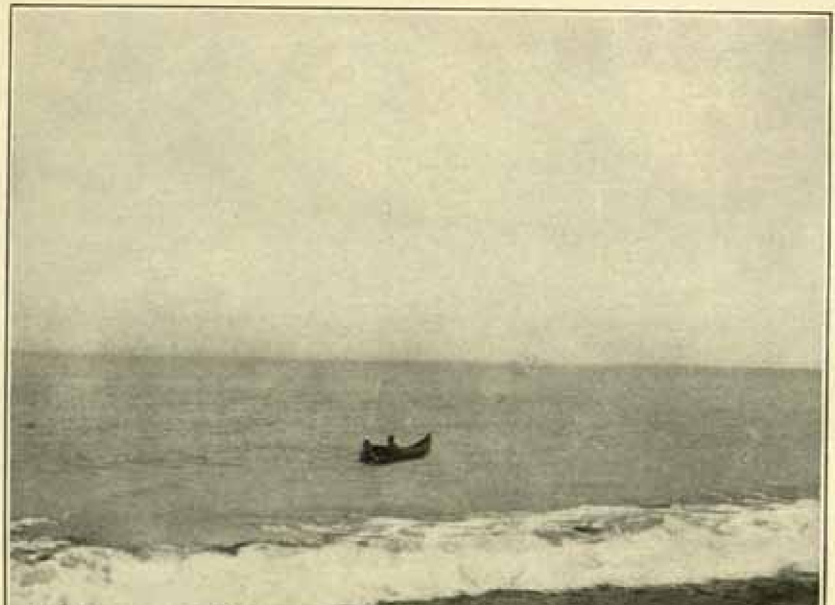
VAI WOMEN.



A "DEVIL DANCE" IN A VAI TOWN.



A MANDIGO FAMILY ON THE ST. PAULS RIVER.



SURF ON THE LIBERIAN BEACH.

part of the Kongo Free State. The *Funtumia africana* is more strictly West African in its range, from Portuguese Guinea to the Kongo basin. In the western regions of the Kongo Free State and in Angola a third *Funtumia* is found, which, like *Funtumia africana*, is of not much value to the rubber trade. Mr. Alexander Whyte, in his systematic examination of the Liberian flora, which he undertook at my request during 1904, has discovered two new species of wild coffee—*Coffea nudiflora* and *Coffea ligustrifolia*. The well-known Liberian coffee with a big berry is, of course, indigenous to the country, and is now being exclusively cultivated by the Americo-Liberians on the coast.

In Liberia, of course, as in most densely forested countries, the displays in color masses of large aggregations of flowers are not so often observed as in the park lands and more open country. Still, there are many objects of beauty in the forest which should be enumerated as prominent features in Liberian scenery. Every pool and creek of still water is covered with water lilies, chiefly the common *Nymphæa lotus*, a small variety of which is also present, and is peculiar to Liberia. In the damp glades there are abundance of *Crinum* and *Hæmanthus* lilies. A small and very beautiful terrestrial orchis grows on the surface of the water in shallow pools. In the dense forests there are numerous epiphytic orchids, chiefly *Angræcums*, with enormously long nectaries. A species of vanilla grows wild in the bush. There are many zingiberaceous plants in the undergrowth of the forest, sometimes with large and delicately colored flowers, at others remarkable for the size and rich coloring of their leaves. Among these may be noted *Costus*, *Amomum*, *Thalia*, and *Renealmia*. Another family of plants well represented in the undergrowth, and remarkable for the variety and beauty of their foliage, are the arums. Prominent among these are *Anchomanes*, *Culcasia*, *Nephthytis*, *Aglaonema*, and *Cytosperma*. The *Lonchocarpus* tree has at times magnificent displays of lilac blossom, not unlike wistaria in shape and color. The waxy-white camelia-like flowers of the *Anona* are objects of great beauty, especially where they are thickly clustered along the horizontal branches. The *Mussændas* also light up the forest with their red or white bracts. One *Mussænda*, or a closely allied plant, has gorgeous scarlet-crimson bracts like a *Poinsettia;* another, which is very common, not only in Liberia, but throughout the whole forest region of West Africa from Portuguese Guinea to Uganda, has a cluster of large white bracts below the yellow flowers. These bracts, which are leaflike in shape (though not like the leaves of the plant itself), look at a distance like foliage cut out of white velvet. The *Ochna multiflora* is a beautiful flowering tree.

Beyond the forest region a parklike country is entered, inhabited for the most part nowadays by a more or less Mohammedanized people, belonging chiefly to the Mandingo stock. These Mandingos keep large herds of cattle, examples of which find their way down to the coast through the forest roads. They are similar to the breed which is on sale at the market of Sierra Leone—smallish, straight-backed cattle (without a hump), one-colored as a rule (fawn or gray or reddish-yellow), with rather long horns. This breed resembles in miniature the long-horned Gala ox which is found in southern Abyssinia, and thence, with several breaks in its distribution, to Uganda and the west side of Tanganyika, and across the Nile to the shores of Lake Chad. The Mandingo ox is, to my thinking, simply a dwarfed variety of this Gala breed, which seems to have been the oldest form of domestic ox known in Africa. In origin it is thought to be more connected with the Indian cattle than with the descendants of *Bos taurus;* but when it is found in its purest form, it has not got the hump that is associated with the zebu species, though it freely mixes with that type, and sometimes thus acquires the zebu hump in addition to the characteristics of the extremely long, spreading horns (longest in the cow) and the tendency to be one-colored. I am not so sure myself that this type of ox is necessarily descended from *Bos indicus.* It is represented in the paintings of the Egyptian monuments together with the zebu type. It may have been descended from an intermediate type of wild ox native to north-east Africa—intermediate between *Bos taurus* and *Bos indicus.*

In this open Mandingo country of hills, mountains, and grass lands there is said to be a great deal of big game. The lion exists there, hartebeests of the West African type, water buck, giraffe, roan antelope, reed buck, possibly zebra, rhinoceros, and giraffe. Elephants are abundant all over Liberia down to within about 30 miles of the coast region. In fact, many of the paths through the forest are little else than elephant tracks. Elephants are a good deal dreaded by the natives of the forest region, as they are alleged to attack man quite unprovoked. They do a great deal of damage to plantations. The Mandingos, by-the-bye, have horses similar in appearance to the native breeds of Nigeria. Occasionally one of these horses finds its way down to the coast in Liberia, but, as a rule, the few horses one meets with at Liberian coast towns have been brought by sea from French Guinea (Konakri). It is an important fact, however, of great negative value, that apparently there is no Nagana or tsetse fly disease in Liberia. No doubt there are one or more species of *Glossina* related to the tsetse fly, but they do not carry the celebrated tsetse disease to horses and cattle.

The principal and remarkable animals of the Liberian forest region are, among antelopes, the handsomest of the Tragelaphs, the bongo.

This splendid animal, good specimens of which are to be seen in the Natural History Museum, at South Kensington, is almost the largest in size of the Tragelaphs, being exceeded only by the eland. It is magnificently colored bright chestnut red, with a few points of black, and bold white stripes and bars. It seems to be fairly common in the Liberian forests, which also conceal in their recesses curious developments of the cephalophine antelopes, or duykers. These duykers in other parts of Africa are usually associated with the idea of a very small antelope; but in Liberia there is the widespread *Cephalophus sylvicultrix*, which is nearly the size of a small cow, and *Cephalophus jentincki*, which is about the size of a fallow deer, with short stout horns. Besides several small types of duyker there is the tiniest of all the antelopes—the royal antelope—not so large as a hare; and there is the beautiful zebra antelope, which is bright yellow bay boldly marked with bold black stripes, a most unusual coloration in this group. The buffalo of the forest region is the red-haired, dwarf, short-horned buffalo. The ordinary big hippopotamus is said to be present in the lower Kavalli River, but Liberian streams and forests are for the most part frequented by the pigmy hippopotamus, an animal which probably extends its range from the interior of Sierra Leone to the French Ivory Coast. Before I leave the question of the fauna I should like to mention that, in addition to there being apparently no Glossina fly to spread the tsetse disease, there is a great relief in other directions from the ordinary insect pests of Africa. Mosquitoes are very seldom met with. In fact, they seem to be entirely absent from much of the forest region. Nor are white ants very common or destructive in the centers of population.

The human population of Liberia consists of the following elements, which may be divided first of all into indigenes and Americo-Liberians. The former number something like 2,000,000 and the latter between 12,000 and 15,000. So far as the outside world is concerned, the world of treaties and congresses, the country which we know as Liberia is considered to belong to and be governed by this small caste of English-speaking negroes and half-breeds of American origin. These English-speaking negroes certainly govern and administer the coast line and a belt of more or less settled country which extends from 20 to 40 miles inland. Of late years they have been on generally friendly terms with the 2,000,000 indigenous negroes, some of whom have come very much under their influence.

The Americo-Liberians are the survivors or the descendants of freed slaves or persons dissatisfied with their social condition in the United States of America during the early part of the nineteenth century. A considerable number of them also came from the British West Indies; but the movement which founded Liberia—the black Republic on the west coast of Africa—originated with certain philan-

thropic societies in the United States about 1821. The idea, however, in its genesis was the outcome of that still earlier movement in Great Britain which led to the formation of Sierra Leone. When British philanthropy in the eighteenth century was awakened to the injustice of the slave trade and the unhappy condition of many of the runaway slaves or freed negroes in the West Indies or in British America, it was decided to repatriate a number of these people, and for that purpose (possibly also with an eye to the main chance in securing for Great Britain one of the few good natural harbors on the west coast of Africa—Seirra Leone) a settlement was formed on the site of the modern Free Town, without overmuch regard to the feelings or rights of the local inhabitants. In the same way, when it was decided in the United States to found a home for the repatriated African, the prior experiment of Sierra Leone turned attention toward the same coast, and in 1821 and at subsequent dates settlements were effected, firstly at Monrovia, and later on at Roberts Port, Grand Basa, Sino, and Harper (Cape Palmas). Usually those who conducted the enterprise went through the form of buying small plats of land from local headmen or chiefs; but, as a rule, the promoters of this movement did not trouble overmuch about the rights of the "bush niggers," as the indigenous natives were termed. Consequently the first fifty years of the history of Liberia were marked by constant struggles between the Americo-Liberian invaders and the native blacks. During the last ten years, however, there has been a marked advance in good relations between the American settlers and their native subjects, as many of them may fairly be called. The wise policy of President Barclay has greatly promoted this good feeling since 1904. He has been able to assemble at different times at the capital chiefs or their representatives from almost all parts of Liberia, even from the Mandingo districts just beyond the limits of the coast belt. Therefore they have no subject of disagreement. Curiously enough one example of this mild rule of black by black is that the white man in Liberia is everywhere received with great friendliness, because he is not associated in the minds of the natives with anything like conquest or oppression.

How far the original experiment will succeed the next twenty years will, perhaps, indicate. The negroes of American origin who have settled in Liberia have not, as a general rule, been able to stand the climate very much better than Europeans, and, as a rule, they have not been able to rear large families of children. Yet it seems to me as though Liberians of the new generation born in the country are beginning to take hold, but this is partly due to the increasing and I think very sensible practice of intermarriage with women of the fine, vigorous, indigenous races. Probably the future of Liberia will be a negro state very like Sierra Leone in its development, with English as its government language, and such English or American institutions

as may prove to be suited to an African country, a coast belt inhabited by negroes professing Christianity and wearing clothes of European cut, and a hinterland of Mohammedans dressed in the picturesque and wholly suitable costume worn at the present day by the Mandingos and by most Mohammedan negroes between Senegal and the White Nile.

The native races of Liberia, the languages they speak, and the religions they profess may, to a certain extent, be grouped under two classes—the Mandingo on the one hand and the Kru negro on the other. I am aware, of course, that the Mandingo type is a very variable one physically, according to the less or greater degree of Caucasian blood which permeates its negro stock, and also that the Kru man proper is confined in his distribution to a small portion of the southern coast of Liberia. But each of these types is sufficiently representative to serve as a general illustration of the two classes of Liberian peoples. Associated with the Mandingos, to a great extent in language, in Mohammedan religion, and in the adoption of the Arab dress, are the Vai and the Gora of western Liberia, and to some extent the Buzi or Kimbuza. All the remaining tribes are more or less related to the Kru stock in language, appearance, physique, customs, and the profession of a pagan and fetishistic religion, similar in general features to the fetish religions of all western and west central Africa, with some points of resemblance to the Bantu beliefs in the southern half of Africa. The Gora language of western Liberia is rather a puzzle in classification, and it must be admitted that it only offers the slightest affinity to the Mandingo group and an equally slender connection with the Kru family. In a still more generalized way it may be said that there are distant resemblances between the languages of the Kru and Mandingo stocks; nor can these slight resemblances be altogether explained by the mere imposition of linguistic influences. The Mandingos, who are destined to play a most important part in the development of Liberia and of much of West Africa, are nothing but a varying degree of cross between the Fula race of the West African park lands and the ordinary West African negro. This crossing and the founding of this group of people—the correct pronunciation of whose name seems to be Mading'a, or Manding'a—may have been a relatively ancient one. The Mandingos, in fact, are the Swahilis of West Africa and offer a striking resemblance in face to the average type of Swahili porter that one meets with on the Zanzibar coast. They also often resemble natives of Uganda, and for the same reason—that a good deal of the population of Uganda is infused with a slight Hamitic element derived from the Hima aristocracy. Several Mandingos whom I met at Monrovia were able to speak Arabic in a halting fashion. The Arab words they understood best were those pronounced in the

North African dialect. It seems to me that in some cases the Caucasian element in the Mandingos was derived from direct intermixture of Berbers and Arabs from North Africa with the negroes of the Upper Niger. I doubt if any pure-blooded Fula people extend their range into the northern limits of Liberia; but they have had an undoubted influence in times past over the development of the park land which lies beyond the forest. By their minglings with the indigenous negroes of the Sudanese and West African type they have created the Mandingo peoples and have also carried Mohammedan civilization and tenets into that part of Africa, as well as, no doubt, the Sudanese breeds of cattle and sheep. The domestic sheep of all the *forest* region of Liberia is that common to the other forested parts of West Africa—the sheep with erect ears, fairly well-developed horns, small size, black and white coloring, a tail without any fatty development, and a long throat mane in the male. Far back in the interior of Liberia I am informed that the Mandingo sheep are similar to those of the Sudan, with fat tails and without the throat mane.

It should hardly come within the limits of the present paper to discuss one of the most interesting problems in Africa—the origin of the Fula race. Personally I am still disposed toward the old theory that the Fulas were an early cross between the Libyans of North Africa and the negroes of Senegal, a cross in which the Caucasian element predominated considerably. They certainly offer marked resemblances, however, to the Hamitic aristocracy of the Upper Nile and the lake regions. Their language is a complete puzzle. At present it can not be said to offer affinities of a marked kind to any group of negro speech, but it is emphatically a negro tongue (with a faint suggestion here and there of the Bantu family), and not in any way influenced by Hamitic, Libyan, or Semitic characteristics. As to the Libyan affinities of Hausa there can be no doubt, but nothing of the kind has as yet been discerned in the structure or vocabulary of the Fulfulde. It even seems to offer less resemblances in structure to the Hamitic language family, for example, than can be discerned in the Bantu.

Of all the peoples in Liberia affiliated with the Kru stock perhaps the most numerous group is that of the Kru, which occupies the coast of Liberia between the French frontier at the Kavalli River and the river Sestos. With the Kru I associate the Grebo, as the two peoples differ but little in language and scarcely at all in physical type. The Grebos are inclining strongly toward Christianity, but very few, if any, converts to that religion have been made among the Kru people proper who inhabit the coast between Greenville and Garraway. Krus and Grebos together number something like 375,000. The next most important group of people, as regards numbers, are the Mandingos, of whom there are perhaps 300,000 within the limits of Libe-

ria. After them may be ranked the Kpwesi people, a general term for a congeries of tribes speaking dialects of a common language. These Kpwesi (familiarly known by the Americo-Liberians as Pessi, or Pessa) may be as many as 250,000. In an appendix to this paper the rest of the tribes and their approximate numbers are enumerated.

In the central parts of Liberia, within the limits of the forest, there is no doubt that cannibalism prevails. This is a very marked feature in the life of the Beila, or Bele. These people are said to relish most keenly the hands and feet, and this very dainty dish is usually set before a king or chief alone. Nowhere in Liberia have I noticed—nor has any explorer encountered or reported—any race of negroes wholly naked, either among men or women, such as are so commonly met with in eastern Equatorial Africa, or until a few years ago in parts of South Central Africa. A certain degree of complete nudity in unmarried women was at one time quite a common feature of the natives of the Niger delta, the Cross River, and the Kamerun, while on the upper Cross River complete nudity among the men was just beginning to disappear twenty years ago. Throughout Liberia no one has ever observed complete nudity among either men or women. Though there are a few rare exceptions to this rule, it may generally be observed that the marked feature of male nudity so characteristic of the Upper Nile, the eastern equatorial regions, and originally of the north end of Lake Nyassa and central Zambezia, is never met with in the forested regions of Africa, except possibly here and there among the Pigmies. Throughout the Kongo basin and countries as completely savage as the innermost parts of Liberia, the men wear a minimum of clothing, which is a concession to ideas of decency, and which, when the race is quite out of touch with the trade of the outer world, is generally a strip of bast (bark cloth) from a fig tree. I have not observed any of the savages from the interior of Liberia wearing dressed skins. I am told that so greedy are they after food that when any beast is killed the hide is roasted and eaten. On the other hand, the civilized Mandingos of the north have learned from the Fulas or from the Moors, or possibly from both, the most beautiful work in leather.

Nowhere along the coast of Liberia is there a harbor in the sense of the bay at Sierra Leone. All the anchorages, in fact, are open roadsteads. But on the other hand, this is not a particularly dangerous condition for ships, as the south wind never blows strongly enough to raise a big sea, while the north wind, coming from off the land, can only affect the Atlantic at some distance from the shore. But of course this portless condition adds very much to the discomfort of dealings with Liberia. Although the swell from the choppy surface raised by the wind may not be sufficiently serious to affect big vessels lying at anchor, it is not at all nice for small boats or steam launches, and generally during the rainy season of the year transfer-

ence from the big steamer to the shore-going boat has to be effected by means of a crane and a cradle. Still more to be dreaded on some points on the coast is the landing or the going off on account of the surf. Perhaps the best approach to a sheltered harbor which exists is at the capital, Monrovia. Here there is a bar to a small river or creek which communicates with the St. Pauls River. The bar is very seldom rough, being to a certain extent sheltered by a promontory, and once across the bar you can land quite comfortably on the beach in perfectly smooth water. But at places like Grand Basá, Sinó, and Cape Palmas, the landing can be extremely dangerous and disagreeable. One seldom arrives at or departs from these places without, at any rate, a wetting from the rollers that break over the stern or bow of the boat. However, real accidents to persons or property are, it must be confessed, of rare occurrence, and the whole question depends very much on the good or ill will of the Kru boys who direct the steering.

The Kavalli River, though probably less in volume than the St. Pauls, is the most navigable as a means of access to the interior. Unfortunately there is a very bad bar at the mouth of the Kavalli or it would have played a very different part in the history of West Africa. Once across the bar, a steam launch or a rowing boat can ascend the river for about 80 miles, when the first rapids are reached. The upper Kavalli is imperfectly known, and, indeed, its extreme upper course is still a matter of conjecture. On the definition of its course depends to a great extent the laying down of the northeastern frontier of Liberia according to the French treaty of 1892.

The St. Pauls River is only navigable as far as a place called White Plains, about 20 miles from the mouth. There is no difficulty about the bar at the mouth of the St. Pauls, for this reason, that one can land with little or no risk at Monrovia; and once inside the Mesurado River (which is merely a creek), one can embark on a small river steamer, of which there are two or three in existence, enter the St. Pauls River by the Stockton Creek, and thence ascend the St. Pauls to the first rapids near the settlement known as White Plains. All the lower part of the St. Pauls River is pretty thick with Americo-Liberian settlements, some of them of a distinctly prosperous and prepossessing appearance. Several of the officials at Monrovia have country houses on the banks of the St. Pauls amid charming surroundings. This great virtue may be attributed to the Americo-Liberians, that they certainly know how to build houses, comely in appearance, sanitary, and lasting, or as reasonably durable as one can expect in a land of heat and moisture. In fact, the leading characteristics of the Americo-Liberians are their love of building and their remarkable politeness.

For some distance above its first rapids the St. Pauls River is scarcely navigable for canoes; but in the little-known region north of Dobli Zulu Island, it is said to be navigable for canoes up to its junction with the Tuma, which is also stated to be an important stream.

Eastward of Monrovia, the Mesurado River or Creek reaches, as a navigable piece of water, to within a very short distance of the Junk Creek, which is a branch of the Dukwia River; so that, except for a little isthmus of sandy soil, Monrovia might be situated at the western extremity of a long island. With developments that might come later on, it would be very easy to cut a canal to join the Mesurado and the Junk rivers. This would then give access for vessels of light draft to the Dukwia and Farmington rivers. These streams debouch at a settlement of some importance named Marshall; but the bar at Marshall (mouth of the river Junk) is extremely bad and dangerous. As a matter of fact, with a very little expenditure of money Monrovia might be made a good port.

The population of Monrovia, so far as Americo-Liberians and foreigners are concerned, is about 2,500. It has a system of telephones which connects it with the settlements on the St. Pauls River. This has been set up and is well worked by a native Liberian. It is, perhaps, hardly necessary to remind you that Monrovia was named after the celebrated President of the United States, Monroe, who is responsible for that doctrine which inhibits any European nation from further conquests in the New World. The capital of Liberia is divided into two parts, the low and shoreward section being given over to large settlements of Kru boys and indigenous negroes, while the upper part of the town is inhabited by Americo-Liberians and European consuls, traders, etc. This civilized part of the town is composed of broad, grass-grown streets, and substantial, well-built, comely looking houses, churches, offices, and public buildings. The smart appearance of the houses, in fact, is in somewhat striking contrast to the neglected condition of the roads. These have never been made, and are simply the unleveled rock of more or less flat surface. Consequently at the present time they are absolutely unsuited to any vehicle, though I have seen an enterprising Liberian negotiate them with a bicycle. They are generally covered with a very short, close turf of thickly growing plants, which is kept in the condition of turf by the constant nibbling of the pretty little cattle that frequent the streets of Monrovia. A less agreeable feature are the pigs, which exist in great numbers and perform the office of scavengers. The appearance of most of the houses is, as I have said, either very striking or comely both in form and color, and this appearance is enhanced by the beautiful clumps of trees and the gardens which surround most of the houses. The Americo-Liberians seem to be

very fond of flowers, and have gardens full of roses, oleanders, allemandas, bougainvillia, and frangipani in constant bloom. There are numerous churches and a masonic hall.

There is a good deal of civilization and comfort and signs of proggress at the settlements, which are grouped together under the general name of Grand Basa, and also at the Sino towns, the principal of which is named Greenville. But perhaps, on the whole, the most go-ahead and energetic assemblage of Americo-Liberians is to be found at Harper (Cape Palmas). Here there is a philosophical society, which is doing a good work in collecting and printing statistics about Liberia. But Harper, unfortunately for Europeans, is a good deal more unhealthy than Monrovia.

Compared with other parts of West Africa, I should say that Liberia is less unhealthy for the European than Sierra Leone, the Ivory coast, the Gold coast, or Lagos. But it is, perhaps, too soon to judge. It is noteworthy, however, that the remarkable absence of mosquitoes should to a great extent coincide with a less marked prevalence of malarial fevers.

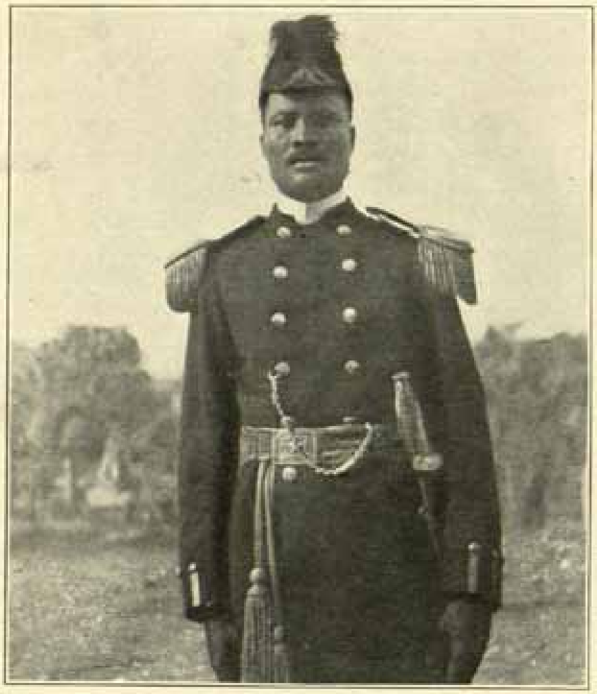
From the European point of view, perhaps the most healthy part of Liberia is the northern half, and from all accounts it would be the Mandingo plateau that Europeans would prefer for their trading or mining settlements.

The great undoubted wealth of Liberia lies, as I have already pointed out, in its rubber, but the trade in this product is as yet only in its infancy. Another important article of export in the future will be timber. Piasava, which is a fiber derived from the rind of the fronds of a Raphia palm, figures to some extent in the exports, which also include coffee, a little cacao, ivory, copal, palm oil, palm kernels, ginger, camwood, and annatto.

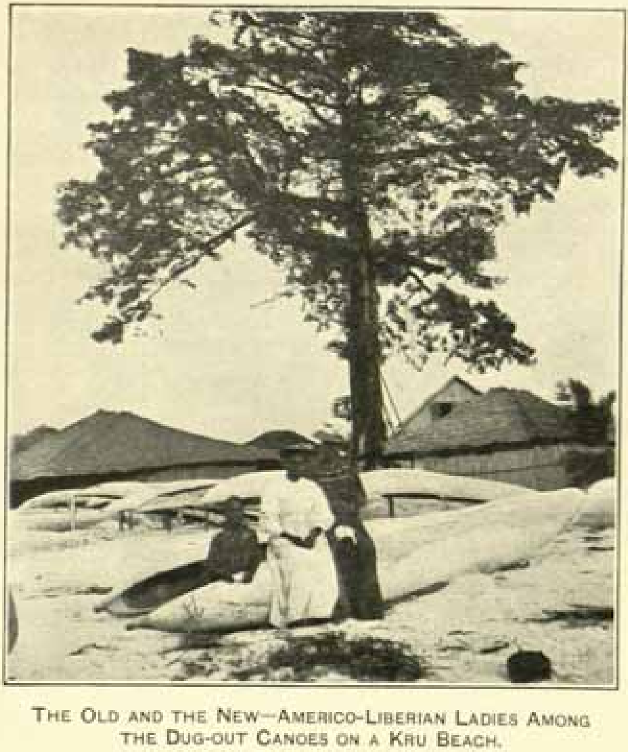
APPENDIX I.

PEOPLES AND TRIBES OF LIBERIA.

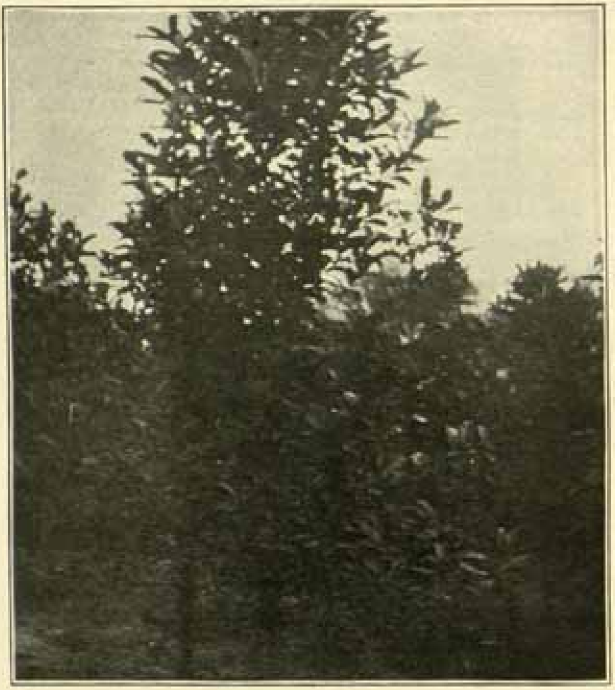
The following is a summary of the principal Americo-Liberian towns and settlements with their approximate populations. The enumeration commences with Roberts Port, not far from the western (Sierra Leone) frontier of Liberia, and proceeds northward, southward, and eastward to the French frontier along the Kavalli River:



A LIBERIAN COLONEL OF MILITIA.



THE OLD AND THE NEW—AMERICO-LIBERIAN LADIES AMONG THE DUG-OUT CANOES ON A KRU BEACH.



A LIBERIAN COFFEE PLANTATION.

STUDY OF THE FOREST ON A LIBERIAN RIVER.

		Americo-Liberian population.
County of Montserrado:		
Roberts Port		400
Royesville		50
St. Pauls River settlements—		
New Georgia	200	
Virginia	100	
Caldwell	200	
Brewerville	300	
Clay Ashland	400	
Louisiana	100	
New York	50	
White Plains	300	
Millsburg	250	
Arthington	300	
Careysburg	400	
Crozierville	100	
Bensonville	150	
Robertsville	150	
Harrisburg	250	
		3,250
Settlements on the Mesurado River—		
Barnersville, Gardenersville, Johnsonville, Paynesville		200
Monrovia		2,500
Junk River settlements—		
Schieffiin and Powellsville	225	
Mount Olive	150	
Marshall	125	
Farmington River and Owens Grove	300	
		800
County of Grand Basa:		
Basa settlements—		
Little Basa	50	
Edina	250	
Hartford	50	
St. Johns River	350	
Upper Buchanan	400	
Lower Buchanan (Basa)	600	
Tobakoni	50	
		1,750
Coast between Grand Basa and River Cestos		150
On the River Cestos		50
County of Sino:		
Sino settlements—		
Sino River	50	
Lexington	100	
Greenville	350	
Philadelphia	125	
Georgia	125	
		750
Settlements on Kru coast—		
Nana Kru, Setra Kru, Nifu, Sas Town, Garawe		150
County of Maryland:		
Settlements round Cape Palmas and on the lower Kavalli River—		
Rock Town	100	
Harper	900	
Philadelphia	100	
Latrobe	50	
Cuttington	100	
Half Kavalli	50	
Hoffman	50	
Middlesex	50	
Jacksonville	75	
Bunker Hill	25	
Tubman Town	100	
New Georgia	25	
Hillierville	25	
		1,650
Americo-Liberians scattered about Kelipo in far interior of Maryland County; in the Boporo country, near the Sierra Leone frontier, and on the upper St. Pauls River, etc., say		150
Total Liberians of American origin		11,850

The approximate total coast population of "civilized" Liberians (mostly Christian, and of mixed American and indigenous negro races) amounts to 40,000. The "Liberian" community, therefore, at the present time amounts to a population in the coast region of about 50,000 in number.

There are a good many other native villages and small isolated settlements or farms of Americo-Liberians which it would be tedious to enumerate by name. The ones and twos in such scattered settlements as these (such as Fish Town, Puduke, Weabo, Pequenino Ses, etc.) may be taken as a set-off against any possible exaggeration of numbers in connection with the more populous places.

These Americo-Liberians at present constitute the governing caste of the country. In origin about two-thirds are from the United States of America and one-third from the British West Indies. It is curious that in a general way the men who have come most to the front in the history of Liberia have been of British West Indian descent rather than emigrants or descendants of emigrants from the United States. They came, or their ancestors came, to Liberia rather to seek a profitable field for their enterprise than in any attempt to flee from conditions of slavery or other kinds of unsatisfactory social environment. The Liberians of British West Indian origin have generally been removed one or even two generations from a condition of slavery. They are also for the most part better educated and remember more as to their actual African origin than is the case with those whose immediate ancestors have come from the United States. For instance, the present President of Liberia, the Hon. Arthur Barclay, knows that the negro stock from which he sprang came from the district of Popo, now on the borderland of French and German territory, in the western part of the Dahome coast. English is naturally the universal language used by the Americo-Liberians. It is variously spoken by them, those originally of United States origin speaking it with a very strong "American" accent, while the Liberians who have sprung from the British West Indies talk English—that is to say, educated persons do—with but slight accent, and in the case of those who have received additional education in England, with no very obvious accent at all. A good deal of connection in sentiment is still kept up with the United States, though perhaps there is an increasing tendency, so far as higher education is concerned, for the dispatch of young Liberians to study in England at such places as the Liverpool schools and the African Training Institute of Colwyn Bay. But several local educational institutes are generously maintained by American philanthropists. The station of Arthington, on the St. Pauls River, is named after the celebrated philanthropist of that name connected with Leeds (Yorkshire), who did so much to establish the first missionary steamers on the Kongo, and whose name is very gratefully remembered in Liberia for the assistance that he has given in educational work.

The indigenous population of Liberia, not of extraneous origin, may be estimated with some correctness at a total of about 2,160,000. [In Vol. II, pp. 884–901, of his book on "Liberia," New York, 1906, Sir Harry Johnston gives additional information about the native races, estimating the population at 2,000,000.] They may be enumerated as follows:

Locality.	Name of tribe.	Approximate numbers.
County of Mesurado	Vai	100,000
	De	10,000
North of the Vai	Bandi	200,000
North of the Bandi	Kisi	150,000
Beyond the Kisi people	Buzi	50,000
Beyond the Buzi, stretching over to the northwestern and northern parts of the Republic	Mandingo	[a] 300,000
Behind the De people, along the St. Pauls River at the back of Monrovia	Gora	150,000
North and east of the Gora people	Kpwesi [b]	250,000
Beyond the Kpwesi, to the west and north, are the Buzi (already mentioned) and the tribe known as	Bere, or Bele	50,000
To the north of the Bere	Gizima and Buni	30,000
On the coast, beyond the De people of Monrovia, begins the big tribe of Basa people, and farther inland the	Basa Gibi [c]	200,000
South of the Basa group, along the coast from the northern limits of Sino County to the Kavalli River, are the	Kru tribes [d]	375,000
Behind the Kru coast are the	Putu people [e]	150,000
Behind the Grebo, in the Kavalli region (Maryland County)	Kelipo	150,000
Approximate total of indigenous negro population of Liberia.		2,165,000

[a] It is probable that the total population of the various Mandingo tribes considerably exceeds this estimate, which is arrived at by putting together the computations of each separate branch as given to me by its representatives at Monrovia. The proper pronunciation of the well-known tribal name Mandingo appears to be "Manding'a," or "Mading'a." They are a race that will play a very notable part in the development of West Africa. The whole of this tribe, which populates the hinterland of Liberia, parts of Sierra Leone, and the southern part of the French "Sudan," must number one or two millions. Their language is harmonious in sound and simple and logical in construction, therefore easily acquired. They are Mohammedans to a very great extent, only a few branches in the Liberian hinterland remaining pagan. In consequence they dress picturesquely and suitably, like the majority of Mohammedanized Africans in the Niger Basin and the northern Sudan, with wide breeches, voluminous tobes, and fezes, or round skullcaps. They are a fine-looking race as regards physical development, and their physiognomy reveals the secret of their power, namely, the slight infusion of Caucasian blood. They are, in fact, the result of an early intermingling of the Berber from the Sahara Desert with the negroes of the Niger Basin. They are a very industrious people, with a remarkable feeling for art, which is at present confined to elaborate leatherwork and the shaping of picturesque garments. The principal divisions of the Mandingo race in the hinterland of Liberia—proceeding from west to east—are the following: Boporo, Kwang'a, Mwela, and Dukwira. Their towns are nearly always surrounded by clay walls, the architecture of which, judging from such photographs as I have seen, is strongly reminiscent of the towns of Nigeria.

[b] This is the race named on most maps in the incorrect orthography "Pessy." It knows itself as Gbele, but for some reason is called by most of the surrounding tribes Kpwesi, which, on various grounds, is the most convenient name. A portion of the Kpwesi race is known as the Gbwalin, a name that appears incorrectly on our maps as "Barline."

[c] Behind the Basa and Gibi peoples one comes again to the great Kpwesi tribe.

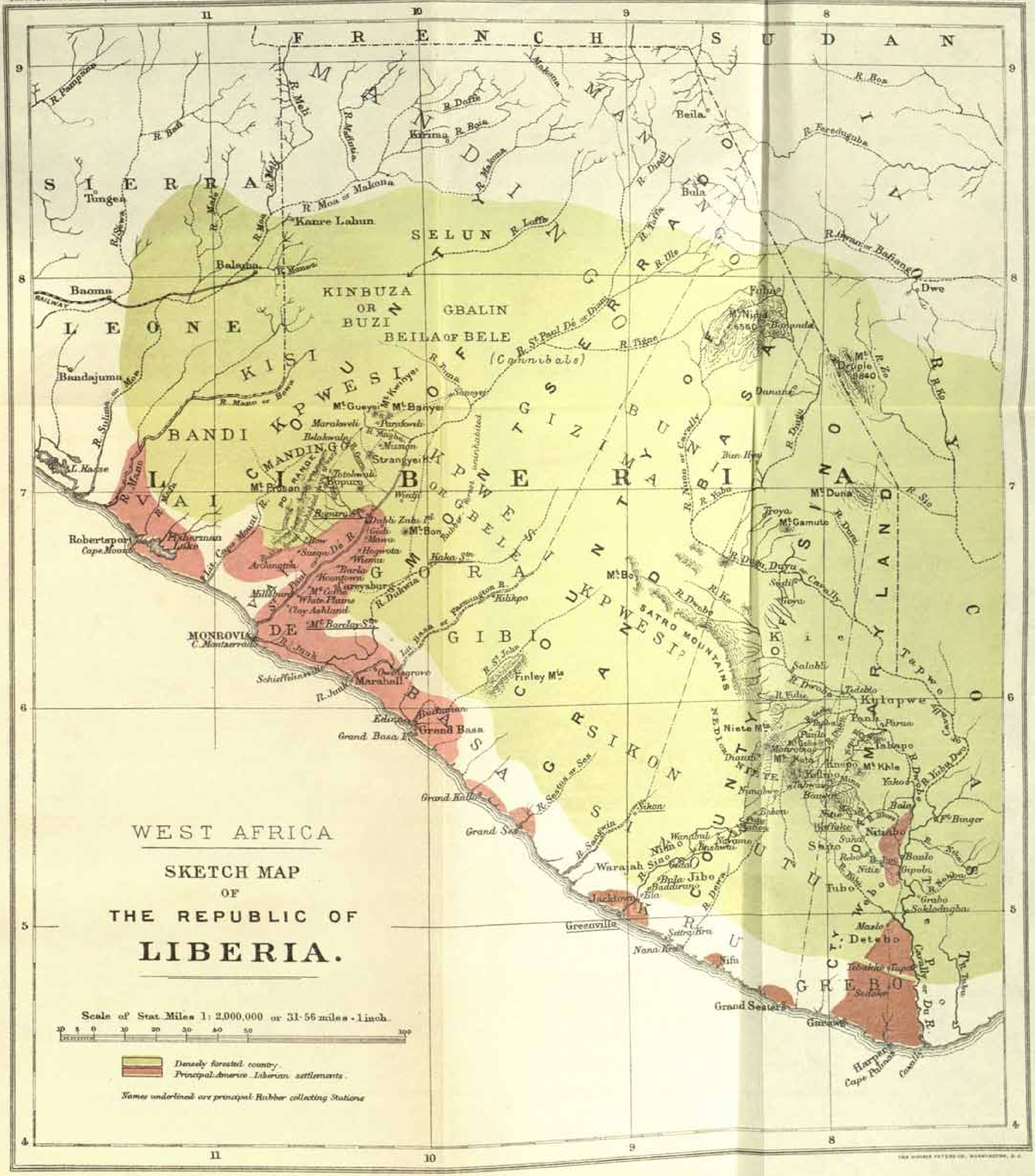
[d] The Kru tribes may be divided up under the following designations, but all the people included under these names do not extend farther into the interior than about 60 miles from the coast:

Sino people	75,000
Sikong (beyond the Sino)	100,000
Kru people proper (including all isolated colonies of Krumen elsewhere in Liberia)	140,000
Grebo people	60,000

[e] The Putu people seem to include the following subdivisions or separate tribes: Tatue, Nyapo, Pete, Tuo, and Gireo.

The Americo-Liberians of course are Christians, belonging entirely to various sections of the Protestant churches—Anglican, Methodist Episcopal, Methodist, Baptist, Presbyterian, etc. There is one establishment at Monrovia of the White Fathers, a Roman Catholic mission, mainly French and Dutch in the nationality of its missionaries. So far the fathers have made no converts, but the mission has only just been established. There is a good deal of activity amongst the various missionary societies dependent on the Protestant churches represented in Liberia, and this is largely financed from the United States of America. The work is carried on almost invariably by missionaries having some proportion, large or small, of African blood in their veins. A good deal of their work is educational, and has certainly brought solid advantages to the coast negroes of Liberia. Outside the negroes of American origin there are not many converts to Christianity. Such as there are come from the Kru peoples and the Grebo principality. Perhaps of all the native races the Grebo is the most Christianized and civilized. The Vai, some of the Gora, and nearly all the Mandingo peoples are Mohammedan—not fanatically, but very genuinely as regards adherence to Mohammedan precepts. The spread of Mohammedanism in the western and northern districts of Liberia has been of immense benefit to the country, diminishing the traffic in alcohol and checking drunkenness, which elsewhere in Liberia is so common among the negroes—a drunkenness induced just as often by the native forms of alcohol (palm wine, etc.) as by the consumption of European spirits.

At the present time the ports of entry into the Liberian Republic at which foreigners may settle and trade are the following (running from west to east): Roberts Port, Monrovia, Marshall, Grand Basa, Grand Ses (Cess), Greenville, Nana Kru, Cape Palmas, and Kavalli. Foreigners also are allowed to trade within a zone of 3 miles along all the inland frontiers of Liberia. It is, I believe, the intention of the Liberian executive to add to these recognized ports of entry places in the interior and on the coast as soon as communication has been opened up and the Liberian Government is in a position to maintain law and order at these places.


WEST AFRICA
SKETCH MAP
OF
THE REPUBLIC OF
LIBERIA.
Scale of Stat. Miles 1: 2,000,000 or 31·56 miles - 1 inch.
Densely forested country.
Principal America-Liberian settlements.
Names underlined are principal Rubber collecting Stations
FRENCH SUDAN
SIERRA LEONE
LIBERIA
KINBUZA OR BUZI
GBALIN
BEILA OF BELE
(Cannibals)
SELUN
KISI
BANDI
VAI
GIBI
GREBO
Monrovia
C. Montserrado
Robertsport
Cape Mount
Marshall
Grand Basa
Edina
Grand Bassa Pt.
Grand Kolli
Grand Sess
Greenville
Nana Kru
Nifu
Grand Sesters
Garawe
Harper
Cape Palmas
Baoma
Bandajuma
Tunge
Kanre Lahun
Balahun
Beila
Bula
Dwe
Mt. Nimba
Mt. Druple
Mt. Duna
Mt. Gamuto
Finley Mts.
SATRO MOUNTAINS
Jibo
Warajah Sino
Tubo
Kulopwe
Mt. Khle
Nitiabo
Baulo
R. Sulima or Moa
R. Mano or Bewa
R. Moa or Makona
R. Loffa
R. St. Paul Dé or Diani
R. Junk
R. Sestos or Ses
R. Duyu or Cavally
Cavally or Du R.
L. Kasse
Fisherman Lake
Cape Mount
Mt. Barclay St.
Kaka St.
Sikon
Jacktown

GEOGRAPHICAL RESULTS OF THE TIBET MISSION.[a]

By Sir Frank Younghusband, K. C. I. E.

Though I shall tell to-night of a journey to the "Forbidden City," there is, I fear, little, strictly speaking, new that I shall have to say. My companions and myself were, indeed, the first Europeans to enter Lassa for many years. Still, we can not claim credit for having been the first of all, and all I can do is to corroborate and emphasize the work of former travelers, and especially of those hardy Indian explorers A-K, Sarat Chandra Das, and others, who had made such careful surveys and interesting notes that some at least of our obstacles were removed.

Such corroboration is, however, very necessary, for an impression had of recent years grown up in Europe that Tibet was a wretched, poor, inhospitable country; and this is not what those few travelers, European and Indian, who had been to Lhasa before had described, nor is it actually the case. The northern part of Tibet, which is all that recent European travelers have seen, is indeed barren, uncultivated, and worthless, and this forms quite two-thirds of the whole. But Tibet is a large country—as large as the provinces of Bombay, Madras, and the Punjab put together, and there is a third part still remaining which is remarkably well cultivated, which is dotted over with thriving villages and the well-built and comfortable residences of the Tibet gentry. Taking it as a whole, then, and excluding the worthless desert portion, Tibet is probably fully as rich as Kashmir or Nepal. The valleys in which Lassa, Gyantse, and Shigatse are situated, and the valley of the Brahmaputra, are neither barren plateaus nor yet narrow V-shaped gorges. They are flat valleys from 4 or 5 to as much as 10 miles broad, covered with good soil, well irrigated, and richly cultivated. This is the most important geographical fact which, though mentioned casually by former travelers, we are able to reestablish and confirm.

And with this fact clearly impressed upon your minds, let me now ask you to follow in the footsteps of the Tibet mission in its journey

[a] Read at the Royal Geographical Society, February 13, 1905. Reprinted, by permission from The Geographical Journal, London. Vol. XXV, No. 5. May, 1905.

from India to Lassa. We unfortunately had to take our bodies there, and for the human body Tibet and Sikkim, through which we had to pass on the way into Tibet, are at certain seasons anything but attractive. You, however, need go there in mind only, and for the mind I do not know, in the whole realm of nature, any greater glories than Sikkim and Tibet afford. At the very outset of our travels was the sight which in all the world I consider the supreme—the view of Kinchenjunga from Darjiling, described by many travelers before, but by none better than by Mr. Douglas Freshfield in his recent book on this region. We had then to pass through as superb tropical forests as are anywhere to be met with, and emerging onto the high Tibetan tableland it was our good fortune to live for a month in full view of the magnificent panorama of 150 miles of the highest peaks in the Himalayas, with the loftiest mountain in the world as the culminating object. Lastly, we had ever before us in the dim mysterious distance the Sacred City, of which so little was known, and entrance to which was barred by every obstacle which man and nature could raise; and while my military companions had constantly to think of how best to overcome the resistance we might encounter, we of the political service had continually with us the earnest desire and the ambition to lessen by all our powers of reasoning and persuasion the military resistance, and above all so to impress the people who were now first making our acquaintance, that on our departure their disposition toward us should be one of friendliness rather than hostility, and that they should no longer look upon us as people to be roughly and rigidly excluded, but on the contrary respected and welcomed.

What more inspiring task could any men be intrusted with? And while this is not the place to speak of the military and political work of the mission, I may at least say that our objects were attained, and I may express my firm conviction that from this time onward all European travelers will be the gainers for what the British mission to Lassa did in 1904. One only evil geographical result I foresee. This society will have one less destination for the adventurous explorers of Great Britain, and the Sven Hedins of the future, like a fast-expiring race, will be driven back and back till they finally vanish from the earth amid the arctic snows. But for this misfortune not we only are to blame, but also and chiefly one of your own gold medalists, the great Viceroy of India, to whose initiative the whole enterprise was due and without whose constant support it could scarcely have been brought to a conclusion so disastrous for future explorers.

Our start from Darjiling in June, 1903, was miserable enough. The monsoon was just bursting, the rain was coming down in cataracts, and all was shrouded in the densest mist. Few knew of the enterprise upon which I was embarking, but a little knot of strangers who had assembled in the porch of the hotel had got an inkling and

shouted "Good luck!" as I rode off, covered with waterproofs, into the mist to join my companions, Mr. White and Captain O'Connor, in Sikkim. And detestable though the rain was, there was still a large surplus of joy in riding through those wonderful Sikkim forests, day after day seeing fresh marvels of forest growth or flowery beauty. The mountain sides were everywhere a wealth of tropical vegetation, rich and luxuriant. And here under the shade of the mighty giants of the forest grew the stately tree ferns, often 40 or 50 feet in height, with fronds 10 or 12 feet long. All were in bright fresh foliage, and besides ferns of every graceful form and of the subtlest delicacy of tracery were variegated colored plants, like caladiums, and closely connecting all together and festooned from tree to tree were creepers of every size, from the great elephant creeper, whose leaves resembled elephant's ears, to light trailing vinelike tendrils lightly strung from bough to bough; while here and there, as some bright surprise, the eye would light upon the most perfect orchid, or other flowery marvel, which brought one to a halt in an ecstasy of enjoyment. Nor should I omit to mention the brilliant butterflies glinting past on every side. Seventeen different kinds did I count in the space of 200 yards in the Teesta Valley; and in few other places in the world are to be found such a variety of rare butterflies, so many different orchids, and such a wealth of trees and flowers as in Sikkim. There are, I believe, over 600 different orchids alone to be found here and over 60 separate kinds of rhododendron.

Fain would I dwell longer on the attractions of this wonderful country, but it is with Tibet itself that we are chiefly concerned to-night, and thither I must without delay transport you. Just cross one pass and all is changed. On the far side of the Kongra-lama Pass not a tree is to be seen. If in some secluded nook a plant a foot high is met with, it is a curiosity. In place of the deep-cut valleys of Sikkim there are great plains 10 or 12 miles wide. The sky is cloudless, and the view extended over many and many a mile. Here at Khamba Jong Mr. White had laid out a camp, and here we spent many delightful months, doing our best to bring to reason a people nearly as obstinate as ourselves, and between whiles making roving expeditions to distant valleys—geological investigations with Mr. Hayden, of the geological survey; botanical trips with Doctor Prain, of the Botanical Gardens in Calcutta; natural history expeditions with Captain Walton, I. M. S.; every day and every hour enjoying the charming summer climate, and, above all, the unrivaled panorama of the mighty Himalayas at the very culminating point of their grandeur, where all the loftiest peaks in the world were majestically arrayed before us. Captain Ryder, known to you for his journey in China, surveyed and measured all this wonderful region, and will,

I trust, before long give you full particulars of his surveys. But who will ever be able to adequately describe the fascination of that glorious range of mountains? From sunrise to sunset the days were a continual delight. As I looked out of my tent in the early morning, while all below was still wrapped in a steely gray, far away in the distance the first streaks of dawn would be just gilding the snowy summits of Mount Everest, poised high in heaven as the spotless pinnacle of the world. By degrees the whole great snowy range would be illuminated and shine out in dazzling, unsullied whiteness. Then through all the day it would be bathed in ever-varying hues of blue and purple till the setting sun clothed all in a final intensity of glory, and left one hungering for daylight to appear again.

And all was rendered doubly interesting from the history of its geological past, which Mr. Hayden was able to describe to me. He was indeed enraptured with the district from the geological standpoint, and a bed of fossil oysters he discovered there had more fascination for him than Lassa itself. He was able, from the oysters, to accurately determine the age of the hills in this part of Tibet. According to him they were "recent"—that is to say, not more than two or three million years old, and the main axis of the Himalayas was thoroughly modern, perhaps not more than a few hundreds of thousands of years old. In what to geologists are really ancient times Tibet was below a sea which washed around the base of the Himalayas—a mighty granite ridge which is constantly being protruded upward from the interior of the earth and ever being worn away by the snowfall on its summit. Never have I been able to see nature at work on such a mighty scale as here, and when the scientific results of Mr. Hayden's work in this region have been thoroughly investigated I feel sure they will prove of the highest interest and value.

The mission remained at Khamba Jong from July 7 to December 6, but long before the latter date we had discovered that our political objects would never be obtained until we advanced farther into the country. A move on to Gyantse was accordingly ordered, and, as a considerable body of troops under the command of General Macdonald was to escort the mission, the line of advance was changed onto the Chumbi route.

Winter was now on us, and the difficulties which General Macdonald and his troops had to contend with can hardly be realized in England. But not even the rigors of a Tibetan winter were able to stop the advance of the little force of British and Indian troops.

Early in December we crossed the Jelap la and descended into the Chumbi Valley. At Yatung, the trade mart established under the old convention, a wall had some years ago been erected to exclude our trade, and beyond this our traders had so far never been allowed to

pass. As we debouched on a bright frosty morning from the pine forest in which we had encamped for the night, we saw this wall built right across the road and high up the mountain side on either hand. Whether we should have to fight our way through or whether the Tibetan general would respond to the arguments I had used the previous day and gracefully allow us through had yet to be proved, and General Macdonald used every military precaution. But to our relief we saw the great door in the tower standing open, and we were soon passing peaceably through the gate of Tibet, never, I hope, to be closed against us again.

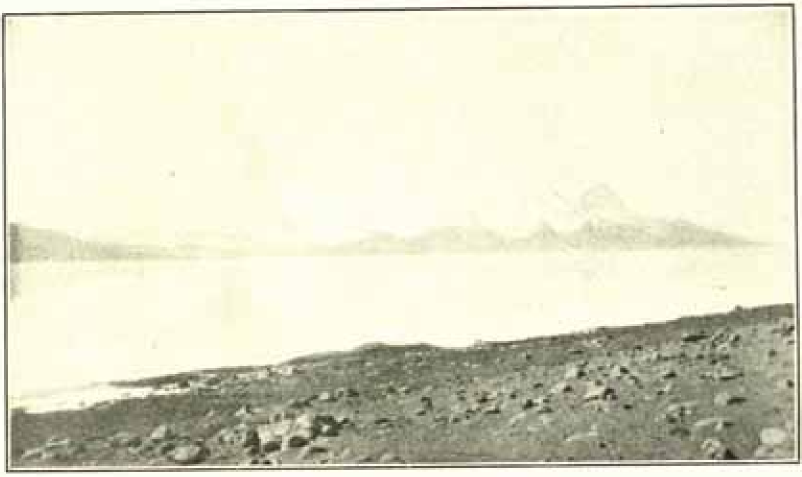
We then emerged on to the main Chumbi Valley, which, though not wide and open like the valleys we afterwards saw in Tibet proper, is decidedly less steep and narrow than the Sikkim Valley. Both in the valley bottom and on the hillsides there was room enough for comfortable villages and cultivated fields. The people were very well to do, and, what was more satisfactory from our point of view, decidedly well disposed. They soon showed themselves to be keen traders, and must have made large fortunes out of us during last year. They are not true Tibetans, but are called Tomos. Nor is their valley, which is on the Indian side of the watershed, considered a part of Tibet proper, which is looked upon as extending only as far as the mouths of steep gorges we a few days later passed through in the upper part of the valley. The rainfall is only about half that of Darjiling, and the climate in general much superior.

The mission remained three weeks in Lower Chumbi, while military preparations for a further advance were being made, and then in the very depth of winter, on January 8, we crossed the Tang-la, 15,200 feet high, on the Tibetan plateau again. Never shall I forget that day. Reveille sounded at the first streak of dawn, and as I looked out of my tent the very spirit of frost seemed to have settled on the scene. The stars were shooting out sharp, clean rays from the clear steely sky. Behind the great rugged peak of Chumalhari the first beams of dawn were showing out, but with no force yet to cheer or warm, and only sufficient light to make the cold more apparent. Buckets of water were, of course, frozen solid. The remains of last night's dinner were a hard, solid mass. The poor Sikhs were just crawling out of their tents, so shriveled with the cold it looked as though if they shriveled much more there would be nothing left of them. The thermometer stood at 18° below zero, or just 50° of frost, and though this is not considered much in Canada and Siberia, and I dare say those who have just returned from the Antarctic would consider it pleasantly warm, I should remind you that 50° of frost at a height of 15,000 feet above sea level is a very different thing from 50° of frost on the sea level. At 15,000 feet where the effort of breathing is a continual drain upon one's strength, the mere weight

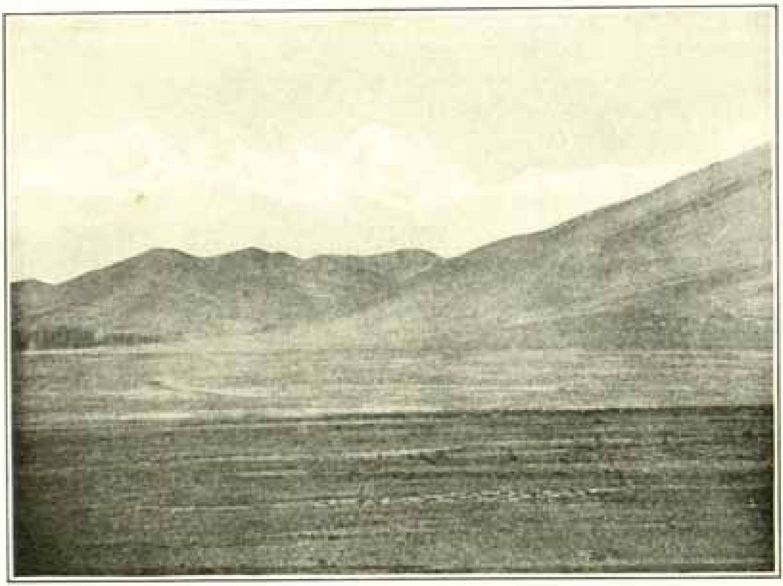
of the heavy clothes one has to wear in cold weather is a sufficient strain in itself. Any additional effort exhausts one immediately. And if it tries us Europeans, who are more or less inured to cold, how much more distressing must it be to the natives of India, and that they were able to march 15 miles across the pass that day and spend the rest of the winter, as they had to, immediately on the other side, at a height of but little under 15,000 feet, is, I think, a striking testimony to their powers of endurance and the high spirit which prevails among them. Colonel Hogge and the Twenty-third Pioneers most willingly faced this ordeal, and by this act of endurance proved once and for all to the Tibetans that their country was no longer inaccessible to us, even in the depth of winter.

Here at Tuna more fruitless parley with the Tibetans ensued. They paid one or two visits to me, and once I rode over with Captains O'Connor and Sawyer to see them amid their own surroundings, to gauge their capacity, and to estimate the strength and direction of the various influences at work among them. It became sufficiently evident to us that the real control of affairs was in the hands of the Lassa lamas, three of whom—one from each of the three great monasteries at Lassa—were present on the occasion. The four generals whom we then met were amiable and polite enough. They repeated by rote the formula, "Go back to the frontier." But the impetus to obstruct came from the three lamas, who, with scowls on their faces, remained seated on the ground, showing not the slightest signs of civility or ordinary politeness, and instigating the generals to detain us in the Tibetan camp till we would name a definite date for withdrawal. When I think of their rabid fanatical obstruction on that occasion and compare it with the almost cordial reception we subsequently had in all the great monasteries and in the most sacred shrines before we left Lassa, I can not help feeling that we went a long way toward breaking down that barrier of exclusion which, set up by the lamas for their own selfish ends, has kept away from us a people who, when left to themselves, showed every inclination to be on friendly terms with us and indulge their natural instinct for trading.

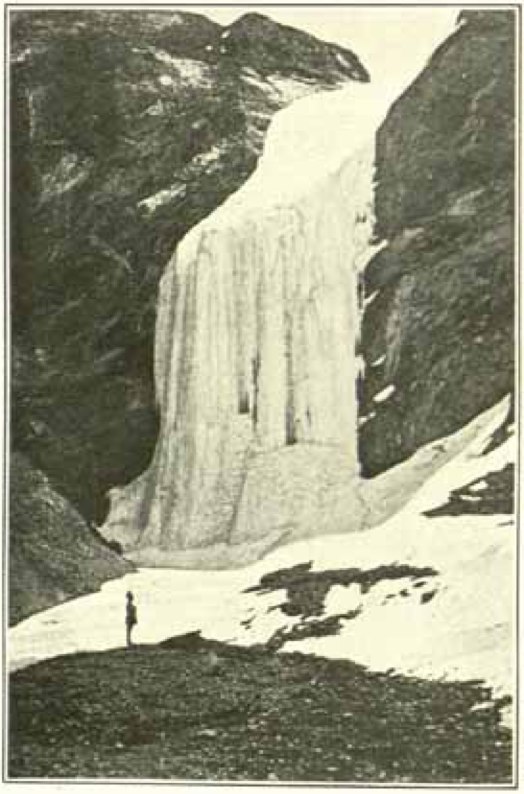
But parleying with the Tibetans occupied only an insignificant part of my time at Tuna, and I had ample leisure to enjoy the magnificent natural scenery around us. Immediately before us was an almost level and perfectly smooth gravel plain, which gave a sense of space and freedom, and on the far side of the plain, 10 or 12 miles distant, rose the superb range of mountains which forms the main axis of the Himalayas and the boundary between Tibet and Bhutan. They were an unceasing joy to me, and the sight of them alone was ample reward for all the hardships we had to endure. The sun would strike our tents at about 7 in the morning. The sky would generally then be cloudless save for a long soft wisp of gauze-like haze, and perhaps



THE BAMTSO LAKE AND BHUTAN RANGE.



MOUNT EVEREST FROM KHAMBAJONG.



FROZEN WATERFALL AT DOTHA.

THE YAMDOK TSO.

a few delicate streaks of pink or golden cloud poised motionless on he horizon. And the great snowy mountains, in the early morning when I used to go out and watch them, instead of being sharp, clear, and cold, would be veiled in that blue, hazy, dreamy indistinctness which makes the view of Kinchenjunga from Darjiling so marvelously beautiful and the hard stern mountains as ethereal as fairyland. The bare brown of the base of the mountains was toned down into exquisite shades of purple and pink, while the white of the snowy summits shaded softly into the cerulean of the sky above. On the plain, plump little larks and finches would be scurrying about in search of food. Now and then a little vole would be seen basking in the sun at the mouth of his hole. And over all there reigned a sense of peace and quiet which made it hard to believe that only 10 miles off five of the highest lamas in Tibet were solemnly cursing us and publishing to the people round threats of attack upon our camp.

Nor was every day, nor the whole of each day, of this same peaceful nature. Almost invariably at 10 or 11 a terrific wind would arise and blow with fury for the rest of the day. Mighty masses of cloud would come sweeping up from the direction of India. Snow would sometimes fall, and then for two or three days together we would be the sport of a terrific blizzard. The mountains would be hidden and nothing would be visible but dull masses of fiercely driven snow, as fine and dry as dust and penetrating everywhere. For days together the thermometer would not rise above 15° even in the middle of the day. Our camp would be the very picture of desolation. It seemed impossible that the poor sentries at night would ever be able to stand against the howling storm and the penetrating snow or that our soldiers would ever be able to resist an attack from the Tibetans under such terrific circumstances.

Then one morning we would find the snow clouds had passed away from over us and see the great peak Chumalhari emerging calm, strong, and irresistible from out of the mass of cloud still tossing wildly round its base. Below all seemed chaos. It was difficult to stand against the driving wind; the dust and the powdery snow were still battling furiously around one and around the base of the mountain, and the birds were driven hither and thither. But towering above all the tumult below, serene and majestic, and looking prouder, loftier, and purer than ever, rose the great peak, reverenced even by the unimaginative Tibetans, and above it lay the calm blue sky, illimitable in its restfulness and light—a sky of bright and liquid azure, through which one seemed able to pierce right into heaven itself.

Throughout January, February, and March the bitter winds continued, often accompanied by snow in blinding blizzards, through which the convoys and their escort had to force their way with per-

haps even greater sufferings than fell to us. But gradually, as week by week went by, the temperature rose. The military preparations in rear were completed by General Macdonald, and early in April we marched down to Gyantse. Of the military incidents on the way I will say nothing. It was the deepest disappointment to me that fighting should have been necessitated, and the Tibetan generals were as little anxious for it as I was, but they had impossible orders from Lassa—orders not to fight, not to negotiate, and not to let us proceed. Unless, therefore, we were prepared to abandon the whole object of the mission, fighting was inevitable.

Arrived at Gyantse on April 11, we found a flat open valley 5 or 6 miles wide, dotted all over with flourishing hamlets and intersected by numerous water channels. Round each hamlet, along the water channels, and by the bed of the river were willow and poplar trees just showing signs of bursting into foliage. The banks were covered with masses of iris plants, which later on were to flower out into sheets of purple. The piercing cold of the Tuna uplands was left behind. There was only a slight touch of frost at night, while the days were beautifully fine and bright; and we were looking forward to a restful summer of peaceful negotiation, when suddenly ominous clouds began to collect around us, and early on the morning of May 5 we were awoke by wild shouts and firing, and, looking out of our tents, we saw Tibetans firing into us through a wall only 10 yards off. How Major Murray and his gurkhas warded off the attack; how Colonel Brander defended the post for nearly two months against the Tibetans, who had now invested us, and how General Macdonald eventually returned with a relieving force, drove back the Tibetans, and captured the jong, has been told elsewhere. Geographically, the important point is that the refusal of the Tibetans to negotiate at Gyantse necessitatedd our advance to Lassa. On July 14 we set out, much impeded by heavy rain, and soon set aside the delusion that Tibet is a rainless country. Well on till September we had frequent rains, and the size of the rivers and side streams was quite sufficient evidence that this part of Tibet receives—probably up the Brahmaputra Valley—a quite considerable rainfall, say between 20 and 30 inches, at a rough guess.

We crossed the easy Karo-la Pass, about 16,000 feet, where Colonel Brander had fought his gallant little action early in May, and the next day debouched on to the most lovely lake I have ever seen—the Yamdok Tso. In shape it was like a rough ring, surrounding what is practically an island; and in color it varied to very shade of violet and turquoise blue and green. At times it would be the blue of heaven, reflecting the intense Tibetan sky. Then, as some cloud passed over it, or as, marching along, we beheld it at some different angle, it would flash back rays of the deep greeny blue of

a turquoise. Anon it would show out in various shades of richest violet. Often, when overhead all was black with heavy rain clouds, we would see a streak of brilliant light and color flashing from the far horizon of the lake; while beyond it and beyond the bordering mountains, each receding range of which was of one more beautiful shade of purple than the last, rose once more the mighty axial range of the Himalayas, at that great distance not harsh in their whitey coldness, but softly tinted with a delicate blue, and shading away into the exquisite azure of the sky. What caused the marvelous coloring of this lake, which even the Tibetans call the turquoise lake, we could none of us say. Perhaps it was its depth, perhaps it was its saline character, or some chemical component of its water. But whatever the main cause, one cause at least must have been the intensity of clearness in the liquid Tibetan sky, so deep and so translucent that even the sky of Greece and Italy would look pale and thick beside it.

For three days we marched along the shores of this beautiful lake, and then we ascended our last pass and looked down onto the Brahmaputra River and almost upon Lassa itself. But the sacred city was still left hid. Masses of mountains in range after range were all we could see in that direction, and General Macdonald had still the very serious obstacle of the Brahmaputra River, now in almost its full flood, to overcome before we could reach our goal. The Brahmaputra we found to be divided into numerous channels, but we were able to cross it at a spot where it narrowed to 200 yards, though not without the loss by drowning of the one officer to whom, of all others in the force, our success in reaching Lassa was due—Maj. G. H. Bretherton, the chief supply and transport officer. The river rushed in whirling vortices past a cliff, from which Captain Sheppard, R. E., suspended a wire rope to the opposite side and upon it rigged up a flying ferry. The river valley was from 3 to 5 miles wide, and, like the Gyantse Valley, richly cultivated with wheat and barley, dotted over with hamlets, monasteries, well-built and comfortable residences of the great men of the country, and with pleasant groves of poplar, walnut, and even a few peach and apricot trees. The side valleys were also well cultivated, and the hillsides, though bare of trees, were covered with grass, which should afford excellent pasturage for many more sheep and goats than we actually saw there. It was altogether a smiling prospect, and doubts as to the possibility of being able to supply our troops with the necessaries of life, for the year round if required, were at once removed.

I was now met by a variety of deputations, each one of increasing weight and importance, and each more urgent than the last in begging me not to proceed to Lassa. The Dalai Lama himself even wrote to me, an act of unprecedented condescension on his part, and he sent his high chamberlain to say that if we went to Lassa his

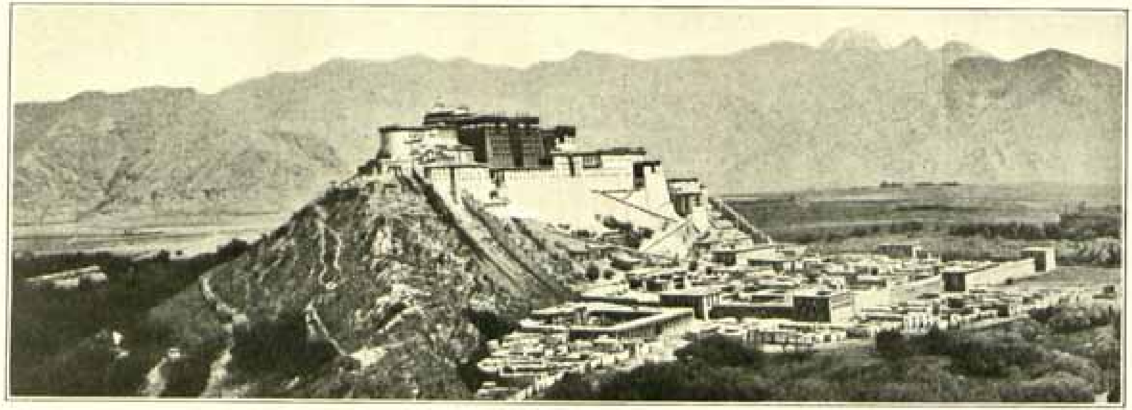
religion would be spoilt and he would die. I had to inform him, in reply, of the delicate and painful position in which I was placed, for if, on the one hand, I went on to Lassa I understood that his holiness would die, while if I stayed where I was I would myself die, as I would undoubtedly have my head cut off if I failed to obey the orders I had received and negotiate the treaty in Lassa itself. Reluctant as I was to cause the premature demise of the Dalai Lama, I felt I had no alternative, I informed the high chamberlain, but to proceed to Lassa.

Expectation was now at its height. Each corner we turned we felt sure we should see Lassa. We hastened to the top of one rise after another in the hopes of catching the first glimpse. The advance patrols of mounted infantry, on their return, were eagerly questioned. At length, on August 2, we rounded our last corner and saw the golden roofs of the Potala of Lassa glittering in the distance, and on the following day encamped beneath its walls.

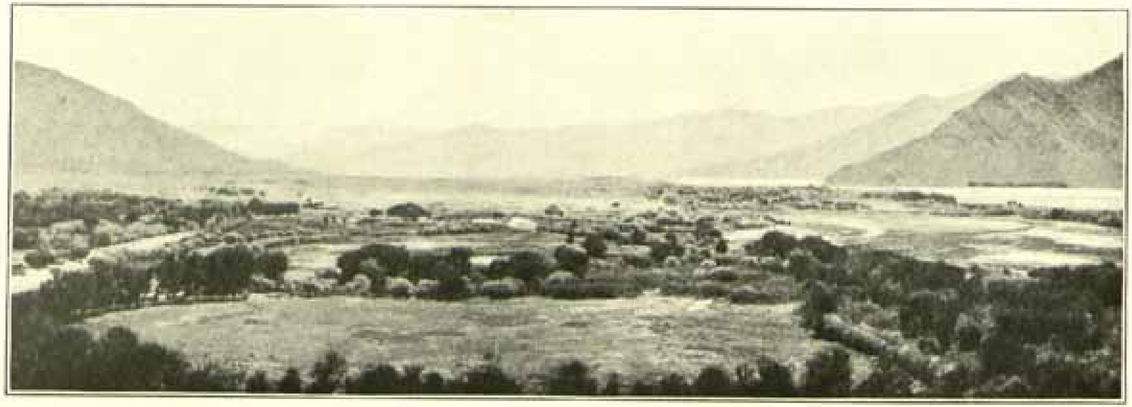
Here in a lovely valley covered with trees, rich with cultivation, and watered by a river as broad as the Thames at Westminster, here hidden away by range after range of snowy mountains, lay the mysterious Forbidden City which no living European had seen before. To many who had supposed, because it was so secluded, it must be a kind of dreamland city, it was, I dare say, disappointing, for it was, after all, built by men, and not by fairies. Its streets were not paved with gold, nor were its doors of pearls. The streets were, indeed, horribly muddy, and the inhabitants less like fairies than any I have so far seen.

But the Potala, the palace of the Grand Lama, was an imposing, massive structure, very solidly built of masonry, and picturesquely perched on a rocky eminence dominating the whole plain and the city at its base. Numbers of the houses in the city were, too, well built and solid, and often surrounded by shady trees. The rock-perched palace and the strange city at its base would be striking anywhere, but set in this beautiful valley, deep in the very heart of the mountains, they gathered an additional impressiveness which all who saw them recognized.

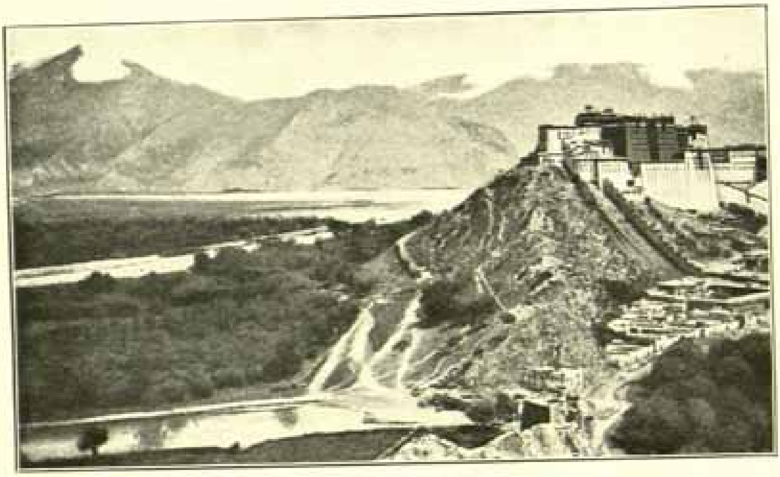
It was, however, more to the inhabitants than to their buildings that I had to devote my chief attention during my stay in Lassa. All the leading men, both lay and ecclesiastical, here came before me, and with them I reasoned and argued and chaffed day after day and week after week. Appallingly ignorant and inconceivably unbusinesslike they were. No one man had supreme authority or full responsibility to negotiate with me. A council were supposed to be the chief executive authorities, but they could do nothing without the consent of the national assembly, and they, without any presiding officer to control them or any sense of responsibility, simply censured instead of



THE POTALA.



PANORAMA OF LASSA FROM BA-MO-RI.



THE POTALA FROM BA-MO-RI.

THE LASSA COUNCIL.

indorsing what the executive council did, while these latter were prohibited from attending meetings of the national assembly to argue their case in person. A more hopelessly inapt organization for dealing with a crisis in their foreign affairs it would be difficult to imagine. But ignorant, bigoted, and apparently immovable as they were, they had their good points. They were almost invariably polite, and they were genial. The humblest little joke was enough to set them off laughing, and I do not recall separating at the close of a single interview of all the many we had at Lassa with any feeling of ill temper. I must confess to a feeling of exasperation sometimes when I reflected that my convention had to be got through in so short a time, and no ray of daylight was for so long visible through the dreary clouds of obstruction; but these poor Tibetans do deserve credit for never having really irritated me. It was, after all, their business to make as good a bargain as they could with me, and pertinacity is a trait which need not be caviled at. Still, it was heavy, weary work. Eight or ten of them would come together. Each one had to have his say, so that when he returned home he could boast that he had for his part spoken up to the British commissioner. Each one I listened to patiently and each one I answered. In this way, as every day produced a few fresh men, I worked through most of the leading men in Lassa, while Captain O'Connor, whose trials were still greater than mine, tackled even larger numbers in his private room.

On the whole, I formed a low estimate of their mental caliber. It is impossible to regard them as much else than children. My talks with them were not only about the business in hand, but about general affairs and about religion. The Ti Rimpochi, with whom the Dalai lama left his seal in his flight for Lassa a few days before our arrival, held the chair of divinity in the Gaden monastery, and was universally reverenced as the leading lama in Lassa. He was recognized as regent, and was the principal in the negotiations with me. But even he, pleasant, benevolent, genial old gentleman as he was, had really very little intellectual power, and but a small modicum of spirituality. In both he was very distinctly inferior to the ordinary Brahmin in India. He liked his little jokes, and we were always on the best of terms. But he was firmly convinced the earth was triangular. His intellectual attainments did not amount to much more than a knowledge by rote of prodigious quantities of verses from the sacred books. Discussion with him upon the why or the wherefore of things ended in bald quotations from the scriptures, and his religion chiefly consisted in ceremonial. The general run of abbots of monasteries and leading lamas had even less to recommend them. One monastery at Lassa contained no less than 10,000 monks, and another had 7,000. But I do not think anyone saw these monks without remarking what

a degraded, nasty, sensual looking lot they were. It is altogether a mistake to suppose that in Tibet is to be found a pure and lofty form of Buddhism. Buddhism and Chinese civilization certainly have raised the rough tribes who, six or seven centuries ago, inhabited Tibet into something very much higher than they were before these appeared. But intellectual and spiritual life is stifled by the rigorous monastic rule. All foreign ideas and individual originality have so far been trampled down. And the result is a people of inflexible rigidity, wholly unable to adapt themselves to altering conditions, and without any intellectual force or spiritual impetus. We sought for, but did not find, the wonderful Mahatmas, who would lead us to more lofty peaks of light and wisdom than ever we had trod before. And while I would not deny that Buddhism has done much to tame and civilize a barbarous race of demon worshipers in Tibet, I would warn those who would look to Lassa for any kind of higher intellectual or spiritual guidance, to seek nearer home for what they need. Imbued, as the Tibetans are, with much of that impassive contentment inculcated by Buddha, they are still, to all intents and purposes, demon worshipers. Their religion is grotesque, and is the most degraded, not the purest, form of Buddhism in existence.

Happily we were able to entirely overcome that feeling of obstruction which the heads of Tibetan Church had so far shown to outsiders. Through Mr. Wilton's influence with the Chinese officials, and Mr. White's connection of many years' standing with the Tibetan lamas in Sikkim, and his tactful suasion, we were able to gain access to all the monasteries and temples, and before we left Lassa British officers went in and out with as little concern as they would to St. Paul's. I insisted upon having the convention signed in the Potala, and in the finest hall in it, and once the lamas saw no harm resulted, and we invariably treated them with consideration, they entirely withdrew their obstruction, and when, just before leaving Lassa, I paid a formal visit to the great cathedral called Jo Khang, I was surprised to find them actually pressing me to come inside the railings and walk round the magnificent image of Buddha—a freedom I have never had accorded me in any temple in India.

I fear I have not sufficient time to adequately describe these monasteries and temples. Outside they were solid and massive, though hardly beautiful. Inside they were weird and quaint, and sometimes grotesque. I carried away with me an impression of immense impassive figures of Buddha forever gazing calmly and tranquilly downward, of walls painted with grotesque demons and dragons, of highly decorated wooden columns and roofs, of general dirt and griminess, and of innumerable bowls of butter burning night and day, as candles are burnt in Roman Catholic churches before figures of the saints.

Sooner than I could ever have expected, the convention was signed, and we prepared for our return to India. Once business had been arranged, the Tibetans were all as happy as possible. No single person was responsible; each had had his say, and if blame had to fall on anyone it had to fall on all, and all equally. But in their heart of hearts they knew full well that they had got off remarkably cheaply, and they had indeed the grace to acknowledge this. On the morning of our departure the regent came down to our camp and presented images of Buddha to Mr. White and myself, as well as to General Macdonald. He thanked us for saving the monasteries and temples, and in presenting the image of Buddha to me said, "When Buddhists look on this they put aside thoughts of strife, and think only of peace, and I hope that you, when you look at it, will think kindly of Tibet."

And certainly I left Lassa with every kindly thought. It was a perfect autumn day; the sun was bright and warm. The valley was looking its prettiest in its autumn foliage. The entire council, with their secretaries, had come a mile down the road to offer us a farewell cup of tea and to wish us godspeed on our journey. Their last words were that they intended to keep the treaty and be friends with us in future. Our hopeless task seemed indeed to have been accomplished and good will to have been established.

And all that has happened since corroborates this impression. The council had willingly given permission for a party of officers to proceed through Shigatse up the Brahmaputra to Gartok, in Western Tibet, and then back to India by Simla. This important expedition was placed in charge of Captain Rawling, who two years ago had made a most successful journey in Western Tibet, while Captain Ryder, R. E., was in charge of the survey. These two officers, with Captain Wood, R. E., and Lieut. E. Bailey as their assistants, have accomplished their arduous undertaking. Though accompanied by only an orderly each, and no armed escort, they have traveled through a thousand miles of Tibet and been well received everywhere. Captain Ryder has surveyed 40,000 square miles of country, including the whole course of the Brahmaputra from Shigatse to its source, the Mansorawar and adjoining lakes, and the sources of the Indus and the Sutlej, and has proved beyond doubt that no higher mountain than Mount Everest lies at the back of the Himalayas. The party suffered indeed terribly from the cold, their thermometer registering 24° below zero, but they crossed a pass 18,400 feet in height in December and reached India in safety.

I trust, therefore, you will believe that the Tibet mission has not been barren in geographical results, and that when you wish exploration work to be done there are good and trusty men in India ever ready and willing to do it.

THE DEVELOPMENT OF RHODESIA AND ITS RAILWAY SYSTEM IN RELATION TO OCEANIC HIGHWAYS.[a]

By J. T. P. Heatley.

In a former paper on "The port of the Upper Nile in relation to the highways of foreign trade"[b] it was my aim to discuss the lines of communication leading to the Upper Nile from Alexandria, Suakin, Massaua, Berbera, Mombasa, and Chinde, and to determine the economic zones that might be commanded by the highways of trade from these several ports. It is my aim in this paper to give an account of the economic development of Rhodesia, and to discuss its railway system in relation to the oceanic highways.

Rhodesia comprises those territories the development of which is directed by the British South Africa Company. It is well named, for it was owing to the energy, enterprise, and sagacity of Mr. Rhodes that the colony was founded and now forms part of the British Empire. "To see all that British is my dream!" Mr. Rhodes is said to have exclaimed when referring to the possible acquisition of these vast territories. As originally defined in the charter of incorporation, the extent of territory open to occupation by the South Africa Company was "the region of South Africa lying immediately to the north of British Bechuanaland, and to the north and west of the South African Republic and to the west of the Portuguese dominions." Its sphere is now bounded by the Transvaal Colony, Portuguese East Africa, the British Central Africa Protectorate, German East Africa, the Kongo Free State, Angola, German Southwest Africa, and the Bechuanaland Protectorate. It is divided into two parts by the Zambezi—Northern Rhodesia and Southern Rhodesia, and each of these again is subdivided into two provinces—Southern Rhodesia into Matabeleland and Mashonaland; Northern Rhodesia into Northwestern Rhodesia and Northeastern Rhodesia.

Africa is a continent of table-lands, and Rhodesia, physically viewed, consists chiefly of a vast elevated table-land, the general alti-

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[a] Reprinted, by permission, from The Scottish Geographical Magazine, Edinburgh, Vol. XXI, No. 3, March, 1905. The magazine article includes some maps and illustrations here omitted.

[b] Scottish Geographical Magazine, XI, p. 571.

tude of which varies from 3,000 to 5,000 feet. One or two points may be chosen to indicate relative heights. The Zambezi at the confluence of the Luangwa River is 780 feet above sea level, and at the Victoria Falls it is 2,850 feet; Lake Tanganyika is 2,680 feet; the altitude of Salisbury is 4,800 feet, and Marandellas, which is 5,600 feet above sea level and 45 miles from Salisbury, is the highest point on the railway between Salisbury and the coast; Bulawayo is 4,250 feet; Fort Jameson 3,600 feet; Fife 5,400 feet. Rhodesia belongs to several hydrographic systems—the Zambezi, the Kongo, the Sabi, and the Limpopo.

Although the whole of Rhodesia falls within the Tropics, its climate is modified by its altitude, and as a very considerable part of it is above 3,000 feet it may thereby be regarded as a white man's country and well fitted not only for British residence, but for British colonization. It has been estimated that in Southern Rhodesia alone there are 100,000 square miles above 3,000 feet with a suitable climate for Europeans, and 26,000 square miles above 4,000 feet where the average temperature allows European children to be born and bred. The year is divided into two parts, according to the rainfall—a wet and a dry season. The wet season begins about the end of October and terminates about the end of April. From May to September there is little or no rain, and this period—the Rhodesian dry season—is the best time to arrive.

The economic possibilities of Rhodesia are manifold and immense. To develop this potential wealth has been the aim of the British South Africa Company. When the company was formed the chief and virtually prescribed objects of its administration were to extend northward the railway and telegraphic systems of the Cape Colony and Bechuanaland; to encourage immigration and colonization; to promote trade and commerce; to develop and work mineral and other concessions.

The fame of gold and other mineral wealth has been associated with this part of Africa since the most ancient times. Many old workings have been found, and these have facilitated modern prospecting. In Southern Rhodesia gold fields have been discovered both in Matabeleland and Mashonaland—chiefly in the Bulawayo, Gwelo, Salisbury, Umtali, and Mazoe districts. The development of the gold fields has been frequently interrupted, but considerable advance has been made, as may be seen from the progressive output. In 1898 the output amounted to 16,706 ounces; in 1899, 56,742 ounces; in 1900, 85,366 ounces; in 1901, 172,035 ounces; in 1902, 194,170 ounces, and in 1903, 231,872 ounces. Copper has been discovered in both Northern and Southern Rhodesia. In Southern Rhodesia it is found in Victoria, Melsetter, Lo Mogundi, and Mafungabusi districts; in Northern Rhodesia on the Kafue River and on the borders of the

Kongo Free State. The principal lodes, so far opened up, are on the Kafue River and in the Lo Mogundi district. The deposits in Northern Rhodesia give every promise of a great mineralized field which is being systematically developed. Several coal fields have also been discovered. Chief among them is the vast coal field of Wanki, which promises to be one of the most important discoveries in Rhodesia. The coal is considered to be second only to the best Welsh. Other minerals found in varying quantities are silver, blende, antimony, arsenic, lead, and iron.

Although gold and other mineral wealth promote the speedy development of new territories, the permanent prosperity of such a country as Rhodesia must ultimately depend upon its pastoral and agricultural resources. "Owing to its fertile soil," says Mr. Ross Townsend, secretary for agriculture in the Rhodesia administration, "regular wet season, ample rainfall, genial climate, and cheap land, Rhodesia offers prospects for successful farming operations second to none in South Africa, and comparing favorably with most British colonies. The fertility and variety of soils are capable of producing most kinds of cereals, tobacco, vegetables, and fruit where energy and enterprise are brought to bear on it, as has been practically demonstrated in the different districts of the country." It is worthy of note that, owing to the geological formation of the country, the best arable land is usually situated within a reasonable distance of the gold reefs. There is always a great demand for agricultural produce, at remunerative prices, at Bulawayo, Salisbury, and Selukwe. It is estimated that in Matabeleland alone there are 50,000 square miles available for pasture and arable land, and of this about 6,000 square miles are suitable, without much preliminary work, for European cultivation. The size of farms in Mashonaland is generally about 1,500 morgen (approximately 3,000 acres). Matabeleland farms are about twice the size. Rhodesia offers attractive prospects to the man of energy and enterprise who has a knowledge of agriculture and a capital of £500 to £1,000. Mealies—maize or Indian corn—is the staple cereal product and can be made to produce as heavy a yield as in any other part of the world. The demand is practically unlimited, not only for local markets, but throughout South Africa. Wheat grows well and yields abundantly in many parts of the country. Samples of Rhodesian wheat have been well received on the British corn market. Root crops of all kinds do remarkably well and yield heavily, especially potatoes. Cattle generally do well everywhere. Sheep and goats—Cape Boer goats, Persian sheep, and the Cape fat-tailed sheep—thrive well all over Rhodesia and the increase is rapid. The merino sheep is found to do well in the eastern highlands, where a million sheep could be grazed without overstock-

ing. The prevalence of horse sickness has hitherto prevented the breeding of horses and mules; but Doctor Koch is convinced that a simple process for immunization is possible much on the lines of his process for inoculation against rinderpest, by which means South Africa has been rid of that disease. If this system of inoculation succeeds, as is anticipated, then there will be a great future for horse and mule breeding in Rhodesia, not only in meeting local requirements, but in supplying remounts for the British army.

Of tropical and subtropical products the most important for Rhodesia are rubber, tobacco, and cotton. Rubber is found in abundance in the Sabi Valley, along the Zambezi, and in many parts of Northern Rhodesia. Mr. Lyttelton Gell has discussed the future development of this industry and has advocated the systematic cultivation of rubber. Tobacco grows well everywhere, and in the opinion of an American expert there is a great field for enterprise, as the different varieties of soil are capable of growing the light cigarette tobacco, the cigar leaf, and heavy smoking tobacco. A special report on tobacco culture has been prepared by Mr. G. M. Odlum, of the department of agriculture of Southern Rhodesia in which he shows, from an investigation of the industry in America and from analogy, that the growing of tobacco will play an important part in agricultural development.

Another promising industry is the growing of cotton. Samples both of native wild cotton and of that grown from Egyptian seed have been favorably reported on, both by the British Cotton-Growing Association and by the director of the Imperial Institute, London. "I have examined," says Mr. Wolstenholme, in his report (January 7, 1904) on behalf of the above-mentioned association, "the samples of cotton grown in Rhodesia now on view at the Liverpool Exhibition. At the present moment they are worth considerably more than the prices affixed to them, these, I think, being the figures I placed on them some months since. The Egyptian seed lots are worth 8½d., and the native seed 8¼d. to 9d. I feel sure that if you can keep up the standard of these samples there is a large fortune in the business. Your Egyptian samples are much superior to the Nyassaland cotton sold at 7¼d. per pound. Planters from the Zambezi inform me that they could obtain plenty of labor, as the natives from Portuguese East Africa prefer to work cotton to working in Rhodesian mines. It is evidently one of the few countries where the product of the Egyptian seed maintains its characteristics, Peru being the only other I know, though it has been tried everywhere. If you have sufficient land and labor available to produce quantity equal to the samples, you probably have more valuable gold mines above than below ground in Rhodesia." If Rhodesia develops her cotton belt, it will be not the least of her services in contributing to the economic prosperity of the United Kingdom and the Empire.

Rhodesia is an inland country. This fact has an important bearing on its economic development. The vital problem here, as in several other parts of Africa, has been the inland carrying trade. Since such an important river as the Zambezi flows through Rhodesia, it might well be assumed that it would afford an easy line of access, and that its waterway would become a great artery of commerce. But on account of the configuration of the African Continent the navigation of the Zambezi is interrupted by falls and rapids at several points where the river descends from the table-lands of the interior. It is a river subject to great fluctuations of depth. During the wet season it floods and rises as much as 15 to 20 feet; at the height of the dry season it is reduced to shallow and uncertain channels which vessels with merely a draft of 18 inches would find hardly navigable. The former difficulties at the delta have been removed since 1889, when the navigable Chinde mouth was discovered, and the port of Chinde is now the chief entrepôt for the several fields of trade commanded by the Zambezi highway.

The Zambezi may be physically divided into three sections: The lower river extending from the sea to the Kebrabasa Rapids—a distance of about 400 miles—the middle, from Kebrabasa to the Victoria Falls, a further distance of 900 miles, and the upper, from the falls to the source of the river, 600 or 700 miles. The lower section up to Tete is navigable for stern-wheel and other small draft steamers for eight or nine months in the year. During the other months the shallows near Sena, where the river widens to a breadth of about two miles, make navigation difficult. From Tete goods are taken overland to Cachomba, a distance of over 130 miles, in order to avoid the rapids. At Chicoa or at Cachomba, above the Kebrabasa, navigation again becomes possible to and beyond Zumbo, where the river is again obstructed at the Kariba Gorge. At present goods are forwarded from Cachomba either by carriers or by water to Zumbo and Feira, and are distributed from these points. In order to facilitate the transit of goods to the west, it is proposed to construct a wagon road round the Kabrabasa rapids, and ultimately a light railway. From Chinde the rates are £5 per ton to Tete, £10 for each passenger; to Feira £25 and £30, respectively. Several of the transport companies are devoting their energy and enterprise to developing this highway of trade and the waterway of the upper Zambezi.[a]

In January, 1901, at a meeting of the Royal Colonial Institute, Major Gibbons discussed the Zambezi system as a waterway and suggested schemes by which it might be developed into a great commercial highway. "I look forward," he said, "to the day when a boat

[a] See Foreign Office Reports on the Trade of Chinde for the years 1902, 1903, 1904; and Foreign Office Reports on the Trade of Tete and District for the year 1901 (annual series, 2812) and 1903 (annual series, 3210).

will travel those 1,200 miles from Chinde to Molele without the necessity of transshipping." This is a long view, but it indicates the direction in which development is proceeding apace. At several points along the main river the transit trade is rapidly increasing. Thus Tete has become a convenient depot for the transit of goods and an important point on the lines of communication to north, south, and west. Through Tete the telegraph system passes from Rhodesia to British Central Africa, and from the east coast to Zumbo. A postal service has been established by a weekly overland mail between Tete and Salisbury and a commercial route will probably be developed up the Mazoe Valley with Southern Rhodesia. Another route of increasing importance is that from Tete to Fort Jameson and other parts of Northeastern Rhodesia. Goods are shipped to Tete from Chinde and thence forwarded to Fort Jameson by carriers. The rates of freight from Tete to Fort Jameson are 8s. to 10s. a load of 50 to 60 pounds. A road is at present under construction between these two places to facilitate communications. From Chinde to Fort Jameson the rates for goods by way of Tete are £25 a ton; for passengers, £28.

The Zambezi system comprises that of the Shire River and Lake Nyassa, and this is the best route to the northern and eastern districts of northeastern Rhodesia. This Nyassaland route follows the Zambezi and Shire waterways to Lake Nyassa. At Chiromo, or Katunga, 60 miles higher up the river, navigation ceases and goods are carried overland, through Blantyre, to the Upper Shire. Stern-wheelers provide transport as far as Fort Johnston, at the south end of Lake Nyassa. From this point steamers ply to the several ports on the lake. The ports for Northeastern Rhodesia are Domira Bay and Kota-Kota for Fort Jameson, and Karonga, on the northern shore, for Fife and Abercorn and the districts bordering on Lake Tanganyika. The rates of freight by Lake Nyassa from Chinde are, per ton to Fort Jameson, £28; to Karonga, £20; to Fife, £35; to Abercorn, £50, and to Mweru, £75. The passenger rates to the same points are £35, £30, £41 5s., £52 10s., and £75. A railway is now being constructed from Chiromo to Blantyre and thence to Lake Nyassa. When completed it will form an important link in this system of communications and greatly promote the increasing success of this commercial highway to the heart of Africa.

The Zambezi, however, has hitherto played but a subordinate part in the opening up of Rhodesia to commerce and civilization. It was from the Cape that British enterprise developed communications with the northern territories in the basin of the Zambezi.

One of Mr. Rhodes's earliest efforts was to get the Cape parliament to extend the Cape Government Railway to Kimberley. This was allowed, notwithstanding considerable opposition. Afterwards the

Afrikander Bond determined that Kimberley should remain the terminus of this railway, and that any further extension should be from the Cape to Bloemfontein and Johannesburg. That this would give control of the trade of the interior into the hands of the two Boer States, and so be a menace to British interests, was only too evident. The true route to the north was, according to Mr. Rhodes, through Bechuanaland. When the British South Africa Company took over the administration of the country Kimberley was the nearest center of communication. After the charter was signed permission was obtained to extend the Cape Government Railway from Kimberley to Vryburg. This extension of 126 miles was begun in November, 1889, and finished in December, 1890, the work having been completed in little over a year. Want of funds, however, put a stop to further extension for some time; but in May, 1893, the Bechuanaland Railway Company was incorporated to continue the line northward from Vryburg to Bulawayo via Mafeking, Palapye (Palachwe), and Francistown. This, a distance of 587 miles, was completed in October, 1897. During the construction of this line the great rinderpest scourge swept over the country, practically killing the whole of the trek oxen. It is estimated that before the outbreak in 1896 there were over 100,000 cattle in Matabeleland, and by the end of the year there were only about 500 left. The difficulty of transport thus brought about and the outbreak of the Matabele war impelled the company to push on this work by what may be termed forced marches, so that, in most striking contrast with the earlier construction, the last 228 miles from Palapye to Bulawayo were completed in the very short space of four and a half months. The line was formally opened on November 4, 1897. With the establishment of this direct communication of Bulawayo with Cape Town, a distance of 1,360 miles, was inaugurated a new era in the history of Matabeleland and Rhodesia.

But Mashonaland was the first Rhodesian territory, and communication with the east coast was desiderated. While the Bechuanaland Railway Company, now known as the Rhodesian Railways (Limited), was constructing this line to Bulawayo, a line was being projected from Salisbury to Umtali, and thence to the Portuguese port of Beira. The distance between Salisbury and Beira is about 375 miles, but although the distance was not great, there were considerable difficulties to be overcome. The Anglo-Portuguese treaty of 1891 had a clause which provided for the construction of a line of railway from the Pungwe River to Salisbury via Manicaland, but political causes were responsible for much delay. Another serious obstacle in constructing the line was the hilly nature of the country. From sea level at Beira the country gradually rises. An altitude of 5,600 feet is attained at Marandellas, 45 miles from Salisbury, which

is the highest point on the Salisbury-Beira line. From Marandellas there is a gradual descent into Salisbury, which is 4,800 feet above sea level. The chosen starting point of this line was Frontesvilla, 35 miles up the Pungwe River, from which place the line, 2-foot gauge, was laid in a westerly direction for a distance of 75 miles. This section was opened in October, 1893. Considerable delay was occasioned in the construction of this first section, which runs through the Pungwe Flats, by the frequent "washaways" which occurred during the wet season. There were other difficulties also on account of the swampy nature of the country; yet the work went on surely, and in November, 1894, the rail was carried on as far as Chimoio, a distance of 118 miles from Fontesvilla. This point remained a terminus for some years. It was not until October, 1896, that a line was constructed between Beira and Fontesvilla. Thus there was a 2-foot gauge line for a distance of 153 miles. Great difficulties were, however, experienced in continuing the line from Chimoio to Umtali, on the Portuguese border, and it was not until February, 1898, that the 2-foot gauge line to the border was completed. In 1897 the Mashonaland Railway Company was formed to carry out the construction of a 3-foot-6 gauge line from Umtali to Salisbury. The work was begun on January 11, 1898, and the line was completed in May, 1899, on which date Salisbury was in direct railway communication with Beira. As the line from Beira to Umtali was only of a 2-foot gauge, considerable expense and delay were incurred in transferring goods from the narrow-gauge to the broad-guage line, and as it was also found that the 2-foot gauge line could not cope with the necessary amount of traffic, it was decided to widen it to the standard gauge of 3 feet 6 inches. Before this work was entered upon the line between Beira and Umtali was partly resurveyed, some of the worst gradients were thus avoided, and a saving of 18 miles was effected. The broad-gauge line from Beira to Umtali was completed in August, 1900. Since 1900 vast improvements have been effected on this line. In former years "washaways" were frequent and dangerous, but the addition of numerous culverts has done much to lessen the constantly recurring damage caused by the rains to the permanent way.[a] The great need of Mashonaland had been from the outset a rapid and cheap system of communication with the coast. Mr. Rhodes hoped by a railway from Beira to Salisbury to reduce the cost of importing food stuffs into the country from £70 to £10 a ton. The completion of this railway system was therefore a great boon to all concerned in the economic development of the eastern districts of Rhodesia.

The next phase in the development of the Rhodesian Railway system was the linking up of Bulawayo with Salisbury. In 1898 Mr.

[a] Vide Foreign Office Report on the Trade of Beira for 1902 (Annual Series, No. 3024), p. 7.

Rhodes contemplated the extension of the main trunk line from Bulawayo via Gwelo and the Zambezi to Lake Tanganyika as part of his great Cape-to-Cairo scheme. After an unsuccessful attempt to obtain the cooperation of the Imperial Government in this undertaking, the various mining and exploration companies were approached, and sufficient funds were raised for the construction of the first section of 150 miles. It was also decided, while the railway was being pushed northward via Gwelo, to construct a line from Salisbury to meet the northern extension. The line from Bulawayo to Gwelo was begun in May, 1899, but its continuation was interrupted by the Transvaal war. Although the northward extension was thus stopped, the viligant and vigorous directors of the Rhodesian Railways (Limited) decided to extend the line from Salisbury toward Bulawayo, and by January 1, 1902, the 188 miles from Salisbury to Gwelo were completed and open to the public. After peace had been proclaimed, and the line from Cape Town could be used for transport of railway material, the construction of the line from the Bulawayo end was proceeded with, and on December 1, 1901, six months after the Salisbury extension had reached Gwelo, Cape Town and Beira were in railway communication. Thus the Rhodesian Railway system became a connecting link in a through system of South African communication from coast to coast.

This Rhodesian highway may be regarded as the vertebral system of the colony. In an old and settled country the general direction of a railway system is mainly determined by the recognized importance of the towns and localities which it connects. But in opening up new territories, while the topography must needs have a determining influence, the problem is one also of the potential; the call is for prevision—for a prudent anticipation of industrial centers and of the general growth of the community.

These conditions have been well satisfied in the route chosen. The alignment of the Rhodesian system follows the trend of the healthy uplands, where the British born may settle and form permanent homes. Already several thriving townships are found along the route of the main railway. The effect of rapid and cheap communication soon became manifest in the noteworthy development of Bulawayo. The line from the Cape reached Bulawayo some eighteen months before Salisbury was connected with the coast. Although the township of Bulawayo was three years younger than Salisbury, it soon exceeded the latter in population and in the number and size of its buildings. The streets are well laid out, and the buildings are both handsome and costly. Government House, built originally as a private house by Mr. Rhodes after the style of Groote-Schuur, on the slopes of Table Mountain, is on the site of Lo Bengula's old kraal. An extensively laid out park connects it with the

town, and its avenue, which has been planted throughout its entire length, promises to become a rival to the great avenue at Cape Town. Salisbury, which is the seat of government, has likewise some good buildings and a well laid out park. On the railway between Bulawayo and Salisbury are the rising townships of Gwelo and Hartley. The former is the center of the best gold-producing country. The latter, which is 111 miles from Gwelo and 77 miles from Salisbury, has many gold mines in its vicinity. Other townships in southern Rhodesia are Victoria, Umtali, Enkledoorn, Melsetter, Rusapi, Selukwe, Gwanda, and Tuli. Bulawayo and Salisbury have been constituted municipalities. The smaller towns are controlled by local sanitary boards.

Granite has hitherto been utilized only in building bridges and laying foundations, owing to the heavy working expenses entailed. It is found, however, in large quantities throughout Rhodesia and merely awaits the advent of hands and head.

The economic development of Rhodesia has necessitated the building of branch lines to several mining districts. From Bulawayo a line has been laid down to the Gwanda district, which is rich in gold and coal fields. The work, which was begun in 1899, was stopped on the outbreak of the war. By March, 1904, 91 miles had been completed, and since that time there has been an addition of 13 miles, which makes this important branch line 104 miles in length. The interests of Selukwe, which is fast becoming the center of a large gold-mining district, have also been advanced by connecting it with Gwelo. This line, which is 24 miles long, was completed in 1903. It is also intended to construct a line from Salisbury to the Mazoe Valley, another mining district. The survey has been completed, and the line will be about 26 miles long. By August, 1902, a 2-foot gauge line was laid down from Salisbury as far as the Ayrshire gold mine. This line is the property of the Ayrshire and Lo Mogundi Railway Company; 84 miles have already been constructed, and it is contemplated to carry it on for 30 miles more to the Alaska mine. Another branch is under consideration from Umtali northward to Penhalonga.

As an indication of local developments in the winning of gold, the following statistics are derived from the Report of the Secretary for Mines, Southern Rhodesia, for the year ending March 31, 1904. The tons crushed amounted to 516,747, producing by milling 198,477 ounces, giving an average of 7·6 pennyweights per ton. In addition to the gold obtained by milling, 29,272 ounces were recovered by cyanide treatment, 5,511 ounces from concentrates, and 1,431 ounces from various pannings. The grand total for the year amounted to 234,693 ounces. The production according to districts was as follows: Sixty-two thousand four hundred and forty-seven ounces in the Bulawayo district; 136,292 ounces in the Gwelo district; 1,604

ounces in the Salisbury district; 26,907 ounces in the Umtali district; 7,160 ounces in the Hartley district; 38 ounces in the Lo Mogundi district; 242 ounces in the Victoria district.

Gold mining, however, has not been the only mining industry which has contributed to the development of the Rhodesian railway system. In order to tap the northern parts of Rhodesia it was originally intended that the line from Bulawayo should branch off at Gwelo and thence proceed through the Mafungabusi district to cross the Zambesi at the Cariba Gorge, through Northwestern and Northeastern Rhodesia to Lake Tanganyika. This route, however, was found impracticable, as the country north of the Kariba Gorge was in no way adapted to railway construction. In view of the difficulties to be encountered from Gwelo, and on account of the important discovery of a large coal area (600 square miles) at Wanki, it was decided to carry the line from Bulawayo in a more westerly direction than was originally intended, through the vast timber forest of the Gwaai River district, and on to the falls through the great Wanki coal field, thence on to Lake Tanganyika. The work of laying the line was commenced in May, 1901, and in September, 1903, the rail reached Wanki, a distance of 200 miles from Bulawayo. On the route to Wanki the line runs parallel with the Khami river, and after crossing the Insese and Umguza rivers it enters the extensive Gwaai forest. The Gwaai River is crossed at a spot about 90 miles from Bulawayo, at which point the altitude is 3,240 feet, or about 1,200 feet lower than that of Bulawayo. The line then leaves the Gwaai, and after passing through a large expanse of sandy plains, it comes to Wanki. From Wanki to Victoria Falls is a distance of 75 miles, and over this part of the country, which is of a more hilly nature, the line was carried and completed on April 25, 1904. The bridging of the Zambezi has been a considerable engineering feat. It is expected that the construction of the bridge will be completed in June of this year. The extension of the railway north of the falls has been authorized as far as Kalomo, 100 miles beyond the falls, the capital of Northwestern Rhodesia. In order that the construction of this part of the line may not be delayed, the material is being conveyed across the Zambezi by means of an aerial cableway. At the present time (February, 1905) the earthworks on the north side of the Zambezi are completed for the first 29 miles, and the rails are laid for 12 miles. From Kalomo the railway will be continued northwestward to the Kafue River. Beyond the river it will bifurcate, one line proceeding northwestward, to develop the great mineral field of the Hook of the Kafue, from which point it may ultimately be continued to the great copper field of Kansanshi, on the border of the Kongo State. The main branch is designed to proceed through Northeastern Rhodesia

to Lake Tanganyika to form part of the Rhodesian section of the great meridional highway from the Cape to Cairo.

Although the Victoria Falls will play an important part in the economic development of Rhodesia when the immense power, there available, is utilized for industrial purposes, it is as one of the greatest sights of the world that they will appeal to visitors, to whom they are now rendered easily accessible. The fame of these falls has resounded through the world since they were first made known by Doctor Livingstone. It is therefore fitting that the township which has been founded in their vicinity is to bear his name. The site of the town is near the left bank of the Zambezi, some 2 or 3 miles from the falls, and the railway line to the north passes by it.

The origin of the falls was ascribed by Livingstone to a volcanic rift, and this view has been universally accepted. But another view has been recently mooted regarding their physical history which ascribes the origin of the chasm and canyon to erosive action.[a]

The Victoria Falls are about twice as broad and two and a half times as high as Niagara. They are over a mile wide and about 400 feet high—higher than the top of St. Paul's Cathedral. The Zambezi at about half a mile above the falls is one and a half miles in breadth, then it contracts and is suddenly precipitated into a comparatively narrow, profound trench or canyon, at the eastern end of which there is an outlet about 100 yards in breadth through which the whole of the contracted Zambezi rushes, forming the Boiling Pot, and thence through a deep and narrow gorge of basaltic cliffs, which is continued in a narrow winding canyon of about 45 miles in length. The railway will cross the gorge a few hundred yards below the Boiling Pot. The bridge, built on the cantilever principle, forms a handsome span 650 feet long, with a width that allows a double line of railway. When completed it will be the highest bridge in the world. The falls themselves are not visible from the railway where it crosses the river; but, in accordance with the wish of Mr. Rhodes, the trains will pass through the perpetual spray rain while crossing the bridge. The vicinity of the falls is celebrated for its natural beauty, and parks are to be laid out on both banks of the river. It is therefore hoped that the development of this renowned locality will combine utility and amenity.

There are two other renowned localities in Rhodesia which have led to the building or projecting of branch railways. Near Bulawayo are the renowned Matopo Hills, where Mr. Rhodes in 1896, unarmed and accompanied only by an interpreter, had an interview with the Matabele chiefs, which resulted in a speedy cessation of hostilities.

[a] Vide "The Physical History of the Victoria Falls," by A. J. C. Molyneux, F. G. S., F. R. G. S.; The Geographical Journal, January, 1905.

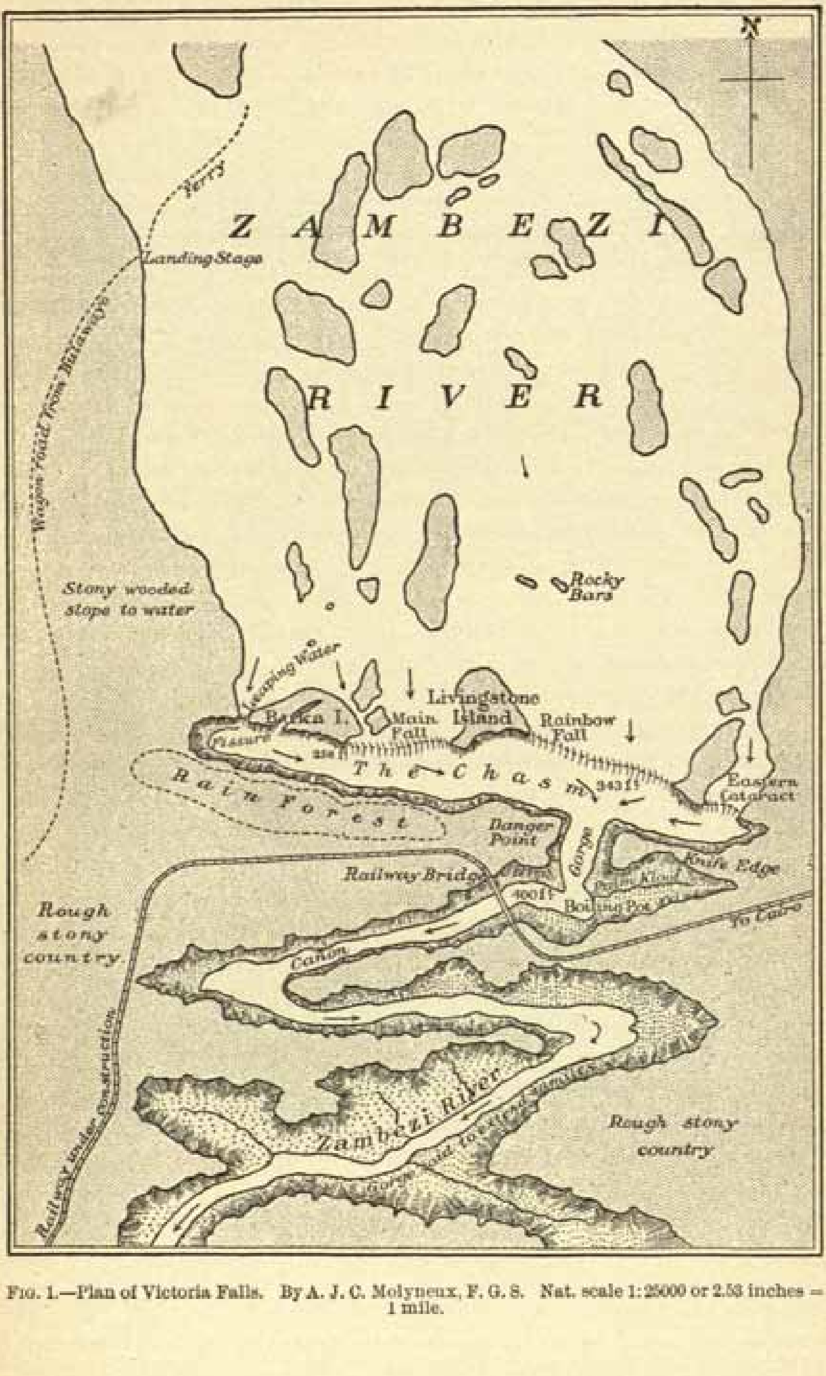

FIG. 1.—Plan of Victoria Falls. By A. J. C. Molyneux, F. G. S. Nat. scale 1:25000 or 2.53 inches = 1 mile.

Among the Matopos Mr. Rhodes, according to his own wish, was buried. A railway has been built from Bulawayo to the Matopos by the trustees of the Rhodes estate, as it was Mr. Rhodes's wish "that the people of Bulawayo may enjoy the glory of the Matopos from Saturday to Monday." The grandeur of those hills is aptly described in the words of Mr. Rhodes when he called them "the view of the world."

The other renowned locality is that of the Great Zimbabwe. The historical associations of these ancient monuments contrast with the modern associations of the Matopos; but they have this in common, that they represent the commerce and civilization of their respective ages. When the contemplated railway to Victoria has been built, it will give access to the Great Zimbabwe, which is now recognized as one of the finest ancient shrines in the world.

The founder of Rhodesia and the builders of the Great Zimbabwe bring into association the British and the Sabæans, and thus unite across the ages two of the most celebrated commercial nations. How to develop and maintain communications between the coast and inland parts has been the vital problem in modern economic development, as it probably was in that of ancient times. The chief ports at present available are Chinde, Beire, and those of the Cape. To these will probably be added, in time, Durban and Lourenço Marquez. Schemes have been mooted which will give access to Rhodesia from the West Coast through Angola and German Southwest Africa. At present the two main highways of trade are from Beira and the Cape ports. Bulawayo, which may be taken as the central point of the Rhodesian system, is distant 676 miles from Beira, 1,198 miles from Port Elizabeth, 1,259 miles from East London, 1,360 miles from Cape Town. There is not much difference in the amount of goods passing through Beira and the Cape ports. Much will depend, however, on the future railway administration. According to the British consul at Beira, it would appear that under present arrangements "freights to Umtali and Salisbury, which are respectively distant 203 and 375 miles from the coast, cost approximately £5 per ton more than the railway freights to these places over the Cape government railways from Port Elizabeth, which traverse over 1,400 miles to reach the same destination."[a] There has been some concern at Cape Town regarding the future relation of the town and port with Rhodesia; but it would seem from the above report that there is a reasonable prospect of Cape Town, with its rapid oceanic communications, maintaining its commercial and strategic importance as the chief gateway to Rhodesia and the north.

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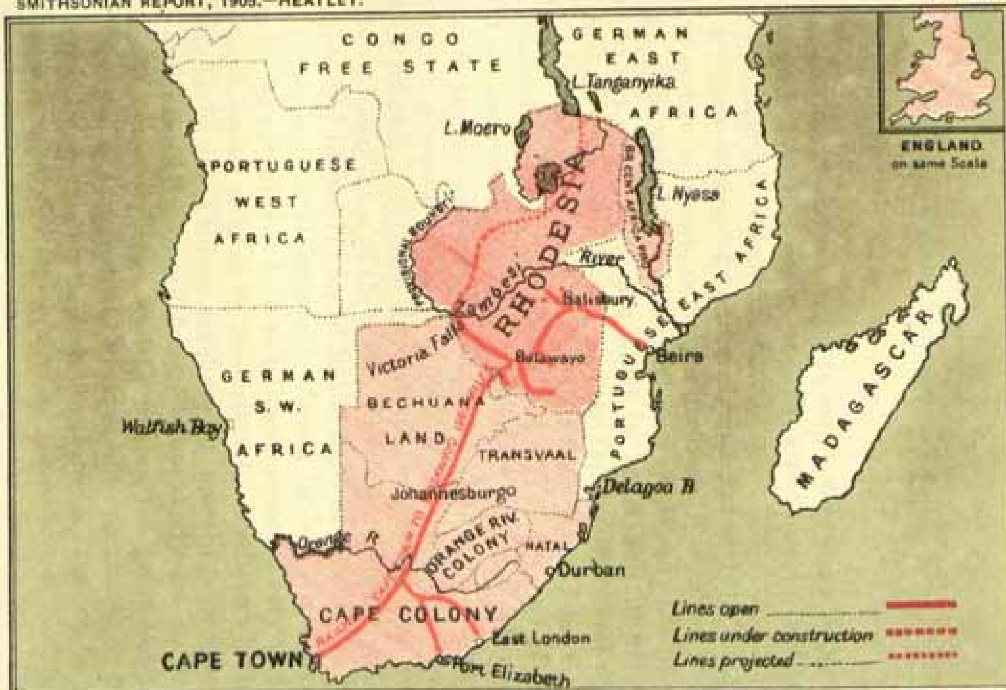
[a] Foreign Office Report on the Trade of the Consular District of Beira for 1902. (Annual Series, No. 3024.)



RAILWAY MAP OF SOUTH AFRICA IN 1904.

THE NORRIS PETERS CO., WASHINGTON, D. C.

THE ETHICS OF JAPAN.[a]

By Baron KENCHO SUYEMATSU, B. A., LL. M.

I have been asked by your council to read before you a paper on the ethics of Japan, and this is my attempt in response to that request, though very imperfect it must necessarily be.

There are three sources of factors which influenced the molding of the ethical system in Japan, namely, Shintoism, Buddhism, and Confucianism. The first is the native religion of Japan; the second is, needless to say, a religion originated in India and introduced to Japan through China and Korea, and the third is the moral teaching of China. As to the relative positions of these three, I have already fully explained this in an article entitled "The religions of Japan," in the December number of the Independent Review. They are not antagonistic to one another, as people not living in Japan might imagine, and as would only appear natural to them from their own notions of religion. Of these three, Buddhism is the most religion-like in the ordinary sense of the term. Shintoism ranks next, but it is very simple and liberal if viewed in the light of a religion. Confucianism comes last; it is ordinarily classed by western writers as a religion, but as a matter of fact its religious aspect is very vague, and it is not considered a religion by the Orientals. Perhaps a better term for it would be the Chinese teaching of morality, because moral notions which can be gathered from Chinese study are comprised in all sorts of Chinese writings, and Confucius, the great sage, is only one of the exponents thereof. Confucius, however, takes a very high place among those exponents, and therefore he came to be revered more than any others by Orientals, and thus Chinese teaching came to be usually associated with the name of the great sage. I can not do better than follow this example and call Chinese teaching by the name of Confucianism.

Comparing these three systems of teachings with regard to ethics, Confucianism stands out very prominently in its systematic exposition

[a] Reprinted, by permission, from Journal of the Society of Arts, London, No. 2729, Vol. LIII, March 10, 1905.

and practical utility. Buddhism, it is said, is very philosophical, and deep in its ideas of the cosmos, and there is no doubt that it is capable of exercising a great influence on the popular notion of a future life, though it does not do so as much in Japan as in some parts of the Asiatic continent. It has, however, very little to say with regard to ethics relative to the actual life of the human being. It says you must not do wrong; it says you must do good; but as to what is good or what is bad it is very vague in its meaning. It suggests rather religious notions than practical ethics, how one should behave in this world toward one's fellow-creatures or toward the community or state to which one belongs. It speaks of ten warnings and four benevolences. The ten warnings are: 1. Do not kill the living. 2. Do not steal. 3. Do not commit adultery. 4. Do not speak wantonly. 5. Do not make sensational exaggerations. 6. Do not calumniate. 7. Do not use a double tongue. 8. Do not be greedy. 9. Do not be angry. 10. Do not entertain crooked views.

The four benevolences which one has to remember are: 1. The father and the mother. 2. The ruler of the land. 3. "All beings." 4. The three treasures, i. e., the Buddha, the laws, and the priesthood (order).

It speaks of compassion and forbearance. It also speaks of eight correct ways: 1. Correct views. 2. Correct thoughts. 3. Correct words. 4. Correct conduct. 5. Correct living. 6. Correct ministration, meaning self-reflection and aspirations. 7. Correct conception. 8. Correct mediation. In their essense, however, all these teachings are mostly of negative character, and, moreover, I must say that they have more importance from a religious point of view than from an ordinary and a practical ethical point of view. Therefore I can say that Buddhism has very little to do with the ethics of Japan in the sense of a systematic exposition of them, though in an indirect way it has had some influence on the moral atmosphere of the Japanese, as I shall show later on.

The Chinese teaching, otherwise called Confucianism, is a system of moral teaching founded upon a patriarchal system of community. It does not, therefore, only speak of the good conduct of an individual as relating to his fellowship with other individuals, but also from the point of view of the whole system of community as a state. Therefore it speaks of modes of governing and of being governed, as well as of individual relationship between man and man. It does not recognize any difference between sovereignty and ruler, nor does it notice a difference between state and country. In it the greatest natural bonds of humanity are five, and they are: (1) Sovereign and subjects; (2) father (implying also mother) and child; (3) husband and wife; (4) brothers (implying also sisters); (5) friends. To each of these relationships the essential duty which is to be borne in

mind by each individual is separately attributed, and to each of these duties a special term is given to designate its actions from the point of view of a virtuous nature. Besides these five relationships there are two other relationships which have to be added, namely, the relationship between the elder and the younger, not necessarily meaning brothers, and also the relationship between master and pupil. The term "the sovereign and subjects," in oriental notions, signifies in their bearing a very deep meaning in their mutual relationship. I once heard from a very trustworthy authority that a Western diplomatist, well versed in oriental affairs, had said that the oriental idea concerning sovereign and subjects was not and could not be thoroughly understood by Occidentals, and I think that remark is not far from the truth.

The idea of the best virtue that a sovereign can have is "jen," meaning to be as humane as possible to his subjects, detesting oppression, giving the best administration to his country—in a word, to be the best ruler that ever ruled a land. The idea of the best subject is loyalty. The idea of that of father and son is filial piety on the part of the child and strictness on the part of the father, which is modified in the case of the mother toward tenderness, for which there is a special term. The idea which governs the relationship between man and wife is harmony. The older word for this was "distinction," meaning "not to be unseemly," but the word "harmony" is also used sometimes, and we Japanese prefer it. The idea of that of brothers and sisters is brotherly friendship, for which also a special word exists. The idea of that of friends is trustworthiness. In this way all the five cardinal bonds are dictated by desirable manifestations of sympathetic attentions to one another. But of course more prominence is given to the virtue of a subject, a child, or younger brother, in the case of a sovereign and subjects, of parents and children, and of brothers, respectively. Then, again, the elder and the younger in general are expected to respect each other as the case demands, and the relationship between them is to be regulated by a term which is equivalent to the English word "order;" that is to say, the younger should not seek to supersede the elder, but to pay respect to him, while the elder is expected not to take advantage of the younger, but to treat him with kindness. The relationship between master and pupil is also regarded as very important. The pupils are expected to respect their masters almost as much as their parents, while the master is expected to treat his pupils with parental kindness; no businesslike thought is to enter their minds. In the olden times in the East the system of teaching and learning was very different from that which exists in these modern days. The teacher taught his pupils out of the love of imparting his knowledge and virtuous example, as well as the doctrinal principles he entertained, while the

pupils were supposed to gather around him out of their admiration for the personality of their master and for the purpose of receiving his instructions and influence for their personal improvement and future usefulness. Such being the case, it was no wonder that the relationship between a master and his pupil was regarded with so much importance in ethics.

Apart from these classifications the virtuous attributes of man are spoken of in several other ways. We have first of all "wisdom, humanity, and courage." These three are considered to be the three greatest traits of character to be embodied in one person. Wisdom may not exactly fall under the category of a virtue in its strictest sense, but I suppose we need not be very critical on this point. In this instance humanity—that is, "jen" in the Chinese original—may be interpreted as comprising every other virtue besides mere mercifulness. There is another catalogue, viz. "humanity, justice, decorum, wisdom, and faithfulness." These five are considered essential elements of virtue for regulating a community, and should be observed by each member of it. There is another—"filial piety, brotherly friendship, loyalty, and faithfulness;" these give guidance to a man in his capacity of a son, a brother, a subject, and a friend. There is yet another—"sympatheticability, goodness, respectfulness, self-restraint, and modesty." These are virtues considered important as regards one's self-control. As to the women, "quietness, modesty, and purity" are considered the ideal traits of their character, besides all those which I have just described above, which are of course applicable to women to an extent almost equal to men.

In the West the term love plays an extensive part in governing all the mutual relationships of the kinds enumerated above. The essence of oriental ideas does not differ from it in its purport, but expressed in words the word love does not play so extensive and imperative a part as it does in the West, because in the Confucian doctrine different technical terms are used, as we have already seen, to meet each particular case. The word love is used very sparingly in the Confucian books, and it is used more especially for designating one kind of virtue, as, for example, "extensive love," meaning philanthropy in the western sense. The word "jen," which ordinarily may be translated as humanity, more resembles the western word love, because that word "jen" may be interpreted in many ways suitable to the occasion on which it is used, almost in the same way, and in a similar sense, that the word love can be used. But the meaning of that word "jen" is more comprehensive and deeper because it implies some other meaning than mere attachment. I will not worry you by going into full details of the interpretation of that word, as it is too technical. There is, however, one thing worth noticing about the word love in Chinese. When that word is singled out it is also applicable

to many cases, including the relationships above enumerated. Thus it can be used in a very comprehensive manner, and thence there arises a question about the essence of the word. The question is whether the notion of love is absolute, and consequently has no gradation or differentiation in its nature. At the time of Mencius, some time after Confucius, there was a school of philosophers who maintained that there ought not be any differentiation, but Mencius maintained that that was a fallacy. The word may be the same, but the practice may be differentiated according to the circumstances. The meaning is that one should love a nearer object more than a distant one, and thus the ethical notion of cosmopolitanism was reconciled with other notions of different virtues—in other words, if one does good to his neighbor more than to a stranger, or if one does more good to his country than to other lands, out of the feeling of love, it is quite justifiable from an ethical point of view, and thus Chinese ethics are made reconcilable with the principles of state. And this is, I think, an important landmark in which Confucianism differs from the features of an ordinary religion, which in its essence is, as a rule, founded upon cosmopolitanism, and knows not an artificial boundary of states.

There is a Chinese maxim which says, "No loyal subject serves two masters, and no virtuous woman sees two men." The cardinal points of the Chinese ethics are loyalty and filial piety; so that, although all sorts of virtues are inculcated, greater importance is placed on these two points. In China, learning means studying moral teaching. There are, of course, many subjects for study, but moral notions pervade every branch of literature. It is so, even with history, Chinese histories, as a rule, record only events as they occur; they have no historical or political observations, and any observations made by the writers are written in such a way as to draw attention from a moral standpoint. Their histories, therefore, have very little value in the ordinary sense of history as the term is employed among Western nations, but the fact remains that they pay much attention to moral lessons. Their expositions of moral teaching are done more in the way of philosophical or scholastic dissertations. The ethics of China, however, were not necessarily identical throughout the long period of her history, extending over several tens of centuries. There were several schools of philosophers besides Confucius, some of whom even went so far as to differ from him in many points; and also the interpretations of Confucianism differed at different epochs. But the chief feature of his teaching has always remained the same, and all that I have said about it above represents fairly the idea of Confucian doctrine. It is natural that Confucianism should be regarded as a sort of religion, because its followers respect it almost as a believer in religion respects his creed; moreover, Confucianism

recognizes in a measure the existence of some supreme power. It speaks of heaven in the sense of a power; it speaks of the "order of heaven;" it even speaks of the "supreme emperor," meaning the Supreme Being. It also recognizes the immortality of the soul, though in a vague manner, and pays great attention to festivals given in honor of one's ancestors; to use a common phrase, it worships the ancestors. But the parts of Confucianism which relate to the future of man only form a subordinate element of it, so much so that Confucius himself once said, "I do not yet know the living, how can I know the dead?" At all events I, in common with most Orientals, do not regard Confucianism as a religion in its ordinary sense. There are of course many customs and matters of etiquette sanctioned by Confucianism, or rather enforced by it, which are absurd or impracticable in the eyes of the Japanese, but there is no necessity for me to dwell upon these shortcomings here.

Let us now see what is Shintoism. It is essentially indigenous to the soil of Japan. It may be regarded as religion, and yet if it be a religion it is certainly of a unique kind, having nevertheless much similarity to the ancient cults of the Greeks and the Romans. It has no founder, nor has it any dogmas, in the ordinary sense of a religion. It has grown up with the customs and traditions and general characteristics of the nation. It recognizes the immortality of the soul; it acknowledges the existence of supernatural powers; it reverences the ancestral spirits, and therefore it may be called a religion of ancestral worship. In that respect it resembles Confucianism. It concerns itself, however, with temporal affairs far more than with spiritual affairs. In this respect also it very largely resembles Confucianism. It has existed in Japan from time immemorial, long before the introduction of Confucianism and Buddhism.

From an ethical point of view it has more teaching in it than Buddhism, but it is not so elaborate as Confucianism. Nevertheless it has a tight grasp of the Japanese mind. It is supremely content with its simple tenets, so much so that a well-known scholar, who was a devout supporter of it, when speaking of its ethical teaching in comparison with Confucianism, once said that "We do not want so many nomenclatures as Confucianism requires to signify all sorts of virtues and good conduct, and our simple teaching is quite enough to cover all."

Shintoism is also based upon a patriarchal form of community. Its essential notion of ethics is cleanliness of conscience; but the idea of cleanliness is applied not only mentally, but also physically—hence its tendency to bodily cleanliness as well as other cognate matters. It speaks of good and bad; it designates bad minds as "black" or "muddy," and good minds as "red" or "clear." Its ideals of conduct are honesty and straightforwardness. It reverences its

ruler from the very nature of its cult, and a magnificent ideal of a subject and a citizen is developed from these simple notions.

Such are, then, the three great sources of Japanese ethics. It is like the foam produced by currents of water. The water is the source, but when foam is produced it differs from actual water. So Japanese ethics are produced by the intermingled notions of these agencies, but they are no longer of the same substance as their source. I mean to say that our ethics have formed their shape quite independently of the orthodox or dogmatic parts of any religion, and people regard them as such in the same way as one would ordinarily regard foam as differing from water. I will now explain how this has been brought about. From about the sixth century of the Christian era Chinese study was introduced into Japan, and almost simultaneously Buddhism was also introduced to our country. The study of Chinese, as I said before, means the study of Chinese ethics, and I may say that Chinese has become almost like our own literature, though we had our vernacular literature coexisting. The study of Chinese, therefore, meant the introduction of Chinese ethical notions, in the same way as the study of Greek or Latin introduced Greek or Roman notions into European countries. This, however, did not mean that it supplanted our own ideas of morality, but it rather supplemented and augmented our notions in so far as it concerned the nomenclature and classification of different ethical virtues. We did not mean to make ourselves slaves to Chinese notions, we rather utilized Confucianism; and therefore Confucianism, as interpreted in Japan, is not the same as Confucianism in China. There is a story told of a Japanese professor, who was a deeply read Chinese scholar, and his pupils. The master once asked his pupils: "Suppose China invaded Japan with an army led by Confucius himself as the generalissimo, and assisted by Mencius as his lieutenant; what would you do?" The pupils replied: "It would be our bounden duty to take up arms unhesitatingly for our country and beat and crush them to pieces." Thereupon the master smiled and expressed his glad assent. This will show how we interpret Chinese teaching.

Then also Buddhism, poor as it is in ethics, has contributed something toward forming our national character, in that it has indirectly assisted in inculcating gentleness and also kindliness to living beings. I may go a step further. Buddhism itself, as interpreted in Japan, is not the same Buddhism as it was originally. It had to accommodate itself to the requirements of the country. Then, also, Buddhism in China and Japan is studied in books which are translated into Chinese, and therefore the priests who study their own religion have also to study Chinese, which, I repeat, involves the study of Confucianism, and therefore they are familiar with that teaching. The Japanese priests, therefore, made use of Shintoism

and Confucianism in their own teaching on any points where they found their own teaching was deficient—that is to say, they did so in practical and moral teaching. And not only that, we notice even the dictum of Buddhism itself is sometimes modified to suit such purposes. I mentioned above four benevolences spoken of in Buddhism as being "the father and the mother," "the ruler of the land," "all being," and "the three treasures." I do not know whether this is to be found in the Sanscrit original; I think it is not. It sounds more like a Chinese Buddhistic notion. It is still further modified in an old Japanese book as "heaven and earth," "the ruler of the land," "the father and the mother," and "all beings." And thus for "the three treasures" is substituted "heaven and earth." This occurs in a passage which is put into the mouth of a famous Shigemori in a discourse which he made when he severely admonished his father, Taira-no Kiyomori, though with filial tenderness, when the latter had behaved badly toward his sovereign the Emperor. The passage is to be found in a famous book written in the middle of the fourteenth century by Kitabatake Chikafusa, who was a court noble, a royalist, and a man with much knowledge of Buddhism.

Here I have to speak of Bushido. The term, as well as its general purport, has been of late made widely known in this country; but, as many people wish it, I will say something about it, although it may be only, as we say, "adding legs to the picture of a serpent"—I mean it may be quite an unnecessary addition. Bushi literally means a military gentleman or, in more common English, a military man, and "do" literally means a road or way, and in its extended significance, a principle, a teaching, or a doctrine. The term for "bushi" in old refined Japanese is "mononofu" and the term for "do" is "michi;" therefore the more refined ancient Japanese name for Bushido was Mononofu-no-Michi. The origin of the "bushi" is as follows: They were originally large or small landlords of the provincial parts of Japan, and had their retainers or vassals. At the time when, in the court of the Empire, over refinement, or rather effeminacy, succeeded enlightenment, and nobles who usually resided in the capital came to despise military service, those landlords and their retainers began to play military rôles under different distinguished leaders. They were more prominent in the eastern parts of the country, called Kwanto, namely, the large plain, in the middle of which modern Tokyo, is situated. With the march of events, when the governing power fell into the hands of the military leaders, these landlords and their retainers began to form an hereditary class, and the system extended to the whole country. This is the origin of Daimio and Samurai. I do not say that in the case of later developments of this system all Daimio and Samurai necessarily belonged to the same ancient stock,

because at the time when the country went through many stages of war many new men appeared on the scene and enlisted themselves in the ranks of the Samurai, among them the bushi, several of whom became Daimios themselves by their personal valor and the distinction they attained. But I may say that, on the whole, the successive stages of the class always inherited and handed down the same sort of sentiments and notions as their predecessors.

We may, in a measure, compare this military class with the country squires in this country, who gradually became barons of the middle ages, together with their children and retainers. "Bushido" is no other than the doctrine held and cherished by that class as its code of honor and rule of discipline. In the earliest days of the development of that class individuals forming it were not cultured or enlightened in the sense of luxurious refinement; in other words, they were mostly illiterate. But, on the other hand, they were mostly men with healthy notions of manliness in contrast to those who usually lived in the capital town where literary and artistic culture under Chinese influence had been attained in a marked degree. The motive and sense of their culture were therefore more like those belonging to primitive Japan, unstained by foreign influences. The families belonging to this class were called in their early days "the houses of the bow and arrow." Needless to say that the early projectile weapons of warfare were the bow and arrow, and they had a place of honor among the warlike instruments of those days. Little by little a phrase "yumi-ya-no-michi," literally meaning "the ways of the bow and arrow," came into existence, and it was the original name of Bushido. At first, perhaps, the word referred more especially to the proper use of the instrument of war, but it soon came to signify something more. There were many ceremonies and etiquettes which grew up with a warrior's life and military affairs, not only with reference to his comrades or to his superiors and inferiors, but also with reference to how he should comport himself toward his enemy. At the bottom of all these matters there lay the idea of honor, not merely one's own honor, but also a compassionate regard for the honor of the enemy. All these ideas came to be implied in the term "the ways of the bow and arrow." Here we see that special moral sentiments were being awakened among this class. Bushido, however, has no particular dogma or canon, except such as grew from practice and except those of which we can gather some idea from instructions given by certain leaders or by certain teachers of military ceremonies or science in the way of interpretation of such matters. Here we have an instruction given to his men by Yoritomo, the first shogun, and therefore one of the early leaders of the system. The essential points of the instructions are these: 1. Practice and mature

military arts. 2. Be not guilty of any base or rude conduct. 3. Be not cowardly or effeminate in behavior. 4. Be simple and frugal. 5. The master and servants should mutually respect their indebtedness. 6. Keep a promise. 7. Share a common fate by mutual bondage in defiance of death or life.

We may say that notions such as these were the foundations of the ethical parts of Bushido. These will mean when interpreted in ethical terms of the Chinese school: 1. Diligence in one's profession. 2. Love and loyalty between master and servants. 3. Decorum and propriety. 4. Gallantry and bravery. 5. Trustfulness and justice. 6. Simplicity and frugality. 7. Contempt of meanness.

At the bottom of these lay the sense of honor. When speaking of any action as unworthy of a bushi, the following phrase was customarily used in early days, "It is disgraceful in the presence of the hand of the bow and arrow," as in later days one would say "a disgrace to bushi," in the same way as you would say in English, "It is unbecoming to a gentleman." The term "bushi" has in many ways a similar meaning to "gentleman" in English. Bushido, of course, encouraged bravery above all things. In an old book describing the war between Gen and Hei, an account of the bravery of bushi of Kwanto—namely, the plain above referred to as that where Bushido originated—is put into the mouth of a general of Hei as having been addressed to his generalissimo, who commanded the army of Hei, which was formed of recruits coming from Kioto and its neighborhood. The narrative was to this effect: "According to the usage of the warriors of the East, the son would not withdraw from the battlefield, though his father might die, or the father would not think of retiring though his son might fall. He would advance and advance, and jumping over the dead, would fight regardless of death or life. As to our own men, they are all weakly recruits from the neighborhood of the capital (where effeminacy reigned at the time). If the father were wounded, the son and all the members of the family would take advantage of this and retire; if the master were killed, his followers would utilize the chance and, hand in hand with their brothers, would withdraw and disappear." This may be a somewhat exaggerated account, but it will show how greatly the original bushi estimated bravery in the same way as our men do in these days.

In addition to these characteristics some other features which were brought into more prominence are entitled to be singled out—namely, fortitude, generosity, imperturbability in the presence of danger or on any unexpected occurrence, compassionateness, and straightforwardness. This kind of attitude was inculcated even in physical exercises of different modes of fighting, such as fencing, practice

with the spear, and jujitsu. There is a verse composed by a Japanese which may be translated thus:

> Even in the eyes of the warrior
> Whose beard is ten fists long,
> The one thing that softly flows from them
> Is the tear which is due to love.

This aptly expresses the innate tenderness of heart of a Japanese warrior. There is another verse composed and penned by Commander Takeo Hirose in Chinese just before he went to his doom on the occasion of the second bottling up of Port Arthur, and which, therefore, constituted his last utterance in this world. Translated into English it runs as follows:

> Would that I could be born seven times
> And sacrifice my life for my country:
> Resolved to die, my mind is firm,
> And again expecting to win success,
> Smiling I go on board.

This will show the fortitude and determination of a bushi at the hour of his exit from this life, and though Hirose was a man of our own day, he may be regarded as one of the best types of an old bushi.

Bushi is not foreign to Shintoism. As a matter of fact bushi generally respect Shinto deities, and, moreover, some military ceremonies were performed in the supposed presence of a Shinto god. Bushi openly invoke the god of war without any compunction, but bushi never have done so in a bigoted way. It was more in the way of reverence paid to a deity of their inherited cult. They were never devotees of Shintoism as a religion. This sort of sentiment of the Japanese is very difficult to explain with clearness, but my meaning is that though they do not despise religion they place more importance on the affairs of the world and on their own exertions in the matters which they undertake. The Samurai do not worship their deity in order that their souls may be safely rescued in the future. I can therefore say that Bushido, as such, has no bearing upon Shintoism. It has its own independent existence, although to the extent I have just referred to it has its connection with Shintoism. In other words, Shintoism was a cult founded upon our old customs and traditions, and therefore Bushi also shared the sentiments pervading that cult, but we can not say that Shinto has produced Bushido.

And again, bushi do not despise Buddhism; on the contrary, many of them may revere it, but Bushido, as such, has no connection with this faith. In documents they often make use of a phrase in a vague way, "by the help of Shin-Butsu," meaning both the Shinto deity and Buddha; but it does not mean that it has any foundation in

Buddhism. If a bushi were a believer in Buddha he probably would not like to show it. We have a story about Yoritomo, the first head of the Shogunate. When he first started in his youth his campaign against Hei, and hid himself in a mountain nook, having been defeated by his enemy he took out from his queue a small image of Kwanin (Kwannon) which he reverenced, saying, "if my head be taken by the enemy it would not be becoming to the generalissimo of Gen if this image were to be discovered." This will give you an idea of the way in which Buddha was viewed by bushi. As we all know, Buddhism chiefly speaks of the future world. The idea of the bushi was that it was an act of cowardice if one merely did good because one wished to be saved in the future world. Their idea was that good should be done for its own sake, and therefore if one believed in Buddha he had a sort of apprehension that he might be considered a coward. Of course history is not wanting in many instances of great warriors believing in Buddhism, but in many cases this fact had no great significance as far as their conduct and conscience were concerned. There was, however, one feature in which a certain aspect of Buddhism had a considerable influence in molding Bushido; it was the influence of the teaching of the Zen sect. This requires some explanation. In the thesis of Buddhistic teaching there is included the idea of absorbing everything in the universe into oneself; in other words, mental annihilation of all things except oneself. This is done by long and fixed meditation, and at least so far as he himself is concerned, a man can for the moment imagine and realize mentally that he is the only being in the universe, and all other things become nothing. Hence, when he is accustomed to meditation of that description, nothing will ever surprise or frighten him.

There is a story about Hieuntsang, the famous Chinese Buddhist of the Tan period, who visited India. This priest was once caught by a band of robbers. He sat quietly down and began to meditate in the way described above. The robbers tried to intimidate him by threatening him with drawn swords pushed right into his face; but the priest took no notice whatever of what they were doing to him, and remained entirely unmoved. The robbers, observing the attitude of the priest, and thinking that he must be an extraordinary personage, all went away and left him alone. This phase of Buddhism was introduced into China, where it became the cult of one separate sect of Buddhism. Bodhi-Dharma, an Indian priest, who visited China, is commonly accepted as the founder of this sect, which practices meditation more than do other sects, but of course meditation is not its only feature. In general, we may say it is more philosophical in the sense of regarding the universe in a nihilistic sense. This sect is called Zen, and it has been introduced into Japan also. It was patronized by several eminent bushi in its earlier stages.

Perhaps it was liked by them in that, according to its doctrine, a man puts aside the idea of reliance upon another and places himself above everything else, and it was found to have an agreeable resemblance to the spirit of self-reliance inculcated by Bushido. In the second place it repels all ideas of luxury and display and values simplicity and cleanliness, and in that respect it was found to bear an agreeable resemblance to the frugal and simple life of the bushi. Thus the Zen came to exercise its influence over the bushi, but not at all in the sense of believing in future felicity; quite to the contrary, from the very nature of that sect. This influence of Zen seems to have helped to a great extent the development of some of the characteristics of Bushido, such as imperturbability, stoicism, fortitude, and simplicity and cleanliness of thought or body. Here I may add that many traits of Bushido are no doubt to be found in the European knighthoods of former days, and therefore they are not really new to the Europeans who still remember those traditions.

The weakest point of Bushido in its earlier stages was its want of literary culture in the way of systematic ethical study, hence it easily happened that a thing one might regard as correct might not be correct in reality when examined from a higher point of view. This difficulty was especially observable when two obligations came into conflict, and one had to be preferred to the other. The bushi, in the earlier stages, knew more about their duty to their immediate master than to higher ones; hence their difficulty in discerning their duty to the supreme ruler of the land and their immediate head. Of course, they knew that the Emperor was the highest personage in the country, but they were unable to find out an ethical solution of the question, and indeed in all matters they wanted more systematic enlightenment.

These wants, however, have been supplied gradually as time went on, especially during the last three centuries. During this period almost unbroken peace reigned in the country. It ceased to have any intercourse with foreign countries except in a limited sense, but internally all branches of art and industry were encouraged and developed side by side. The study of Chinese and of native classics have been carried out in all parts of the land, and it was the bushi who chiefly devoted themselves to such culture. Bushi or samurai were retainers, as everyone knows, of their lords, and certain pensions were given by their lords to each family, according to their rank, so that they had not to work for their own living. Hence their only duty was to make themselves physically and mentally fit to fight for their lords in time of necessity, and in times of peace to make themselves as much like gentlemen as possible. In other words physical training and mental enlightenment, together with the refinement of their manners and habits, were their sole business—they had no other occupation. For, indeed, any other occupation which partook of the shape of business

conducted for profit was forbidden and was despised among them. Bushido came to be deeply imbued with the principles of Chinese and Japanese classics as they were taught.

I have shown above that in the systematic exposition of ethical ideas, Confucianism was the richest of all, and the essential part of it was taken by Bushido; as I have also shown above, there are many defects in the Chinese teaching; all the unimportant parts were cast away and the important parts were taken into the teaching of Bushido, and even these parts only in such a way as to suit our national traditions and characteristics, the essential spirit of Shintoism also being resuscitated in such a way as to give an impetus to Bushido, though in no orthodox manner. Such then is our Bushido. The bushi formed the governing class of the Japanese society, and it may be said the educated class also, or in other words the bushi may be called the gentry of the country. We can, therefore, say that Bushido was the ethics of Japanese society. In one way it may be said that Bushido, as such, was a monopoly of the military class, but in truth its spirit was not confined to this only; the literary study of Chinese, as well as of native classics, was not necessarily limited to the military class; hence the same notions which were imbued in it through these studies were also quietly extending their influence among people at large—among whom, I may add, there were many families of old bushi, or families which were quite equal in their standing to the bushi class. Moreover, the spirit of Bushido has also been making its influence felt by other people. Thus we can see that the nation has been preparing itself for centuries for the promotion of moral ideas of the same kind as those of Bushido.

The cardinal points of oriental ethics, as may be expected, are loyalty and filial piety. In China filial piety takes precedence, but in Japan loyalty stands first. There is a poem by Sanetomo, the third shogun of Kamakura and second son of the first shogun, which may be translated literally as follows:

> The sea may dry up,
> The mountain may burst asunder,
> But no duplicity of thought
> Shall I have to my sovereign.

Such is the idea of loyalty which has been taught to the Japanese for centuries. Side by side with loyalty the idea of patriotism—a term which in Japanese is almost identical in its purport with loyalty—was also inculcated, though the development of this last idea was later than the former. Then, also, all the other ideas relating to ethics, especially on the lines indicated in Confucianism, were inculcated side by side. With the abolition of the feudal system, some thirty years ago, the structure of Japanese society was totally changed, or rather restored to the condition which preceded the

ascendency of the military class in the twelfth century. The question now arises, What is the actual state of ethics in Japan at present? There is a new element which has been introduced into Japan in recent years, and it is in the form of Christianity. The constitution guarantees freedom of conscience, and therefore there is no hindrance to the propagation of the Christian doctrine with its moral teaching, and, as a matter of fact, there are a number of Japanese who have embraced that faith, but they are after all a very small minority compared with the number of the whole Japanese population. The essence of Japanese ethics is the same as existed prior to the new epoch, with certain modifications actuated by the new force of the altered conditions, which, after all, are only in small details. I may say, in a word, that the Japanese ideal ethics form an extension of Bushido among the people at large from the nonextinct class of Bushi with whom it originated. As to how they stand at present and how they are inculcated among the people at the present time, I must refer my audience to an article entitled "Moral teaching of Japan," which was contributed by me to the February number of The Ninteenth Century and After. The sphere of the teaching is extensive, as is necessary from the very nature of the matter, but its essence may be summed up in a comparatively small compass. For this I can not do better than quote a part of the so-called "Imperial Educational Rescript" given to his people by the present Emperor. It is quoted in my article to which I have just referred, but I will recite it once more:

> It is our desire that you, our subjects, be filial to your parents and well disposed to your brothers and sisters. Let husband and wife dwell harmoniously together; let friends be mutually trustworthy. Impose upon yourselves self-restraint and rectitude of behavior. Extend to the multitude philanthropy. Advance learning and regulate your pursuits, developing the intellectual faculties and perfecting the virtuous and useful elements. Further seek to enhance the public good and enlighten the world by deeds of social benefit. Treasure always the fundamental constitution and respect the national laws. In any emergency exert yourselves in the public service and exhibit voluntarily your bravery in the cause of order. And by every means assist and promote the prosperity of the imperial régime, which is lasting as the heavens and the earth. Thus you will not only be our loyal subjects and good citizens, but will manifest the highest and best traditions of your ancestors.

Such, then, are the essential phases of the ethics of Japan. They may be far from reaching your lofty ideals and expectations, but we are contented with their general tendency, while at the same time we do not forget to inculcate the necessary furtherance and expansion of our ideas required by the changing circumstances of the time. We are likewise mindful of the desirability of carrying them out in such a way as not to conflict with the best ideals of any other country, for our sole aspiration is to preserve harmonious relations with the whole of mankind.

PLAGUE IN INDIA.[a]

By Charles Creighton, M. D.[b]

Eight years ago the subject of plague in India was brought before this society in a paper by Mr. Herbert Birdwood, which dealt with the first epidemic in Bombay city in 1896-97 (Journal, February 28, 189, vol. xlvi, p. 305). Mr. Birdwood's intimate account of the beginnings of the infection, of its rapid extension, and of the efforts made to cope with it will remain a document of importance, both by reason of the fresh impression of so novel an experience in an Indian city under British rule and also because it was the first chapter of what is likely to prove a long history. At the date of the paper a second plague season in Bombay had begun, which proved to be more disastrous than the first; the cities of Poona and Karachi were also infected severely, and there were many minor centers along the whole coast northward to Cutch, and in the transmontane districts of Satara and Sholapur to the south, as well as two small spots of plague more than a thousand miles away in the northwest—one around Hurdwar and the other in villages of the Jullundur doab. By that time the government of India was naturally alarmed at a threatened invasion of the whole country, and appointed, in August, 1898, a commission of five to conduct an investigation specially defined as of a scientific character, into origins and ways of spreading, as well as into the mode of treatment by serum inoculation and the mode of prevention by inoculating a solution of dead bacteria. That commission is now ancient history, so that I am at liberty to remark that there was not a single epidemiologist upon it, and that its "scientific character" was ruined by two causes—first, because the two medical members who wrote the report put aside such evidence as did not come within their bacteriological point of view, and, secondly, because the two departmental members were

[a] Reprinted by permission, with author's corrections, from Journal of the Society of Arts, London, Vol. LIII, No. 2743, Friday, June 16, 1905. Read before the Indian section of the Society of Arts on May 18, 1905.

[b] Author of a History of Epidemics in Britain.

disinclined to look into the errors of omissions of sanitation which had prepared the way for plague, especially in Bombay city. However, the witnesses contrived to say a good many things, proprio motu, which make the three volumes of evidence valuable and interesting reading.

PRESENT AREA.

When the commission began its work in November, 1898, the centers of infection were many and widely scattered, so that sittings to take evidence were held at places as far apart as Bangalore and Lahore in one direction, Calcutta and Karachi in the other. But the infected area was still comparatively small. There was no plague in the Madras Presidency, none in Bengal excepting at Calcutta, none in the United Provinces excepting over a small part of the district of Saharanpur, and none in the Punjab excepting in one small spot of the Jullundur doab. During the next six years the area has been extended enormously, but still within notable limits. The Madras Presidency has continued almost entirely free, and, what is more remarkable, also the whole of Orissa, Lower Bengal, and Assam. It is the northwestern plains that have become the chosen seat of plague, from the Jhelum River in the north to a point on the Ganges about 300 miles above Calcutta, while the original area in the Bombay Presidency has extended.

Those regions of India which have been proved by an experience of nine years to be the great seats of plague are shaded on the map. (Fig. 1.) They look somewhat compact and continuous in two divisions—one the plains of the northwest, the other the alluvial valleys of the Deccan and Gujarat. This does not profess to be an exhaustive map of plague. For example, there have been many deaths from first to last in the native States of Mysore, Hyderabad, Indore, and Rajputana, and in the British Central Provinces, but far more in the cities, such as Bangalore, Indore, and Jubbulpore, than in the villages. Also in Sind, Karachi was not the only place infected at first, although it remains almost the only place now. If I had shaded every one of those extensive and sparsely populated tracts of country where plague has ever been in those years, I should have produced a confusing, if not a misleading effect. Without being exhaustive, the blue coloring in the map on the wall shows fairly enough where the interest really lies, and it covers those parts of the Bombay Presidency and of the northwest to which I limited myself during a recent tour of three months, which was undertaken at the instance of the Leigh Browne trust.

SOME FIGURES.

I do not intend to be statistical, but a few round figures may be given to bear out this coloring of certain regions on the map. First, as to the dark area in the south of the Bombay Presidency. The three districts of Satara, Belgaum, and Dharwar, and the native State of Kolhapur have each returned an almost equal total of plague deaths during the last four years, viz, 120,000, being an average of 30,000 a

FIG. 1.—Map of India showing plague areas.

year for each in a population of about a million. The adjoining district of Bijapur had over 20,000 in each of the two last seasons, while Sholapur and Khandesh have each had one season of 25,000 in the more recent period. But in the Punjab those large annual totals have been exceeded in several districts. Sialkote had 50,000 deaths the season before last, Ludhiana almost the same number three years ago,

Gujranwala 30,000 last year, and 45,000 the year before, while the oldest centers of infection in the Punjab, the adjacent districts of Jullunder and Hoshiarpur have shown a steady increase for three years running, reaching last year to 30,000 plague deaths in the one and 25,000 in the other, with the promise of quite as many this season when the returns are completed. For a single week last year in the end of April or the beginning of May, which is the height of the plague season in the Punjab, four of the districts returned 4,000 each, while half a dozen more returned from 2,000 to 3,000. In the United Provinces until this year no district has come near to those enormous weekly maxima; but at length Muttra has reached 4,000 plague deaths in a week, while Ghazipur and Agra have each had a highest weekly total of about 1,600. In Behar the worst district has been Saran, the poorest and most crowded part of India, which has reached 2,000 a week, while two or three other districts of the same Patna division have had each over 1,000 a week at the height of the plague season. Last year the plague deaths in all India totaled over a million, of which nearly 400,000 came from the villages of the Punjab and 300,000 from the villages of the Bombay Presidency. Last year the worst week was that ending the 2d of April, with a total of 46,320 plague deaths. This year the week ending the 1st of April had a total of 57,702, the increase being more than accounted for by the unusual severity of the infection in certain districts of the Agra Province, and in the adjoining districts of the Delhi division of the Punjab, as well as by the extension of area eastward in Behar.

PLAGUE AN OLD AND WELL-UNDERSTOOD INFECTION.

To an epidemiologist this enormous prevalence of plague steadily from year to year among the rural population of India is perhaps the most remarkable phenomenon in his science. It is all the more remarkable that we have never thought of India as a great seat of plague in former times, such as Lower Egypt, Syria, and Irak had been during many centuries of Mohammedan rule, and that we were beginning to look upon plague as a thing of the past everywhere. In writing the article on "Quarantine" for the Encyclopædia Britannica twenty years ago I gave nearly all the space to yellow fever and cholera, remarking of plague that "for many years it has ceased to have any practical interest in this connection," although it had been the original object of all the quarantine laws of Europe. And to show that I was not singular the paragraph on port quarantine in the Bombay Sanitary Commissioner's Report for 1887 has this sentence: "Plague and yellow fever have never to my knowledge existed in Bombay, and are not in present circumstances ever likely to be there met with" (T. G. Hewlett, l. c., p. 82). The outbreak in Bom-

bay nine years ago was a surprise; but the greatest surprise of all, in a historical sense, has been the endemic settlement of the infection in the plains. This is, indeed, a real novelty of the present situation to epidemiologists, as well as a very serious practical matter; but for the rest plague is a very ancient disease, and, I take leave to say, very well known in its type and in its habits to those who are competent in such matters. There is just as little mystery about plague and just as much as there is about cholera, or yellow fever, or typhus, or enteric, and there is actually less mystery about it than about those everyday domestic incidents, measles and scarlatina. What, then, is the meaning of the claptrap about "our ignorance of plague?" So far as I can understand it has arisen from the fashion which the public and the newspapers have adopted of thinking bacterially about diseases. Bacteriologists, when asked to explain plague, are found to be not so lucid as usual. They are at fault in the pursuit of the bacillus outside the body. It runs to earth and gets lost in a crowd of other bacteria in the soil, or disguises itself as a saprophytic mold, or perishes outright in the struggle for existence, although there is no doubt about the infection remaining in the ground all the same. Hence, perhaps, the impression that more bacteriology is necessary before anything practical can be done.

RECENT SCIENTIFIC DEVELOPMENTS.

As plague is not found to be contagious from person to person except in its pneumonic variety, everyone sees that the interest must center in the infection outside the body. In that connection research in India has added only two novelties to the older body of doctrine, both of them of the minor kind. No one can deny, although some would if they could, that the regular way of receiving the infection of plague is by the breath; but inasmuch as rats in a laboratory can be made to take plague, or something like it, by inserting a culture of bacilli at a puncture of the skin, so it is sought to prove that there may be something corresponding in human experience. One theory started in India is that the infection may enter through wounds of the feet, as the people of that country so often uncover their feet ceremonially and so many of them go barefoot for want of shoes. This theory is of course inapplicable to European plague, for example, the great plague of London in 1665. But there is another theory devised to give moral support to the inoculation experiment on rats, which implicates the rat himself; it is that the fleas which infest the rat may introduce infection through flea bites on the human skin. The Austrian plague commission, which was the first in the field at Bombay in 1897, had already considered whether mosquitoes might

not carry plague infection, for example, in the plague hospital (where they abounded), from a patient to a nurse; but they found that it was not so, although everyone was bitten.

Various other insects were next thought of, and at length the interest has centered in fleas as possible carriers of infection from the rat. Researches of a very minute and technical kind were started by this hypothesis on the lines of the well-known microscopic researches on mosquitoes. Captain Liston has conducted, in India, a large amount of research upon the fleas which infest the rat. The question next arises whether those are the same species of fleas which produce the human flea-bites; then there is the question whether those who take plague had been bitten by fleas in matter of fact; and, lastly, the question of microbes in the fleas. All this is, no doubt, a very promising field of academic inquiry; and I am given to understand that the scientific expedition which has been announced with a flourish of trumpets as about to proceed to India "to make a thorough investigation into the causes and origin of plague" is really going out to work in the laboratory at Kasauli, with a view to settling all those open questions in the hypothesis of flea-bites.

PLAGUE LOCALITIES.

Just as in a well-known paper read before a certain scientific club, "the theory of tittlebats" was joined naturally to their habitat, the Hampstead Ponds, so I would wish to pass, with no abrupt transition, from the bacteriology of plague to the localities of it. Before I started on my recent expedition, I spent several months in getting up the gazetteers of the districts which I meant to visit, partly to become acquainted with a strange country and partly to note any facts as to population, poverty, kind of soil, height of ground water, canal irrigation, rainfall, or the like, which might throw light upon the incidence of plague upon some localities rather than on others. There was probably some reason why the villages of lower Bengal should have escaped plague absolutely, while those of Behar have had several bad seasons of it, or why the districts of Oudh should have had so much less plague than those of the Agra province, or why the Punjab districts of Hoshiarpur and Gurdaspur have each lost 80,000 by it, but the district of Kangra none, although it has an incessant traffic with them by the old and new Dharmsala roads. But the contrast which seemed, on paper, to be the best worth investigating was that between the Bombay coast districts of Kolaba and Ratnagiri, and the districts across the Ghats from Satara to Dharwar.

PLAGUE-FREE VILLAGES OF THE KONKAN.

Take for comparison the district of Ratnagiri and the adjoining district of Satara. The coast district might seem to be in some respects the more liable of the two; it has a denser population, there is a constant traffic of the people between it and Bombay City (which is said to contain 100,000 natives of Ratnagiri, working class and middle class), and it is as much an agricultural district as Satara, with about the same number of village communities and one-third more houses per square mile. Again, in matter of fact, plague has been introduced into the numerous small harbors along the coast dozens of times. But it has never taken hold of the villages, and has been so little indigenous in the coast places that the annual average of deaths for the whole district from first to last has been only 400, while that of Satara for the last four years has been nearly 30,000.

PLAGUE IN TWO ADJOINING DISTRICTS.

RATNAGIRI DISTRICT. Population..........1,105,000 Villages..................1,297 Persons per square mile 270		SATARA DISTRICT. Population ....1,225,000 Villages ....1,329 Persons per square mile 240
Year.	Plague deaths.	Plague deaths.
1896-7	305	128
1897-8	351	12,124
1898-9	246	8,646
1899-1900	276	7,953
1900-1	151	182
1901-2	379	34,583
1902-3	558	36,826
1903-4	733	16,169
1904-5	190	[a] 26,275

[a] To February.

Clearly there is something in the Ratnagiri villages unfavorable to plague, and something in the Satara villages peculiarly favorable to it. I have visited both, and shall give briefly what I believe to be the relevant points of difference. The Konkan is a rocky region. Looking down upon it in that magnificent view from one of the "points" of Mahableshwar, one might take it to be a great barren land of red rock, but after descending some miles by the zigzag mountain road, one comes to patches of cultivation and to scattered hamlets, and at the end of 25 miles to a large village surrounded by cultivated fields.

The map of the district shows that there are many such villages hidden in the foldings of the hills, and built usually along a stream. My notes relate to a village on the Savitri River, 9 miles from the

creek of the sea in which it ends. Everything is built of stone. There is an extensive ghât of dressed stone with steps down to a pool of the river. Facing the ghât is the village bazaar, the roadway paved with stone, the houses of one, two, or three stories with stone walls and tiled roofs, raised some 4 or 5 feet above the road on plinths of dressed stone, and sometimes with stone steps below the plinths; the houses of the bazaar in a continuous row with doors close together, but the rest of the village more dispersed along the main road and side roads, at one point forming a hamlet, while another part of the village is in scattered houses across the river. The ground-floor rooms are as dark as they usually are in India, with a fire burning on the floor at the far end. The cattle are usually in the house, or in a veranda, but sometimes in a shed of the small compound.

So far as concerned the want of light and air, and the keeping of cattle indoors, these Konkan village houses did not seem to be worse or better than elsewhere. Their masonry construction, their high plinths and paved roadways were proper to a region where stone is easily got and where the heavy monsoon rains—100 inches average in the year—make durable structure necessary. The other distinctive character of the Konkan villages is the more open order of their houses and small homesteads, which may extend a mile or more along one or both sides of a stream, some villages having only one long paved street with a row of houses on either side, like many of our own villages. This peculiarity of the Konkan villages can be seen everywhere upon the large scale maps of the Kolaba and Ratnagiri districts (fig. 2). On the scale of 1 inch to the mile it is possible to show the extent of the village site more accurately than by the conventional dot or small circle or ordinary maps. This lantern slide shows a bit of Ratnagiri district around the head of one of the numerous creeks which run up 20 miles from the sea. It will be observed that the small squares, or rhombs, or other geometrical figures, by which cartographers indicate homesteads or clusters of houses, are peppered all over the surface, so that the houses of one village along a stream almost join on to those of

FIG. 2.—Villages of Ratnagiri.

the village above or below it. Toward the southern end of the district the villages break up definitely into scattered hamlets.

What has been said of Ratnagiri is true equally of the State of Sawantwari adjoining it, which has had only 5 plague deaths several years ago, besides some 50 deaths among fugitives from neighboring plague districts. Also the Portuguese territory of Goa, with a far denser country population than any of the British districts to the east of the Ghats, but scattered in innumerable small clusters of houses or bamboo huts beside their gardens and fruit groves, is reported to have had no plague, although it is in constant communication with Bombay by sea and with Dharwar and Belgaum by hill roads and the railway.

PLAGUE-STRICKEN VILLAGES EAST OF THE GHATS.

Let us now leave this populous coast region, happily free from plague, or almost free, and cross the Ghats to the eastward. The easiest of the mountain roads is the one that ascends from the coast to the hill station of Mahableshwar and descends on the eastern side to the Southern Maratha Railway at Wathar, a distance of 70 miles. An hour or two below Mahableshwar one comes in sight of an altogether different kind of country and a different type of village from those west of the Ghats. First, there is the upper basin of the Krishna River, with gigantic precipitous sides of red rock and a perfectly flat bottom, shaped like one of those oval bath tubs that are in common use in India. This lies in the district of Satara and taluka of Wai, which was full of plague last cold weather, some of the plague villages being in sight on the flat plain below the carriage road. After passing through the plague-stricken town of Wai the road continues due east over characteristic Deccan country, which is shown in this lantern slide extracted from the survey map 1 inch to the mile (fig. 3). It will be seen that the villages are now large, compact squares at intervals of several miles on a flat ground absolutely bare of intermediate houses or hamlets. In this small piece of map are included villages whose names recur several years in the plague returns. I shall not give particulars of any of

FIG. 3.—Villages of Satara.

these Satara villages, as I have others from districts farther south. But the type is the same in all those black-soil valleys of the Deccan watered by the Krishna and its numerous affluents. What Sir Thomas More said of the towns of his mediæval Utopia may be said of them:

> Whoso knoweth one of them knoweth them all, they be all so like one to another, as far forth as the nature of the place permitteth.

They are all mud villages inclosed within a ring fence of bushes, sometimes with gates and remains of a wall. Many of them are large, with populations up to 4,000 or over, comparatively few of those that recur in the plague lists having their population, as given on the margin, under four figures. In the first season of plague among them, 1898, some villages lost more than a fourth part of their inhabitants in two or three months. Thus the village of Shelwadi, taluka of Navalgund, district of Dharwar, with a population of 4,222, had 1,126 plague deaths in eight weeks of October, November, and December. In the following table I have taken out the figures for a cluster of seven villages in the taluka of Hubli, to show the severity of their first plague season and the extent to which they have suffered in subsequent years:

Deaths from plague in seven villages near Hubli from 1898 to 1904.

Village.	Population in 1891.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	Total.
Byahatti	3,589	799	36	....	75	229	271	43	1,453
Ingalhalli	2,203	810	....	....	60	186	202	35	1,293
Bhandiwad	1,306	485	22	....	44	1	27	17	596
Kusugal	2,548	773	84	....	101	123	80	....	1,161
Unkal	3,915	349	98	....	342	261	126	....	1,176
Hebsur	2,713	270	....	....	....	334	155	....	759
Yarguppi	1,702	356	....	....	10	81	125	....	572

Two villages which I visited, one 12 miles from Belgaum, the other 7 miles from Dharwar, will serve as samples of the large villages in the black-soil basin of the Krishna, each of them having had five epidemics in the course of seven years.

A BELGAUM VILLAGE.

The Belgaum village was considered a rich one, the bulk of the cultivators being prosperous Lingayats. The population in 1891 had been 4,586, it had an area of 2,600 acres, and it was the cattle market for the extensive pastures on the hills and downs to the northwest. The 800 houses of the village covered 64 acres, about 600 of them occupied by Lingayats and other castes of Hindus, 200 by Mohammedan butchers and cattle dealers in a separate quarter. It was inclosed by a

ring of bushes, outside which was the invariable mudhole or so-called tank, with the Hindu burning ghât and the Mohammedan burial place on its high bank. The houses stood upon a series of slight elevations and declivities, in fairly wide streets or lanes; they were close together in rows, but there was no extreme congestion. They were nearly all built of mud upon earthen foundations, but some were raised a foot or two on stone plinths, and had a few courses of stone in their walls above the plinths; the stone being procurable from a quarry in a hill 3 miles distant. As it was the dry season, there was much dust everywhere, and a general look of sordidness unrelieved by a single amenity excepting an occasional carved doorway and two or three verandas. Some of the houses had been rebuilt within a few years, one last year on the old foundations. Some had considerable back yards, very ill kept, but most had no curtilage whatever. Yet in a perambulation of the village site one met with nothing strikingly offensive to sight or smell.

There had been 147 deaths from plague from August to October, but no new cases for six weeks, and the only evidence of the recent visitation was a number of padlocked doors. This outbreak was the fifth since 1898, and the slightest hitherto. I have compiled from the records the following table, showing the whole history of plague in this village:

Five outbreaks of plague in a village near Belgaum.

[Population, 4,586.]

Year.	Worst months.	Plague deaths.
1898..	June–August	375
1899..	August, September	741
1900..		
1901..	July, August	336
1902..	September, October	225
1903..		
1904..	August, September	147
	Total	1,824

The enormous loss of life in 1899—over 700—was felt in the census of 1901, which showed a great reduction from that of 1891, and the aggregate loss of two-fifths of the population in seven years must have left a good many houses empty. I examined only two of these, in which there had been deaths a few weeks before. They were both old and crumbling, built of sheer mud, without plinths, standing side to side on a slight declivity of the main street. Each consisted of a single square room, without window or back door, with an oil mill occupying the center of the worn earthen floor, the occupants of both having

been oilmen. The party wall between them was of mud, only 6 or 7 feet high, and crumbling at the top, so that the houses were open to each other across the whole pitch of the begrimed roof. Plague deaths had occurred in both, and in one of them five had died out of a family of six. There were several other padlocked doors on the opposite side of the street and at intervals in the rows of houses elsewhere. Most of the houses, I was told, had been visited in one or other of the five epidemics, those which escaped in one season being invaded in another, whilst some houses had had the infection in them time after time.

While the infection had crept about to all parts of this village site, it was the unanimous opinion that it always began in a certain quarter, the high ground on the northern side, next to the high road, which was the particular quarter of the Mohammedan butchers and cattle dealers. The Lingayat cultivators had a bitter grievance against their Mussulman neighbors, which they tried to interest me in, having mistaken me for a person of authority. Slaughtering of cattle, sheep, and goats, curing of meat for the Bombay market, dressing of hides, and the like, were the chief industries of that quarter of the village. There was no regular slaughterhouse, but each householder used his house or the space before or behind it for killing in, the flayed carcases and skins being in evidence as one walked past; and of course the whole soil of this elevated corner of the village was saturated with the blood and offal of many years and swarmed with rats, as shambles always do. A year or two before, the sanitary inspector from Belgaum, a native official of the third rank, had made a report upon the nuisance, recommending that the Mohammedans should be removed to a new site outside the village, which could have been found for them with the greatest ease not far off; but the commissioner had not moved in the matter, and the anger of the Lingayat farmers was unappeased.

A DHARWAR VILLAGE.

I shall take next a somewhat different sample of these villages, which also has had five epidemics of plague in the last seven years, but not so severe, and curiously enough always three or four months later in the season, as this table shows:

Five outbreaks of plague in a village near Dharwar.

[Population, 4,661.]

Year.	Worst month.	Plague deaths.
1898......	December	101
1899......	....	....
1900-1....	January, February	229
1901-2....	....	....
1902-3....	January, February	175
1903-4....	March	185
1904-5....	January	32
	Total	722

This village was a purely agricultural one, with no cattle trade, which is the common type on the rich black plain, or desh, extending eastward from Dharwar. The road all the way from the city passed through an unbroken expanse of wheat, jowar, and cotton, many of the wheat fields being of 20 acres. The area of the village in question was about 2,000 acres, but much of it was in the hands of a few large farmers. The patel of the village, a headman in stature as well as in name, farmed 100 acres, another resident farmed 200, and several who were resident in Dharwar City were also large owners and occupiers. About a fourth part of the villagers were laborers who held no land, many having lost it by mortgaging to the wealthier villagers or to pleaders in Dharwar, who had thus acquired their large farms. The village had once been defended by a wall and still retained two gates. Although it contained a number of well-to-do farmers, it did not contain a single pakka dwelling house. The houses were all of mud, many of them raised about a foot above the road on plinths of stone, which was got from a hill overlooking the village on the north. There was only one masonry structure—a variegated marble hall with open-top galleries for public meetings, which had been built recently by subscription. The streets or lanes were fairly wide, unpaved, and deep in dust. Few of the houses had verandas, and they were all equally common or mean. The usual ground plan was three rooms, one behind the other, with a back door opposite the street door, but without windows, the cattle being kept in the apartment next the street. All round the backs of the houses ran a space which was inclosed in places, traversed by not overclean footpaths and overgrown with bushes; but in the dry weather it was not notably filthy, and there appeared to be no particular need for what is called village sanitation; at least, one did not see where the sanitation was to begin, so long as the streets were unpaved, and the whole village, except the marble hall, built of mud. At the date of my visit in December the fifth epidemic of plague had only just begun, but it

appears from the subsequent printed returns that 14 died of plague in December and 18 in January, while a continuance until March was probable, according to precedent.

PLAGUE VILLAGES OF THE NORTHWEST.

Time will not allow me to describe in detail other plague villages, and I regret especially that I must pass over the much better type of village in Gujarat, in which the houses are mostly built of brick (but sometimes repaired with mud), raised on plinths, commodious, and not without traces of taste. Leaving the Bombay Presidency, and coming next to the northwest, which is now by far the worst seat of plague, the many thousands of villages which have had the infection in them are of a very uniform type. As one goes westward, the compact fort-like aggregate of mud walls and flat roofs becomes more distinctive, and throughout the whole of the Punjab that is the type. We have left behind the more open and irregular formation of the small Bengali village, with clumps of trees or bushes between the several homesteads, patches of kitchen garden among the trees, and creepers overrunning the verandas. High-pitched tiled roofs succeed, and after these thatched roofs with broad drooping eaves, until at length we come west of Allahabad to the naked mud walls and flat roofs of the northwest, without a single amenity that the eye can rest on, and in many cases without even a tree beside the village well. The interior of these villages is not unlike that which I have already described for districts of the south, but the houses are often huddled together, with narrow, winding lanes between the rows, and sometimes in compact blocks, back to back and side to side, with no intervals at all. I shall take an extreme instance from a large and wealthy village of Jullundur. Jullundur is one of the most fortunately situated districts of the Punjab, and its villagers are proverbially well satisfied with their lot in life. They have a soil renowned for its fertility, and they have water so easily reached by wells wherever they may sink them, that they can dispense with irrigation canals, and need not pay 2 or 3 rupees an acre for watering their crops. If they are poor, it is because the pressure of population is great, being, indeed, about 600 to the square mile, and the highest in the Punjab; but the signs of poverty, or at all events of distress, are not at all obvious to the passer-by, and the people are of good physique. The district was the first in the Punjab to be infected with plague, and in the last four years it has lost 100,000 by that cause; at the time of my visit, those who were dying were said to be robust men and women in the flower of their age.

A PLAGUE VILLAGE OF JULLUNDUR.

The particular village which I am about to describe had a past history of plague, but I am unable to give it, as the Punjab government does not tabulate and print its returns from villages, as the Bombay government has done from the beginning. Its population was about 3,000, and it had lost about 250 by plague in the months of March and April preceding (1904). The greater number of those deaths had come from a square block of houses (and from one or more like it) which had the most remarkable construction that I saw anywhere in India. It was literally a hive of some thirty or forty mud cells. A narrow passage ran around the square, with doors at intervals in the dead wall. Entering by a door near a corner of the square one came into a room, which somehow held a cow or bullock as well as the family, and had a hatch-like opening in the flat roof with a ladder to ascend by. On reaching the roof one found that it was a continuous expanse of thirty or forty small squares like those of a chessboard, marked off from each other only by ridges of mud, which one had to step across in walking a distance of some thirty or forty yards to descend by another ladder at the opposite corner. Each of the thirty or forty square roofs had a round hole in the middle, invariably covered by an earthenware cap like an inverted flowerpot. Close to this mud block, separated from it only by the 6-foot passage, was a group of ten or fifteen brick houses two and three stories high, with windows, balconies, and the usual features of the pakka houses of towns; this was the only masonry quarter of the village, holding about a twentieth of the population. I could not learn whether its residents had escaped altogether the infection which was so violent in the mud block next to it, but it was certain that most of the plague cases had been in the latter, or in another like it, some cells being pointed out in which as many as four persons had died. Most or all of the apartments were now retenanted, and there had been no sign of a revival of the infection down to the middle of January last. In another village, at the other end of Jullundur district, I mounted the roof of a block of houses in the Mohammedan quarter, thinking to find a continuous expanse like the former, but in that instance there were cattle pens and one or two alleys in the midst of it.

PLAGUE IN THE NEW VILLAGES OF THE CHENAB COLONY.

Having been told that the new regulation villages of the Chenab and Jhelum colonies had had plague in them equally with the old Punjab villages, which was not at all what one would have expected in recently occupied sites, I visited both colonies to see how the matter

really stood. I found from the printed figures of 1904 that the district of Jhang, which included fully three-fourths of the Chenab colony (now the Lyallpur district) had had 4,000 deaths from plague, nearly all in April and May, 1904, which was only a tithe of the rate of other Punjab districts equally populous, and that the southern tahsil of Gujranwala, which included the rest of the new Chenab villages, had had far less plague than the three other tahsils, where the villages were old. Still, there had been plague in the new villages, one of those which I visited having had 30 deaths in the month of December, 1903, with a prospect of more if the villagers had not cleared out into the jungle, and another near it, but built two years earlier, before the regulation plan was adopted, having had 60 deaths. There are more than 1,000 such new villages in the Chenab colony, which have been built within the last twelve or thirteen years. The colonists are in great part retired sepoys of the Sikh regiments, with their subadars, or native officers, as the lumbardars of villages. Sepoys received grants of 18 acres, some officers a square of 28 acres, others two such squares, paying a small land tax, as well as so much per acre for the use of the canal water for irrigating their fields. The land is now nearly all taken up, and is producing heavy crops of wheat, cotton, and sugar, the export of wheat from this district being one of the largest from India, as the railway traffic showed.

The regulation village which I visited, about 6 miles across country from the railway, was a great improvement in some respects upon the ordinary hugger-mugger of an old Punjabi village. It was laid out in regular squares with wide roads between. The compounds were roomy, with the dwelling houses kept apart from the cattle sheds. A certain elevation had been prescribed for all dwelling houses, perhaps 10 feet or more, just as our own local boards have raised the height of all new country cottages. But the public works department had left the colonists a free hand in the matter of building materials, and they had built their villages of sheer mud. In the village I am referring to there was not a single kiln-burnt brick, except in the facing of the village well, and, so far as I could see, there were not even sun-dried bricks in the walls of houses. The whole village was a hasty pudding of crude mud walls, some of which were already cracked. When I asked to see some house in which there had been plague, I was shown a closed door a few feet behind the chair of state in which I was seated at the crossroads of the village. It was a small corner house or shop, apparently a single room without a window, in which two cooks had died of plague. The mud wall was cracked in places and had one or two round holes in it which looked suspiciously like rat holes. All the new villages of the colony are built of mud, except those few which have the good fortune to be stations on the railway.

PLAGUE IN THE OLD VILLAGES OF SHAHPUR.

The other irrigation colony, between the Chenab and the Jhelum rivers, is now being planted throughout the jungle of Shahpur district, following the lines of the Jhelum Canal. Last year Shahpur had the enormous mortality of 33,000 from plague among 524,000 people, most of it in the time of the wheat harvest. I suppose that some small part of it occurred in the new villages, but if the instances which I saw were fair samples most of it must have come from old villages, of which there are many within the valley of the Jhelum, depending, as of old, on wells and on the rainfall for their harvests. The three villages which I saw at close quarters were within a few miles of each other, all raised conspicuously above the dead level of the plain on conical mounds of black earth. Their mud houses covered the sides and summit of these mounds, which were doubtless formed by the débris of former villages upon the same site, and may have been growing by accretions of rubbish ever since the time when Alexander overthrew Porus on a battlefield not many miles distant. They looked the filthiest and most dilapidated villages that I had seen anywhere, and were credibly said to be swarming with rats. Each of them had lost about a fourth part of the population by plague the year before.

Before I leave the villages, which have nine-tenths of all the practical interest for plague, I will give a few minutes to two questions about them. First, is there any real need or excuse for all this mud building? and, secondly, are the large, compact, fort-like villages necessary and likely to continue?

MUD WALLS.

First, as to the almost universal mud walls and roofs in the northwest. In the Punjab districts which suffer the extremes of heat and cold, the excuse is made that mud walls are the coolest in the hot weather and the warmest in the cold. But the more general explanation is undoubtedly the ease and small cost with which mud houses can be run up. On that point I may be permitted to quote a few sentences by the late Mr. Frederick Growse, who gave much attention to Indian architecture and did much to revive the native building arts in his collectorate of Bulandshar.

Replying to a circular of the year 1888 on the question of village sanitation, he wrote:

> Under such supervision an ordinary Indian village would in the course of a few years be less repulsive in appearance than it is at present, but I doubt whether the death returns would be materially reduced. * * * The real scourge of the country is fever. This is felt all the year round, and will con-

tinue to be so until the people adopt a more rational style of house building. At present the ordinary mode of procedure is to dig a pit, and with the clay extracted from it to raise a wall on its margin and roof it over for a habitation, the floor either remaining several feet below the surface of the ground outside or being partly filled up with the first rubbish that comes to hand. * * * In no country, however barbarous, is such a style of building in vogue. It has been adopted in these provinces on account of the tenacity of the ordinary clay soil, which thus lends itself readily to the purpose. But if in other countries, where poverty is as much felt as in India, building materials have invariably to be brought from a distance, the same necessity should be recognized here.

Again, referring to the district of Fatehpur, he says:

Thus for want of skilled labor the villages are all exceptionally mean-looking collections of mud hovels, and the towns which sprang up under the Oudh Nawabs are all in decay. * * * If the standard of living is low, it is more so from habit than from absolute lack of means; large sums are yearly expended on the only public works which a Hindoo ordinarly recognizes, namely, temples and bathing tanks.

The alluvium of the whole northwest makes a sufficiently tenacious clay, and the black soil of the Deccan valleys is even more sticky. The former can easily be burnt into bricks, while there is always red soil suited for brickmaking, or a stone quarry at no great distance from the black cotton soil. When I asked the lumbardar of one of the new villages in the Chenab colony, "Why do you not have pakka houses?" he answered, "We are very poor men." But, as Mr. Growse said, the poor standard of living is more from habit than absolute lack of means; other countries, where poverty is as much felt as in India (and more felt than in the Chenab colony), employ village masons and carpenters, and they have shown their progress in well-being first of all in the improved housing of the peasantry. This has been the recognized test in Ireland in the last fifty years, and in Scotland the great advance in the latter part of the eighteenth century was shown in nothing so much as the disappearance of such "auld clay biggins," as Burns was born in. Yet in India mud villages have entered on a new lease under the auspices of the public works department.

SANITARY ADVANTAGES OF HAMLETS.

As to the large, compact, fort-like villages which are peculiarly the seats of plague infection, it passes as an axiom in India that small villages and hamlets may be almost left to take care of themselves in a sanitary respect. The axiom is embodied in the Government Revenue Handbook, and it recurs time after time in the replies to two circulars on village sanitation issued in 1888 and 1893. What was thus obvious in times of cholera is not less obvious in the present time of plague. The advantages of hamlets are even more marked in the latter, for the Bheels of western Khandesh, who were among

the chief victims of cholera in the last famine, are said never to have plague in their rude hamlets or movable camps, although the infection has been disastrous in the settled villages of eastern Khandesh. The same escape from plague of small and movable hamlets was remarked by Colvill in his tour through the plague districts of Mesopotomia in 1874. The trouble always and everywhere has been from crowded sites too long inhabited without drainage. The more compact the site or the greater the congestion of houses upon it the more will the soil be filled with organic impurities. It is well known that soil has the property of breaking up organic matters by oxidation and nitrification; that it filters off and retains organic substances suspended or dissolved in water, arrests the action of ferments, and retains bacteria in its upper layers. But if the upper stratum be saturated with organic matters beyond the power of the soil to enter into combination with them, each new accretion sinks down more or less slowly to the deeper layers unchanged, there to undergo putrefaction or reduction by ferments, so that beyond a certain point the self-cleansing action of the soil breaks down. The limit of endurance is passed constantly in old inhabited sites, whereas in fields pastured by cattle or sheep or manured for cropping the wholesome chemistry of the soil goes on from season to season without check. That the infection of plague resides in the ground is now accepted by every practical man in India who has been on plague duty, and is perceived intuitively by the people themselves.

CENTERS OF PLAGUE IN OUDH.

Such being the correct scientific theory of plague, one may find in it one reason why those parts of India which have the rural population least congested in particular spots should have had little plague or none. I have given the instance of the Konkan somewhat fully and have a few remarks to make about Oudh. The Oudh landscape is always pleasing. There are other provinces, such as Gujarat, which may dispute with Oudh the title to be the Garden of India, but it is certainly the garden of the northwestern plains. It is the province of hamlets or small villages and of a resident nobility and gentry. Plague has not been absent from Oudh, for two or three of the districts in the south and east, along the Ganges, have had large mortalities. As the government of the United Provinces does not print full details of the villages infected with plague, one has to find out by personal inquiry, and I was advised to choose Fyzabad as a characteristic part of Oudh. In the week before, that district had returned 110 deaths from plague, and the question was, What kind of villages did these come from? One of the four tahsils of the district had to be taken as a sample, and the Fyzabad tahsil was the most

convenient. It appeared that a full half of all the plague deaths in it were being returned by one village, 10 miles from the city, which I went to see, accompanied by the tahsildar. It was a large market village of over 4,000 people and 700 houses, with very little agriculture (chiefly sugar cane) and much cattle trade, more than half the population being Mohammedans. The Sanitary Inspection Book, one of those ordered by Government circular of 1893 to be kept in large villages, contained at various dates severe strictures upon the squalid conditions, especially of 2 of its 9 mahallas, and remarks on the slaughtering of cattle by certain butchers in their houses, and on the common practice of killing sheep and goats in dwelling houses. There had been plague in it two years ago, and at the time of our visit one whole quarter of the village was evacuated, owing to dead rats having been found and to plague cases thereafter. This quarter consisted of the same two mahallas which had been censured as specially squalid long before plague appeared. There had been 65 deaths so far and two fresh cases that day. The other chief center of plague in the tahsil was also a large market village, with a population chiefly Mohammedan. A few other villages had been returning plague deaths, but none of them more than 10 in all, and it did not appear that any of the hamlets had plague. The largest purely agricultural village, with 1,600 people and 2,400 acres, of which fully half were cultivated, was distributed in 10 hamlets and had no plague. On an average the Oudh districts have had hardly more than a third as much plague per head of population as the districts of the Agra province, a ratio which is inversely as the number of hamlets and is most probably dependent thereon.

HAMLETS V. LARGE VILLAGES.

Are there any reasons why the more wholesome kind of country life which is found in Oudh should not be extended to other parts of the northwest? I quote a few sentences to show that the plan or type of large compact villages is neither ancient nor immovably fixed even now. In the Gazetteer, of Muzaffarnagar, it is stated:

> When Sikh, Rohilla, Gujar, and Marhatta together, or in turn, ravaged the district, no small community could exist, and the settlers fell back on the strong villages from which they had gone forth. After the final pacification in 1805, colonies were again sent out, but so gradually that the beginning of not a few flourishing villages is still remembered.

Again, as to the tendency to return to hamlets and their sanitary advantages, Mr. Adams, formerly collector of Benares, wrote in 1888:

> The sanitary commissioner has not, I think, taken note of the manner in which, in many parts of these provinces, the villages are splitting up. The villagers in old days clustered together for mutual protection, but now they find they can live close to their fields, and hamlets have sprung up all over the country.

But they are not springing up in the black soil valleys of the Deccan, nor in the Punjab, except in cases of feud between one part of a village and another: and it will appear from what I am about to read, from the pen of Mr. Alan Cadell, that there are reasons why the large villages should remain large:

The crowding of the population into large villages is to a certain extent disadvantageous, but the power which the large cultivating communities have acquired from their numbers and their wealth is of great service to them in resisting the encroachments of the landlords; and the people must feel that they would lose in unity and defensive power if they were scattered over several hamlets instead of being collected together in the old ancestral village. The fact, too, that nearly all the best land is held by occupancy-tenants, whose fields are situated all over two and even three estates, makes it still more unlikely that any large number of tenants will leave their present dwellings, for to do so would, while bringing them nearer some fields, take them away farther than before from others, and to effect changes of hereditary fields is always difficult and generally impossible.

PLAGUE IN THE CITIES.

The circumstances of Bombay are so special, if not unique, that it would take a whole hour to discuss them. Therefore I shall not begin upon them, however inviting the theme. Poona, infected from Bombay, has had severe plague every season for nine years, and more of it per head of population than Bombay itself; the sanitary problem is complex there also, and can not even be stated in a sentence or two. Karachi and Calcutta I did not visit. I will come to Benares, as a good sample of the northwestern cities.

BENARES.

The mahallas or wards into which Benares is divided fall into two classes—the pakka, or masonry mahals, and the kaccha, or mud mahals. The separation of the two is sharper, I believe, than in any other Indian city, and will be readily understood from the situation of the masonry mahals. They are that famous range of houses, temples, and terraces which crowns the high bank of the Ganges for a space of nearly 2 miles. Some 50,000 or 60,000 of the population are housed there, and twice as many more in the kaccha or mud-built suburbs which extend back from the riverside quarter over a radius of 2 or 3 miles. These kaccha mahals, however, are not all equally mean in construction; for example, the road, 3 miles long, which runs from near the cantonment to the railway bridge over the Ganges is lined on both sides all the way with houses or shops of brick raised on plinths. The pakka mahals along the river are built of stone which had been brought some 20 miles down the Ganges, from the extensive quarries near Mirzapur,

There are no carriage ways through this region, but only a maze of narrow alleys, with houses on either hand three or four stories high, and innumerable temples—a perfect rabbit warren, like the closes of the High street, Canongate, and Cowgate of Old Edinburgh. What strikes one most in the not unexciting passage through this maze is the solidity and durability of the structure everywhere. The walls are of stone, the courtyards and floors are paved with stone, the alleys are laid crosswise with long slabs of stone, which form at the same time the roofs of a network of sewers. In this dense mass of humanity, constantly mixing with pilgrims from all parts of India, there has been hardly any plague. I make this statement on the authority of the police inspector who accompanied me, as well as of the collector, Mr. Radice, who wrote as follows: "In the five years we have had plague (this is the fifth) the pakka mahals have been almost entirely free;" and in the sketch plan showing the incidence of the infection on the several quarters of the city, which he was good enough to make for me, he has marked only one small spot in the riverside quarter, the Gaighat, which had some plague in 1903. On the other hand, the mud-built suburbs and the villages to the west of the city have had much plague; for example, this year a maximum of nearly 400 deaths in a week in March. In driving through them one could tell at a glance where the plague was likely to have been; thus, on the way from the cantonment to the city, a certain dip in the read is lined on both sides with mud houses of exceptionally mean appearance, which is found, on reference to the plan, to be the Tiliabagh, marked as having had plague "every year."

CITIES OF THE NORTHWEST.

In all the other cities of the northwest, which have had much plague, there are extensive quarters of mud-built houses—in Allahabad, Cawnpore, Agra, Lucknow, Bareilly. In Lucknow, beautified as it is with palaces and fine houses, the relative extent of the kaccha mahals seemed to be enormous, and the mud walls of so dusty and friable a kind that the heavy rain of December had been breaking them down. Lucknow this year has had up to 480 plague deaths in a week, a ratio higher than Bombay. I shall give a single illustration of plague in Agra. One of the patients in the plague hospital, a convalescent, was a little girl, the sole survivor of a plague-stricken family of nine. On proceeding with the assistant medical officer to see the house where this tragedy had happened, we found it to be a dilapidated and abandoned mud hut, one of a compact group of three standing at the roadside on the edge of a small pit, from which the earth to build them had doubtless been dug.

The three large cities of the Punjab—Delhi, Amritsar, and Lahore—have had remarkably little plague. Delhi, which is situated in a stony region, appeared to be nearly all pakka built, with the exception of a few lanes around a celebrated black mosque of the fourteenth century; and even the villages round Delhi are built of a kind of conglomerate of stone and clay. Amritsar also is a well-built brick city, and in Lahore there are no such extensive quarters of mud-built houses as in Allahabad and Lucknow. The smaller towns and market villages have in some instances furnished a large part of all the plague deaths credited to a rural area. I was told by the civil surgeon at Ghazipur that the largest totals in his district this year were coming in from certain towns or market centers which had a considerable Mohammedan population; and in the district of Muttra I saw for myself two such market towns with much plague in them, one of them, population of 9,000, having had 400 deaths in the four weeks preceding, and a maximum of 25 the day before; while the other, with a population of 6,000, had 19 new cases reported that morning. It is the melancholy fate of those old country towns of the Mohammedan period, originally well built, with brick houses and paved streets, and in some cases with fine sarais or forts, to have fallen into decay of trade and dilapidation of buildings, the houses often "pakka without, but kaccha within," as explained to me of an old two-storied brick house at a village near Benares, in which the rats had been found dead, and, two or three weeks after, the whole of the inmates, to the number of 18, had died.

MEANS OF AVOIDING PLAGUE—EVACUATION.

According to everyone's belief and experience in India, there is only one thing to be done when plague appears in a place, or the rats begin to fall, namely, to clear out, or, at all events, to avoid spending the night there. Hence the strange spectacle every evening about sunset, in the city of Bijapur, of the whole population, save the inmates of half a dozen bungalows, to the number of some 20,000, quitting the bazaars, workshops, and offices, and making their way outside the walls to a large camp on the downs around the railway station. This phenomenon is the more suggestive at Bijapur, as the city was deserted once before, two hundred years ago, and most probably for the same reason as now, namely, plague, and continued to be in great part deserted until it was made the administrative headquarters of the district about thirty years ago. Also in the country round Bijapur the people have learned the lesson of evacuation very thoroughly. I went through an old fortified village of 3,000 people 5 miles to the west of it, without finding a living creature; the streets were deserted, and the doors of all the houses padlocked, the whole of the

inhabitants being in camp near their fields about a quarter of a mile away. They had taken alarm from the number of dead rats found, and the deaths of 36 persons in October, November, and December, and from the recollection of their first plague epidemic two years before, when 171 died in the village. At Bijapur City I was told by a high native official that, if the infection became active another year, the temporary camp round the railway station would become a permanent residential suburb, so that the area within the walls would be deserted for the second time in its history. This evacuation is at the people's own initiative and at their own expense, which many of them can ill afford. The same thing was going on at Belgaum, where several thousands went out to camp in the evening and returned to their work in the bazaars and offices in the morning.

At Dharwar a small beginning had been made toward permanent evacuation. The government had given a piece of vacant ground to the municipality, which had sold it by auction in lots at a very low price, and a new street of some forty houses, called Gibb street, after the collector, had been run up. At Poona 7,000 or more were in camp along the sides of suburban roads, or on the various maidans of the city. At Bombay there were three large health camps along the seaward side of the island as far north as Mahim. In a group of villages of the Baroda State near Naosari, the cultivators had built lofty and commodious huts near their wells and fields, to which they had removed their bedsteads, chests, and other furniture, and in which they and their children and their bullocks were not unhappy. The weather after the rains is so fine throughout the Bombay Presidency that there is no hardship whatever in camping out.

It is otherwise in the earlier part of the plague season of the northwest, of which I shall give a single instance from the Punjab. I went one day with the medical officer on plague duty to a group of villages 12 or 14 miles from Jullundur. At one of these, a small village of some 200 people, there had been many deaths from plague two years before, and on the day of our visit there were more persons lying sick or recovering in their houses than I had seen anywhere in so small a space except in the hospital at Bombay. After we had gone round the village, a palaver was held with about a dozen of the men and youths, who stood in a semicircle near the village well, the women drawing the water all the while. Their spokesman was a sturdy little Jat who knew his mind, spoke to the point, and bore himself with the aplomb of a man of affairs. They had been asked in advance to consider whether they would not submit to inoculation, and had decided so peremptorily in the negative that the matter was not so much as mentioned again. The only question discussed was evacuation. The spokesman pointed out various practical difficulties in the way of a general camping out, to which Cap-

tain Bradley replied, and at length it came to this, that the whole village might remove to a camp on a certain piece of waste ground within sight of where we stood if some help were forthcoming for the poorer villagers; it was all a question of expense, and as I was again mistaken for the commissioner, I was looked at in a significant way as we took our leave. But to show how many are the difficulties in the Punjab, next day a storm of wind and rain broke which lasted thirty-six hours and was followed by two or three weeks of intense cold. Camping out was of course impossible, and the effects of the cold snap were seen in the abrupt rise of the plague figures about a fortnight after from all parts of the Punjab and the United Provinces.

SCIENTIFIC THEORY OF EVACUATION.

Evacuation of plague-infected houses or village sites had been adopted by the people themselves, without any scientific advice, before the present plague; for example, by the hillmen in Kumaun, and by the Marwaris, who, as White reported in 1836, "instantly quitted a house on seeing a dead rat." The rats themselves, although in India they are the symbols of sagacity, are usually surprised by the underground venom, and are often seen trying to escape in a state of delirium. A scientific explanation of the common practice may be found, first, by including plague fully and frankly among the soil poisons, as I did in my History of Epidemics in Britain, fourteen years ago, and, secondly, by applying to it the laws of soil infection which have been worked out by Pettenkofer and his school. An infection of the soil makes itself felt most inside dwelling houses, and most of all overnight, because there is a natural movement of the ground air toward the walled space. This was shown by the fact that an escape of gas from a main in the street would travel horizontally through the pores of the ground toward the house opposite, and be sucked up into it, sometimes to the danger of the inmates. Von Fodor observed the stratum of air next the floor of an unoccupied cellar at Budapest day and night for a whole year, and found that it always contained more carbonic acid than the ground air outside, having attracted it from the soil around. In disused cellars, vaults, or covered wells, the accumulation of carbonic acid is sometimes so great as to asphyxiate those who enter them first. One reason for the ground air streaming to and rising through the basement or floor of a house is that the ground beneath is drier and more permeable, affording a free upward passage unless there be a concrete foundation or a masonry plinth or stone paving. Another reason is that the air inside a house is warmer and lighter, so that it yields to the pressure of colder and heavier air outside and is thrown into an ascending

current. The penetration of the house by ground air is a peculiar risk in India for several reasons. Where the walls are of mud, as they are in the great majority of plague villages, and have no masonry plinth to rest upon, their porous substance is really a part of the soil, so that the inmates have the ground air not only rising from the floor, but carried up in the walls as if in a ventilating shaft. A dwelling house warmed all day by the sun and by the fire kept up for cooking becomes like an exhausted receiver for the ground air to rise into. If one visits the old chawls at Bombay, in which there has been so much plague, you find the narrow, dark rooms on the ground floor to be heated like an oven even at 8 in the morning.

The intuitive perceptions of the people correspond with the scientific theory of a soil poison. They know that the chief risk of taking plague is from spending the night in an infected place, and generally that they incur the greatest risk when confined most to the dwelling houses by cold, domestic duties, or other cause. One very important thing I must pass over for want of time, namely, the injurious effect of a high level of the ground water and of its seasonal fluctuations in a filth-sodden soil. In the new chawls at Bombay, built by the improvement trust, nothing seemed to me to promise more for the future health than the solid masonry of the foundations, floors, and passages. The advantages of concrete foundations have been proved often in similar circumstances, although in Hongkong they have been only a palliative in plague.

PROBABLE FUTURE OF PLAGUE IN INDIA.

I come lastly to the question, Is there anything to be learned as to its probable duration from historical precedents and from its own course during nine years? One was sometimes asked whether the natural time for plague in India to last was not seven or eight years. The origin of the idea is what is recorded of two former plagues in India—one in the reign of the Emperor Jehangir, 1616, of which it is said that "it continued to devastate the country for eight years," the other in the reign of Aurungzeb, 1688, which "lasted seven or eight years." Each of these epidemics of bubonic plague is authenticated twice over by good contemporary authorities, along with some interesting particulars which I have no time to quote. The earlier of the two began in the Punjab at Lahore and "destroyed many villages and parganas;" the later, seventy years after, was felt most in October and November, 1688, in the city of Bijapur, which Aurungzeb had just captured and in which his army was encamped, including 15,000 cavalry; but it is said to have lasted seven or eight years and to have extended over the Deccan and as far as Ahmedabad and

Surat. The next outbreak in India fell to be described by three British writers. It happened in Cutch and Kathiawar from 1815 to 1821, in peculiar circumstances of aggravation within walled towns, arising out of famine and the mode of collecting the tribute from the recalcitrant petty chieftains of those territories by the army of the Gaekwar, and it came to an end almost coincidently with the new order of things in 1821. The only other epidemic before the present was also a limited one, in Marwar, especially in the town of Pali, which lasted from 1836 to 1839, and may have been a revival of plague which is said to have been indigenous in Marwar "from a remote period."

Turning from those Indian precedents to the much more continuous and extensive plagues of Europe, we find an uninterrupted history in one country or another and in one city or another for more than three hundred years—from the year 1347 to the latter half of the seventeenth century, when the infection disappeared almost simultaneously from all the countries of western Europe. The chief difference between the European plague period and the one which is now running its course in India is that the former did not involve the villages, but only the towns, except in its first great wave, from 1347 to 1350, which swamped country and town alike with an almost unheard-of mortality, and excepting, perhaps, two or three general but minor revivals at intervals in the latter half of the fourteenth century; for the rest, it continued an infection of the towns, and in these it commonly broke out at long intervals—twenty or forty years—excepting in such capitals as London, where it was seldom dormant for a series of years until it was about to cease altogether.

It is not surprising that plague in India should be chiefly an affair of the villages, because that has been also the experience with cholera. So much was that a village infection that Anglo-Indian writers who were at home when cholera reached this country in 1831 prophesied that it would fall most upon the enormously congested rural population of Ireland. But it spared the Irish villages and hamlets almost absolutely, although it attacked the Irish cities severely. European precedents being thus inapplicable to India as to villages, we are thrown back upon the lessons that may be learned from the history of plague in India itself during the last nine years. It is only from the Bombay Presidency that we have data minute enough to be of much use, from which it appears that the huge totals of plague deaths year after year are not so hopeless as they look. When they are analyzed—and it is no small labor to analyze them—it is found that the aggregate of each year has been made up by items from somewhat different places. The cities of Bombay, Poona, and Karachi have been steady, but in the mofussil all the districts have

not suffered severely in the same year, the tálukas within a given district have been affected some one year, some another, and the villages of a given táluka have been affected in a kind of rotation. I have shown on the screen the tables of nine villages, which on the whole agree in proving that each village has had one very severe outbreak, usually the first, that there have been years absolutely clear, and that the subsequent outbreaks have been much less extensive than the original one. It is in the very notion or definition of the word "epidemic" that there shall be intermissions; the word "endemic" means a more steady prevalence from year to year—but in that notion also the steadiness is only in the aggregate of a whole country or province, not in the several counties or parishes of it. It is probable that all the villages of Bombay Presidency by this time have had their worst experience of plague, and that in each village plague has visited all the houses in turn, or as many of them as it is ever likely to visit. The Bombay figures for the season just ended are encouraging. Whether it be owing to the resolute practice of evacuation on the first signs of plague or because the invasion is subsiding naturally, the returns since January have been only about one-third those of the three or four years preceding for the corresponding weeks. It looks as if the maximum had been reached and passed, both for each locality and in the aggregate of the whole Presidency, and that there is to be a pause. Such pauses occur in all epidemic infections. We account for them by a phrase or formula that the infection has exhausted all the "susceptible subjects," and we explain the return of the epidemic after an interval of years by the fact that a new generation has grown up which contains more "susceptible subjects."

What can be proved from the admirably full statistics of the Bombay Presidency may be perceived in a way in the Punjab. Thus, in Jullundur, in January this year, I learned that the average was being kept up to that of former years chiefly by returns from a certain group of villages in the southwest which were having plague in them for the first time. The province as a whole is to have more plague deaths this year than it has had hitherto; but it would certainly have shown a decrease but for the very large items of three districts in the Delhi division—Gurgaon, Rohtak, and Hissar—which are having their first severe epidemic. The prognosis for the Punjab should be that the infection has reached its height and done its worst for the time in the districts first attacked and that it will soon begin to show a decline in the aggregate, following in the wake of Bombay Presidency.

This is the first year in which the United Provinces and Behar have returned such large totals as we have been accustomed to for several

years in Bombay and the Punjab, and as one of them has a population nearly twice as great as these two latter together, it is unsafe to prophesy what heights plague may not reach in them before it begins to decline. In any case we may reckon with plague domesticated in the soil of tens of thousands of villages, making an endemic area larger than that of cholera was ever estimated to be, and from such an endemic area we may expect future outbreaks at intervals of years, if not from year to year. In England, for thirty or forty years after the great invasion of plague in 1348, a poet of the time compared the state of sickness to "the rain that raineth where we rest should" to the drip through a leaky roof, a chronic state of discomfort and uneasiness.

The three centuries of plague in European towns came to an end without any conscious effort to check the infection anywhere, so far as one knows. The most probable explanation is that the towns had emerged slowly from their mediæval life, which was peculiarly favorable to plague, having thrown down their walls and gates and gradually shifted the pressure of population to new sites, which, however, were often befouled by the accumulated refuse of the old walled city, and therefore apt to retain the infection many years longer. The curious statutes of 32 and 35, Henry VIII, on the decay of practically all the chief towns of England and Wales, bear out that hypothesis, according to the reading of their preamble adopted by Nicholls and Froude. At all events mediæval limits were outgrown in all the towns of Europe, and, after a transition period of a century or more, plague died out by reason of changed conditions.

India at the present day contains more traces of changed sites than any country in the world, and some of these changes have actually occurred under British rule. Sometimes the changes of site have been caused by a river deserting its old channel and leaving a city too far from the traffic, but there are undoubted instances of sites abandoned owing to chronic sickness. The British cantonments afford instances in the past and may afford more in the future. Dacca and Berhampore were both condemned, the latter in 1833 after an original outlay of £300,000; they were healthy stations at first and became sickly by degrees until they were untenable. What has been happening in India from time immemorial, both to town sites and to village sites through the pressure of events, may be anticipated by a deliberate policy in order to hasten the disappearance of plague. In some of the towns of the Deccan and Gujarat new suburbs are actually springing up for the richer class to avoid the infection. For the villages it is not out of the question that some law might be made to prevent rebuilding on the same foundation when the mud walls crumble, as they do periodically; but of such a law the essential condition would be the

helping hand of the State to provide new sites. At one time I held that a progressive change of the village site to a clean soil, along with the break-up of a larger village into several hamlets, would be an effectual if very slow means of getting rid of plague. But after seeing a good many of those dreadful mud villages I have come to think that it is their miserable structure that is the real reason why the Indian plains are cursed with plague, and that there can be no real cure without a more civilized kind of dwelling and a great revival of the native building arts as village industries.

THE FIGHT AGAINST YELLOW FEVER.[a]

By A. Dastre.

Once again yellow fever claims our attention. While we are celebrating the victorious effort of science in driving that dread disease from its hereditary domains in Habana and Rio Janeiro, it reappears and desolates New Orleans; it revives in Honduras and threatens Panama. Once more we must fight to renew the achievements of the Americans in Cuba and of the Brazilians in Rio. And that is possible, for we can struggle to-day with hope, with certainty of success. For centuries the disease remained unconquerable. Physicians knew only what everybody sees—the external signs—the symptoms and fatal results, but they were not familiar with the true nature of the disease and the manner of its propagation.

In fact, even to-day our knowledge of the nature of the evil is very elementary; we have few facts concerning the micro-organism of yellow fever. The only proven point is that it is a blood parasite, not feeding upon the red corpuscles like the parasite of malaria, but only upon the fluid part—the "plasma." It is believed that it does not affect the transparency of liquids, that it can penetrate most filters, and that it remains invisible to the microscope.

But if the deadly agent, the ultramicroscopic germ, which is the specific cause of the disease, is not well known, we are at least familiar with the means of its propagation, the sole agent of its transmission, and that is sufficient, as we shall see, rationally and effectually to eliminate contagion.

This definite agent, the only one capable of inoculating a man with the micro-organism of yellow fever, is a particular species of mosquito, the *Stegomyia fasciata*, known also as *Culex calopus* and previously called *Culex fasciata*. At the time of Linné, in 1758, only 6 species of mosquitoes were known. In 1902, 250 different species could be distinguished, and the number has since increased to nearly 400 described species. The English naturalist, F. V. Theobald, an authority on the subject, recognized 29 genera. To one of

[a] Translated from Revue des Deux Mondes, Paris, September 1, 1905.

these he gave the name *Stegomyia* (fly which hides), and in this new genus he established 22 species. It is one of these species, the *Stegomyia fasciata*, which to the exclusion of all others, transmits the yellow fever parasite from the sick to the healthy man. This Stegomyia, moreover, is the most cosmopolitan of all species of mosquitoes, and its wide distribution explains the continuous spread of this terrible malady since the discovery of America.

Before entering into the blood of a man the fever germ must have passed a period of incubation in the tissues of the mosquito, and vice versa. This is a fact of prime importance. The sickness of man implies the sickness of the mosquito, and inversely. The mosquito's illness, however, is light, scarcely perceptible, while that of man is severe. If ever the human race arrives at the point of being freed from the yellow-fever micro-organism, the *Stegomyia fasciata* will be freed at the same time. Thus there is a sort of pathological compact between man and the mosquito, a kind of unhealthy fellowship of which the existence of this infectious bacillus is the binding force. We may therefore believe that in order to eradicate this plague—that is, the parasitic microbe—this fellowship must be dissolved. The healthy man must be isolated from the infected mosquito and the healthy mosquito from the infected man. There would be no danger in the contact of a healthy man with a healthy mosquito. That is the theoretical idea. The practical sanitary scheme follows this formula: To drive out the mosquito, to kill it, or to make it well. Only by accomplishing separately one of these three aims, or all three at the same time, have the sanitary authorities been successful in making healthy the island of Cuba, the Brazilian coast, and more recently the territory of Dakar, in the French West African colony. Success has been attained in purging these regions of the disease which had existed there in an endemic state, and in stifling at the start epidemics threatened by imported infected cases. It is the same line of action that will have to be followed in every locality at each reappearance of the disease until humanity is entirely freed from it.

But to avoid the mosquito, or to find shelter from its bite, we must know its mode of life, its customs, its habits, its peculiarities, or, in a word, its complete life history. And that is just what we have learned from numerous researches by medical naturalists, among whom must be named the members of three commissions organized by the United States, English, and French Governments and sent to the infected localities to study on the spot the evil and its remedies. Mention must also be made of scholars from the Colonial Medical School of Liverpool and from the Institut Pasteur de Paris, who have directed these studies and summarized the results. Besides special memoirs, the perusal of which is incomparable to gain a knowledge of the subjects, several recent publications of a more gen-

eral character have offered the scientific public a collective view of the ideas gained. Among these works special mention should be made of Dr. Raphael Blanchard's elaborate volume upon the natural history of mosquitoes and their relation to medicine, and of the excellent little book of Messrs. Chantemesse and Borel upon the yellow-fever misquito.

Through these documents, traced to their different sources, I shall explain, not so much the practical methods employed in the struggle against yellow fever as the scientific theories upon which the defense is based.

I.

The history of yellow-fever epidemics in various epochs shows a remarkable tendency for the disease to extend its ravages. Originating in the islands and on the coast of the Gulf of Mexico, it remained for a long time bound to its birthplace. At Vera Cruz the Spanish conquerors waged war against it from their first attempts to conquer Mexico at the beginning of the sixteenth century. It was as formidable an enemy to them as the Aztecs. Historians of the conquest record that the band under Diego de Nunes, numbering 780 men when in 1509 it had just taken possession of the lowlands of Vera Cruz, lost 400 men in a short period, and fifteen months later their number was reduced to 60 men. This first disaster was significant. It announced to invaders the frightful consumption of lives of Europeans which this minotaur of the Tropics, known as the yellow typhus, black vomit, or yellow fever, was to make during four centuries.

All along the coast of the Gulf of Mexico, at the mouths and on the banks of rivers, the disease lived in an endemic state, showing at long intervals periods of epidemic outbreak more or less violent. From this permanent center, called the "Mexican source," there extended numerous epidemic radiations. Several, mounting toward the north, attacked the Bermuda Islands and the Atlantic coast of the United States; others, summering in the south, infected the Guianas and Brazil; then encircling the South American Continent, set upon the Pacific ports. Sugar-laden vessels from Cuba carried the contagion to the maritime cities of Europe. In the eighteenth century slave ships returning from the Antilles infected the western coast of Africa.

Most of these epidemics, emanating from their original Mexican center, were extinguished on the spot only after disastrous ravages. But at other times the yellow fever, encountering in the new countries conditions favorable for its development, established itself permanently in an endemic state. This is what happened in Brazil and on the coast of Africa.

Thus were established two secondary sources which became in their turn two new centers of radiation—the Brazilian source and the African source. This African source, which dates, as I have said, from the middle of the eighteenth century, is located in the Gulf of Guinea between the mouths of the Niger and the Kongo. It is particularly in the region of Sierra Leone that the permanent endemic character of the infection is clearly manifest; from here have radiated most of the epidemics which have ravaged Africa.

The Brazilian source is of more recent date; it was established in the middle of the nineteenth century. In 1849 a single ship from New Orleans, the *Brasil*, brought yellow fever to Bahia. From that city another vessel, the *Navarre*, carried it to Rio Janeiro, where it found all the conditions necessary for its naturalization—a low, marshy ground, river deposits, an intense heat, and an excessive humidity. So the disease took permanent root as an endemic; it became a national disease. Finally it branched out from this new center toward the interior countries, following, as usual, the courses of rivers. Thus was produced the epidemic which in 1870, during the war waged by Brazil against Paraguay, broke out in Assumption, on the Parana, 1,200 kilometers from the coast, and with 30,000 victims spread as far as Buenos Ayres.

Europe in its turn has been the object of many repeated attacks by this terrible plague. The southern countries below the forty-third degree of latitude have especially suffered. Spain was attacked for the first time at Cadiz in 1700. The same port was infected from 1730 to 1734, then in 1780, again from 1800 to 1804, and from 1810 to 1812. The epidemic of 1800 to 1804 instead of being confined to regions along the coast climbed the course of the Guadalquivir and gained the interior country; it spread to Andalusia and fell upon Catalonia, with a total of 80,000 victims. In 1812 Barcelona was infected by the ship *Grand Turc*, hailing from Habana, and 20,000 persons perished. Another epidemic broke out in Pasages in 1828. From this date there is nothing to mention except two relatively mild incursions of the plague—one in Barcelona in 1870, the second in Madrid in 1878 upon the return of a Cuban regiment. Portugal was seriously attacked at Lisbon in 1723, and lightly in 1750 and 1751. In 1856 Oporto was the seat of an important epidemic which, brought by two ships from Brazil, killed 7,000 persons. Italy, since it has little maritime relation with the centers of contamination, has remained almost entirely free from the plague. Nevertheless in 1804, at the time of the Spanish epidemic, contagion spreading from Barcelona to Livorno caused the death of 1,500 persons. In 1883 a patient arrived at Torre Annunziata and became the center of a slight spread of yellow fever.

So much for the hot countries of Europe. In the more temperate regions of France and England north of the forty-third parallel there have frequently been yellow-fever cases imported by ships, but never a real epidemic.

In France the ship quarantines of Marseille and of Brest received patients afflicted with yellow fever in 1802, 1804, 1807, 1821, 1836, 1839, and, later, nearly every year from 1891 to 1900. In each case the workmen employed in unloading the vessels were infected, but there was no contagion ashore.

The incidents at Marseille in 1821 and at Saint-Nazaire in 1861 are especially interesting; Messrs. Chantemesse and Borel have shown how instructive they are. While Spain was violently infected during the summer of 1821, a brig, the *Nicolino*, left the port of Malaga bound for Marseille. Upon the day of its departure, August 26, a yellow-fever patient died on board. During the trip a second case broke out, and on September 7, upon the ship's arrival in Marseille, the patient was sent to the hospital at Pomegue and the vessel held in the quarantine basin. Other vessels to the number of 40, hailing from such countries as Tunis, Cyprus, and Alexandria, where yellow fever had never existed, were moored along the quays of the basin and kept strictly apart without the least contact with each other. Nevertheless cases of yellow fever broke out around the brig, even in the quarantine basin. From September 7 to October 2, 22 persons were infected. These were some sailors on the neighboring ships, some health officers stationed on board for their surveillance, and a laborer working on a pontoon anchored a short distance away.

It was a matter of surprise that the disease so contagious on shipboard and in its immediate vicinity was not contagious from the patients transferred to the hospital, nor, as in the case of the workman, in their houses in the city. No case of contagion in fact originated either in the hospital or in the city. It is not, then, the sick man himself nor his clothing, nor his linen, that are the vehicles of the disease, nor even the shrouds of the deceased ones, but the vehicles are the mosquitoes, the *Stegomyia*, household insects, which of their own accord wander no more than a few hundred yards from their birthplace. In the present instance the breeding place of the infectious mosquitoes, their home, was the obscure corners of the ship *Nicolino*.

The epidemic of Saint-Nazaire in 1861 furnishes an analogous example. The ship *Anne-Marie* sailed from Habana June 12 and arrived at Saint-Nazaire July 25. Nine sailors were attacked with yellow fever during the voyage, but they had recovered. The ship's sanitary condition being good it was admitted to port. They opened the hold, the haunt of the insects, a veritable box of Pandora. They

unloaded the cargo and proceeded to make repairs. Presently some cases of yellow fever developed among the workmen, the mechanics, the people dwelling in the vicinity of the infected ship. From July 25 to August 16, 21 individuals were attacked. The epidemic of which the *Anne-Marie* was the center spread to the neighboring vessels, and 10 new cases broke out more or less tardily after they had left port.

England is in the same condition as France in respect to yellow fever. The ports of Falmouth, Southampton, and London have had several outbreaks of the disease. Epidemics may originate on a contaminated ship, carrying in its hold some Stegomyia. These insects, either infected when the ship sailed or susceptible of infection from yellow-fever patients during the voyage, transmit the disease to whoever approaches them. Some mosquitoes pass to ships near by and make them new centers of the disease. That is the story of the epidemic of Saint-Nazaire in 1861. It is likewise the history of the epidemic that occurred four years later at Swansea, England, where the ship *Hecla*, arriving from Cuba, contaminated a score of persons coming aboard and spread the fever to another vessel anchored in its vicinity.

This is not the place to give a story in detail of all epidemics. It is enough to say that all the particular circumstances are clearly explained by the supposition that the mosquito is the sole agent of propagation of the infectious germ and by the knowledge of its mode of life, its habits, and its dwelling places.

II.

What has been said of the geographical distribution of yellow fever has shown the tendency of the disease to spread continuously on land. It is seen that its progress has been steady since the beginning of the sixteenth century. Can we tell where its onward march will stop unless scientific hygiene intervenes to cut it short? Should we suppose that it will continue indefinitely and that the pest without cessation will overrun new regions as navigation is developed and as commercial relations are multiplied with contaminated countries? Finally, what are the countries menaced in the more or less near future?

It is easy to answer these questions. It is enough to translate the statement into a language conforming to the doctrine of propagation of the disease by the mosquito. The yellow fever will be implanted wherever the Stegomyia lives and multiplies, or better, wherever it is capable of living and multiplying. By a happy chance for European countries it is found that this species of mosquito can live only in conditions of high temperature, exactly adapted to the accomplish-

ment of its vital functions. The perfect insect can subsist only at a temperature between 60 and 100° F.; below 60° it is paralyzed, benumbed, it dies; at 65° it moves with difficulty. It bites with energy only above 75°. It mates between 68 and 85°, but there is fertilization only when the temperature is above 75°. It lays its eggs in the water where it lives, in stagnant water of flower vases, gutters, bottles, tubs, and sinks, but only when the temperature is from 80 to 85°.

The conditions of development of the larvæ are not less rigorously precise. The development of the egg and the hatching of the larva demand a temperature between 68 and 85°—the best is at 82°. All lowering under that figure shows itself by a greater or less retardation in their development. The larva is aquatic. Its respiration of air obliges it to fix itself at the surface of the water or to rise there to seek the air periodically. It develops normally into a perfect insect in a period of nine days, provided the temperature at night does not go below 80°; otherwise the formation of the winged insect, capable of mating and of reproducing itself, is prolonged to forty or even sixty days.

To sum up, then, it appears that the yellow-fever mosquito obtains its full and regular vital development only at an average temperature of 82°, and that any lowering of the temperature night or day renders less efficient some one of its physiological functions. This data is consequently of the first importance. The strict dependence of the mosquito on temperature conditions is an essential fact in the interpretation of the history of yellow fever; it is the key to all its mysteries. The Stegomyia needs plenty of heat and of heat steadily maintained. As soon as the temperature falls, the insect's life becomes endangered, and at 60° it is benumbed and soon dies. This sensitive insect does everything in its power to protect itself from the increasing chilliness of the air, and its mode of living offers the means for doing so. It is practically a fellow-boarder with man, under the same roof. It is a domestic animal, like the house fly. Whenever it is cold, it takes refuge in kitchens, bathrooms, heated bedrooms, in bakeries, or in other warm places. On ships it finds a last resort close to the engine room, near the heat pipes or smoke pipes. If the temperature falls below 60°, it becomes torpid and benumbed like a marmot.

These conditions in their rigorous precision are, so far as known, peculiar to the Stegomyia among all mosquitoes, and explains many features in the history of yellow fever. I shall mention but one. This relates to the peculiar immunity enjoyed by the inhabitants of Petropolis, in Brazil. Petropolis may be called the sanitarium of Rio Janeiro. It is a country resort 30 miles

from the capital, at an altitude of 2,800 feet. It is the residence of the well-to-do population—the diplomatic corps, the principal merchants, financiers, and government officials. Before nightfall all these take the tram for the elevated region, where they find bracing air and healthful security. Petropolis, in fact, is free from yellow fever at the very time when Rio is scourged with it, and yet between these two places there is a lively traffic and constant relations. Even more, some yellow-fever patients are taken there for treatment throughout their illness, yet the disease is not communicated to anyone. The reason is that the Stegomyia can not live in that climate, and such as come in the railway trains each day perish immediately, for the evenings are cool and during the night the temperature often falls below 60°. There is sometimes another explanation given for the immunity from fever enjoyed in this Brazilian country resort. It is attributed to the altitude of the region above sea level. This is a mistake. Yellow fever and its mosquito are found even at greater heights than Petropolis. It is enough to mention the epidemics at Morne Rouge, in Martinique (920 feet elevation); at Camp Jacob, in Guadeloupe (1,800 feet); at Newcastle, in Jamaica (4,000 feet). The fact is that thermometric conditions are paramount.

It is found that the extreme heat and humidity best adapted to the welfare of the yellow-fever mosquito are most common along the coasts of tropical countries. The lands best suited to the swarming of this insect and to the spread of the plague form a belt around the earth north and south of the equator. If lines be drawn in the northern and southern hemispheres corresponding to the forty-third parallel of latitude, the circles would mark the upper and lower limits of the home of the Stegomyia and, accordingly, of the yellow fever. The region comprised in this vast zone form what MM. Chantamesse and Borel call the "infectible territories," and the more temperate countries on either side of this zone, denied to the mosquito, are the "uninfectible territories." The *Stegomyia fasciata* considered as a species can not become acclimated beyond this equatorial zone, for it does not find that almost invariable temperature of 82° which is indispensable for the proper exercise of its vital functions, and especially of reproduction.

The infectible zone represents the actual or virtual habitat of the infectious mosquito. It is the region of epidemics and is also the region of possible endemic or permanent centers of infection. At present the Stegomyia, which is a genus of mosquito very cosmopolitan in its habit, lives in widespread districts throughout the infectible zone. Theobald found it in India, the Malay archipelago, in Japan, in Africa, in America, and in all warm countries where he hunted for it. The contagion is capable, if not well guarded, of

spreading over a very large part of the warmer portion of the inhabited globe. Thus, if an infected vessel, having on board men or merely mosquitoes contaminated with the disease, makes a landing in the infectible zone, it threatens a whole country with an epidemic; men inoculate the Stegomyia, and new generations of Stegomyia carry the disease to other men; the plague progresses, the contagion spreads in scope and in duration; the port, the city, the country is ravaged. This is what happened in Spain at the time of the epidemic at Cadiz and at Barcelona in 1804 and 1812.

The case is totally different in the uninfectible territories situated beyond the habitat of this mosquito. The infected vessel occasions only a local epidemic, which exhausts itself on the spot. The infectious insects, on account of their sedentary habits, never wander far from the ship that houses them; they bite only those imprudent enough to disturb them. At the farthest they move only to the neighboring vessels. Since the climate is unfavorable for their reproduction, their ravages last only during their ephemeral life. Hence these minor epidemics are limited to a single ship or to an anchorage basin and vanish of their own accord. This was the case with the yellow-fever invasion observed at Marseille, at St. Nazaire, at Swansea, and in general at all French and English ports. The reason for this is understood. It is because all of England and nearly all of continental France are beyond the forty-third parallel, and consequently the disease does not flourish there.

III.

This line of demarcation between the countries that are susceptible of infection and those which are not, a line fixed by the forty-third parallel, has much importance in the campaign against the yellow fever. On one side of the boundary the peril is great, and sanitary measures should be rigorous. On the other side there is, so to speak, no danger at all, and the subject of sanitation is very much simplified. On either side of this entomological and pathological frontier the health regulations may, and should, differ. They should be made in accordance with scientific facts, which enlighten both theory and practice. How the obscurities disappear! How the paradoxes vanish that troubled investigators just a few years ago! The physicians in the Marseille quarantine during the epidemic of 1821 understood nothing of the nature of that disease which was so frightfully contagious on shipboard and which ceased to be so the moment patients were transferred to the city hospital. All is clear now that scholars on the United States commission of 1900 [a] have taught us that there

[a] See Smithsonian Report for 1901, pp. 657–673; also biography of Dr. Walter Reed in present Smithsonian Report for 1905.

is no contagion from the infected persons, nor from their clothing, nor even from their fæces, but only by infected mosquitoes, which, in the case mentioned, were confined on a vessel. What a paradox it seemed to epidemiologists of that time that of two cities—Barcelona and Marseille—one clean and new, the other insanitary and old, it was the first which was visited by the yellow fever, while the second remained untouched. There is no longer a paradox for those who know that one city is on the northern and the other on the southern side of the frontier that limits the habitat of the contaminating mosquito.

The forty-third parallel strikes the continent of Europe at Ferrol, in Spain, follows the Pyrennes districts, crosses the Hyères Islands below Marseille to the heights of Leghorn in Italy; it leaves below it nearly all of Spain, the southern half of Italy, and of the French possessions part of the Hyères Islands and of Corsica. Care should be taken in directing to any one of these islands any French colonial companies returning from yellow-fever countries.

The infectible countries, possible prey for the pestilence, comprise, as may be seen, a considerable enough portion of Europe, the whole of Africa, a large part of Asia, of Australia, and the oceanic islands. Here is an immense empire that must be watched. It will become more and more formidable, as direct relations are multiplied with the different endemic centers of Brazil, the Antilles, and the Gulf of Guinea. The cutting of the Isthmus of Panama, by opening to the plague Polynesia and the Asiatic world, might create a menacing danger.

The way to prevent this extension is to attack the agent of its propagation, the Stegomyia, both on land and sea; on land by trying to purge the endemic centers where the insect becomes infectious, and on sea by attempting to destroy the mosquito itself in the ships where it finds refuge.

Three signal victories have been gained over yellow fever during these later years—in Cuba, in Brazil, and in Dakar, in West Africa. The first is the most memorable of these events. It is the purification of the endemic center at Habana. This occurred in 1901, during the United States occupation. The daily press in countless articles has spread the details. We know that Brig. Gen. Leonard Wood, governor of Habana, decreed one fine day that the plague should be wiped out and the mosquitoes destroyed throughout the entire city of Habana and its suburbs, and we know that it was done. Praise has rightly been given to the spirit of decision, of activity, of energy, and even Draconian rigor which attended the execution of this work. It remains to point out its wisdom, its exact conformity to scientific theories.

The theory was that the mosquito is the sole disseminator of the disease. This is precisely what the United States commission, appointed the year before, had just proven. It had shown that all the other supposed causes of contagion were imaginary; that a man could sleep in the bed of a sick patient or of one deceased, could come in contact with his fæces, put on his clothes, use his linen, confine himself in badly ventilated rooms at a humid temperature of 100°, and leave unscathed by the test if he escaped the mosquito bite. The extermination of the plague, then, leads to the extermination of the mosquito. But this pretension of banishing such a wily enemy seems foolish at first sight. You can hardly rid a room of one little insect that buzzes around, and yet they say you would rid a swampy country of legions of mosquitoes that abound there.

The yellow fever Stegomyia does not breed in swamps. It has not the habits of the Anophele of the marsh, the malaria mosquito. It does not live like that one, in the open country, but dwells in houses. It is a domestic insect. It stays at home, is wary, and is sensitive to the weather. Like many other mosquitoes, it never goes more than 500 or 600 yards away from its breeding place and journeys only when its home—a vessel or a carriage—journeys. There is no need to fear that the insect may be carried far by the wind, for it dreads the wind. It does not trust itself outdoors when there is the lightest breeze. The problem is thus simplified. It is no longer a question of protecting immense areas. It is enough to protect the house and its immediate environs—the city and a limited surrounding zone. Still it would be useless to capture the insect on the wing or at rest. It is permitted to complete its short life, but is not allowed to have offspring. The female is prevented from laying its eggs. This is accomplished by draining stagnant water left in so many gardens and household utensils where the mosquito seeks a breeding place. Hence the efficacy of the measures which forbade the people of Habana from keeping water in any other way than in covered receptacles or with a coat of oil or petroleum on top.

The success of the measures taken by the American physicians, Gorgas, Finlay, and Guiteras, in Habana was complete. Yellow fever has disappeared from there. On April 4, 1904, the President of the Republic of Cuba, in his message to the Congress, spoke thus:

> There has not been in Cuba since 1901 a single case of yellow fever not imported. The country should know of this excellent sanitary condition, which is due to the perfection of prophylactic measures and the vigilance of the health authorities.

Events happened in the same way in Brazil. Dr. Oswaldo Cruz, in charge of the organization of the campaign against yellow fever, with equal success repeated at Rio de Janeiro what had been done in

Habana. The enforcement of the measures began April 20, 1903. The mortality which before had averaged 150 deaths a month fell to 8 in the month of April and to 4 in June. In January, 1904, there were recorded only 3 deaths.

France decided to follow these encouraging examples. The governor-general of French Western Africa, M. Roume, adopted an administration analogous to that of Habana and Rio de Janeiro, and he knew how to profit by these examples. The result was not long delayed. On May 29, 1905, an imported yellow-fever patient died in Dakar. Thanks to the precautions taken, this death has not been followed by a single other one. The threatened epidemic was stopped at its first stride and that colony saved from a new disaster such as it had suffered twice in less than thirty years.

LUMINOSITY IN PLANTS.[a]

By Prof. Dr. Hans Molisch.

Sixty-two years ago, at the twenty-first meeting of German scientists and physicians at Gratz, over which no less a personage than the famous chemist, J. von Liebig, presided, an Austrian investigator, J. T. Heller, gave an address upon the luminosity of decaying wood, and advanced the idea that the production of light did not come from the decaying wood itself, but from a fungus which penetrated the wood. Not long after this the same investigator carried out a thorough examination of light coming from decaying animals and plants, and discovered that the luminosity in the flesh of dead marine animals and various decaying plant substances was not a purely chemical but a biological process, uniformly produced by a certain plant, a fungus. That is to say, it is not the flesh of a fish or the wood that is luminous, but a fungus living upon these and penetrating them in proportion to their decay. It may be noted that priority for this discovery has been accorded, though unjustly, to the gifted physiologist, E. Pflüger, because Heller's investigations dropped entirely out of sight, and were only recently discovered by me. The priority unquestionably belongs to Heller.

By understanding that the problem is a biological one, an important basis has been gained for further investigations. As, furthermore, R. Koch has enriched scientific knowledge by his bacteriological technique and the method of pure cultures of bacteria, the cultivation of various light-producing bacteria and recently also of luminous fungi has been successfully undertaken. We are now in condition to approach the subject of distinguishing between various species, of investigating the conditions for luminosity, the nature of the light, and the problem of light development. If we exclude light development in the *Peridineæ*, which are sometimes referred to the animal and sometimes to the vegetable kingdom and which play an im-

[a] Translation of Die Lichtenwickelung in den Pflanzen, von Prof. Dr. Hans Molisch, Leipzig, 1905.

portant part in the striking spectacle of marine phosphorescence; and if we ignore the so-called glimmer of flowers, first observed by the daughter of Linnæus, which is attributable to an entirely different cause, probably a purely physical one, and most likely to the appearance of St. Elmo's fire, all light-producing plants may be said to belong to the Fungi; that is, to the Bacteria and the mycelial Fungi.

In order to avoid misunderstanding it may be said that in speaking of light-producing plants I refer invariably to those plants which of themselves produce the light, their own and not reflected light, to which latter phenomenon are to be referred the wonderful iridescence of many sea algæ, the remarkable emerald green gleam of the luminous moss *Schistostega osmundacea*, and the reflection, like liquid gold, of the Flagellate, *Chromophyton rosanofii*. There are in round numbers thirty different kinds of bacteria and about half as many other fungi which have the power of luminosity. If we compare this to the combined number of existing plant species they doubtless appear as a very small proportion. Nevertheless we are frequently surrounded with luminous objects in nature and even in the household, because certain ones of these light-producing fungi are among the most common of all plants. Of these I will give a couple of examples.

Until recently luminosity in butchers' meat was considered to be a spectacle of rare occurrence, a curiosity the cause of which was unknown and the conditions producing it infrequent. When I undertook an investigation of the matter I lacked proper material; and although I communicated with various people and institutions where luminous meat would be most likely to be found, not a single specimen was supplied to me for fully two years. I was about ready to abandon the undertaking when the idea came to me to examine meat supplied to me for household use, and to my astonishment it appeared that such meat, kept for from one to three days in a cool place, began in many instances to spontaneously produce light. In following up the matter I found that the luminosity much more frequently occurred if ordinary butchers' meat was so immersed in a 3 per cent solution of salt that about one-half of it remained out of the liquid. Experiments with meat carried on for three months afforded not less than 87 per cent of cases of luminosity; thus, experiments with beef afforded 89 per cent, experiments with horseflesh 65 per cent. By means of pure cultures it was demonstrated that the cause of the luminosity was invariably the same intensely luminous bacterium, namely, *Bacterium phosphoreum* (Cohn) Molisch. As I have carried on similar researches for a number of years, not only in the city of Prague but in other cities as well and with essentially the same results, it can be stated that the spontaneous luminosity of meat is in fact a quite common occurrence.

The cause of this light development, *Bacterium phosphoreum*, is one of the most widely distributed of the bacteria. It is found on meat in refrigerators, in slaughterhouses, in butcher shops; in fact, it finds an entrance into our kitchens where meat is usually prepared. For in no other way can we explain the fact that so many specimens of meat display the power of spontaneous luminosity. I have of late come upon another form of light production, which, although of common occurrence, is practically unknown. I refer to light from decaying leaves. During walks taken at night in the Tropics, especially in Java, I frequently found the dead leaves of *Bambusa*, *Nephelium*, *Aglaia*, and other plants to be luminous in the darkness. On returning to Europe with the experiences gathered in the Tropics, I looked into the same subject on native ground and found that luminous dead leaves of the oak and beech are quite common in middle Europe. The leaves must be in a somewhat moist condition and to some extent decayed. Such leaves, especially, as display on account of decay a somewhat yellowish or ashen color or show spots of yellow and brown give a particularly beautiful light. The luminosity is usually local, rarely over the entire surface—a white, soft, steady light. Here also the luminous cause is not the leaf substance, but the living fungus within it.

According to my own observations, no inconsiderable percentage of fallen oak and beech leaves are luminous in the summer time; and on all sides the floor of the forest is illuminated with light, feeble, indeed, but easily detected. Unfortunately I have not as yet been able to isolate the fungus which produces this light of decaying foliage. Still I have employed with advantage the methods of pure cultures with the fungus, producing light in wood, and thereby have recognized in *Agaricus melleus* and *Mycelium x* the two fungi which with us most frequently cause this luminosity. At the same time it has become evident that certain cryptogams generally considered as luminous fungi, such as *Xylaria Hypoxylon*, must be stricken out of the list of the Photomycetes, and to this may also be added *Trametes pini*.

In *Bacterium phosphoreum* (Cohn), Molisch and Mycelium "x" (necessarily so called at present, as despite years of cultivation it has not yet fruited), are secured two remarkably valuable experimental adjuncts for accurately studying light development in a definite way, because of their relatively powerful intensity of light and the unusually long period that they are luminous.

Luminosity and the growth of luminous bacteria are dependent, among other things, upon certain salts and organic substances. Table salt plays a prominent part in this respect, seeing that as a rule these bacteria are marine, and for this reason 3 per cent of table salt is generally added to the culture medium. The salt does not serve as

food, but rather performs an osmotic function, by rendering the culture medium more or less isosmotic to the cell contents of the bacteria. Other salts can in the same way replace table salt, as potassium chloride, magnesium chloride, calcium chloride, potassium nitrate, potassium iodide, and potassium sulphate. In fact, I have the impression that potassium nitrate is more active in causing luminosity than the chlorides, such as sodium and potassium chlorides.

We are indebted to Beijerinck for some exhaustive and valuable investigations upon the relations existing between nutriment, luminosity, and growth. The method of his investigations is essentially the spreading upon thin glass plates of gelatin containing photobacteria and supplied with an excess of nutriment. When it is spread out as a thin film the bacterial field quickly becomes luminous. As soon, however, as the excess of nutriment is consumed, the light ceases. If now we add to the gelatin a substance the influence of which on luminosity and growth we desire to test, it dissolves and is disseminated in a circle in all directions. If this added substance is a nutritive one for luminosity, we see, frequently in a few seconds, the area that was affected growing luminous. By this method bacterial fields exhibit reactions of astounding delicacy. Certain materials, preeminently lebulose and glucose, cause the field to grow luminous in a few seconds. In this respect the photobacteria react with so minute a quantity of material that Beijerinck saw in these reactions an analogy to the Bunsen-flame reaction. In one sense this bacterial reaction is superior, in that it continues longer.

The luminous bacteria act in various ways with materials containing carbon and nitrogen. One class, called by Beijerinck Pepton-bacteria, finds the necessities for growth and light development supplied in pepton or some albuminous material; the other class, called by him Pepton-carbon-bacteria, requires at the same time the presence of material containing pepton to supply the necessary oxygen and also carbonaceous matter, which is not necessarily free from nitrogen.

If the nutritive material is well adapted to both growth and a multiplication of bacteria, it will cause not only luminous fields, but fields of growth called "auxanogrammes," characterized by the innumerable colonies of bacteria that develop far more rapidly in the field where the material has been diffused than outside of it. Beijerinck calls such nutritive material "plastic." Luminous substances are uniformly plastic though the reverse of this is not necessarily true. From this the important fact follows that light development by the luminous bacteria is not necessarily connected with either growth or respiration.

Beijerinck has with great ability made use of the luminous bacteria for detecting the most minute quantity of an enzyme.[a]

The following example will illustrate this: He takes advantage of the fact that *Photobacterium phosphorescens* displays light with maltose, while *Photobacterium Pflügeri* does not. He uses a thoroughly cooked mixture of sea water containing 8 per cent of gelatin, 1 per cent of pepton, and one-fourth per cent of potato starch. To a portion of this he adds an excess of *Photobacterium phosphorescens* and to the rest the same of *Photobacterium Pflügeri*, and prepares from these two similar gelatin plates equally illuminated. In both the starch remains unchanged, seeing that these bacteria are unable to secrete the necessary enzyme, diastase. If now some diastase preparation (such as maltose, pancreas-diastase, or ptyalin) is added to these plates, it distributes itself in all directions, transforms the starch into grape sugar, and upon the field of the *Photobacterium phosphorescens* there instantly appear strong, shining flecks, which later spread over the whole field of growth, while on the field of *Photobacterium Pflügeri* nothing of this kind is to be seen. In this way *Photobacterium phosphorescens* can be made to demonstrate through its luminosity the presence of maltose—that is to say, of a diastase.

For an understanding of the nature of light development in plants it is above all necessary to state that the luminosity is absolutely dependent upon free oxygen. The light is conditioned on oxidation. The finest investigations of the dependence of luminosity upon oxygen are the brilliant experiments of Beijerinck. According to his researches the luminous bacteria afford the most sensitive tests for oxygen that we possess. Thus the extremely minute quantity of oxygen which unicellular algæ give off in sunlight by their assimilation of carbonic-acid gas, is sufficient to instantly render these bacteria luminous. If we introduce these green cells into a glass tube filled with bouillon containing luminous bacteria, the light quickly disappears because the bacteria speedily consumes the oxygen contained in the liquid. If, now, such a tube is kept in a dark room and then the light of a match is allowed to fall upon it for a single second the entire mass grows luminous. The green cells give off oxygen, and this fabulously minute quantity of the free gas is sufficient to cause luminosity in the bacteria. It is a remarkable example of the fact that physiological methods not only compete well with the best physical and chemical methods, but plainly surpass them, and that a vital

[a] An enzyme is a product of certain plant or animal cells by means of which food material of a certain kind, such as starch, is transformed into another food material, such as grape sugar. Diastase is an example of an enzyme.—*Translator.*

function itself can be used as a methodical factor of science of the highest value.

A demonstration of the importance of oxygen to luminosity can be made before a large audience in the following way: A glass tube closed at one end, having a diameter of about 8 mm. and a length of 1 to 1½ m. is filled to within ½ to 1 cm. of the top with strongly luminous bouillon (bouillon mixed with *Bacterium phosphorium* or *Pseudomonas lucifera*). Such a tube at the expiration of a quarter of an hour loses its light as the bacteria exhaust the oxygen, except the mere upper surface of the liquid in contact with the air. If, now, the tube is closed with the thumb and inverted, a bubble of air will ascend through the bouillon, making its entire course luminous and appearing in the darkness like a slowly ascending skyrocket. In a quarter of an hour or less the luminosity again disappears, and the experiment can be repeated.

Botanists, as a rule, teach that a direct relationship exists in the fungi between the development of light and respiration. Thus Sachs speaks of phosphorescence as the necessary consequence of respiration, of phosphorescence *by means of respiration.* But F. Ludwig has already demonstrated that luminous bacteria can be cultivated, and therefore made to grow and breathe without any luminosity; and we can therefore easily see how that at increasing temperatures the intensity of respiration may steadily increase, but the intensity of luminosity to only a limited degree. The relation existing between light development and oxygen is analogous to that between color development and oxygen. Most of the color-producing bacteria show color only in the presence of oxygen, as can be seen in gelatin cultures into which an infected needle has been introduced. When the free gas can reach the bacteria, the color appears, but deeper in the gelatin the bacteria, cut off from oxygen, develop without color. Color production and light production are therefore oxydation phenomena. * * *

During recent times quite a number of investigators have been incidentally or directly engaged in throwing light upon the nature of luminosity—E. Pflüger, Radziszewski, Dubois, F. Ludwig, Katz, Tollhausen, Lehmann, Beijerinck, McKenney, and Nadson. However, their interpretations differ from each other considerably. The further our knowledge of the subject is extended the more probable appears the idea that within the cell is a hypothetical substance, "photogen," which has the power of producing light in the presence of free oxygen. This idea receives substantial support from the fact brought out by Radziszewski that a long list of organic substances, such as aldehyde materials, ethereal oils, carbonic-acid, water, fatty oils, and certain of the alcohols, have the power of luminosity when brought into alkaline reaction with active oxygen.

As the light produced by these substances has an external and spectroscopic likeness to that produced by living organisms, and as some of the substances in the list of Radziszewski which are capable of luminosity exist also in living cells (I mention lecithin, fats, cholesterine, ethereal oils, and grape sugar) that investigator has come to the conclusion that light development in living organisms can be explained as an oxydation of these same substances. Radziszewski looks upon the problem, therefore, as solved. We have, however, as yet hardly gotten that far. The question of whether Radziszewski is in the right could be definitely settled if we could extract from the living cell a photogen material which would show luminosity outside of the cell. But up to the present time the attempt has not been successful. Furthermore, according to Pfeffer, no active light-causing oxygen exists in the living plant cell, which does not square with the theory on which Radziszewski's explanation rests, inasmuch as his light-producing substance is luminous only when in contact with active oxygen. Nevertheless, I look upon the photogen theory as the most plausible, though we at present have no knowledge as to the nature of photogen. Possibly it is a material in no sense similar to the luminous substances previously mentioned; perhaps something capable of giving light without active oxygen.

There are certain facts which appear to me to directly support the idea of a photogen. Thus certain animal organisms give out a noncellular luminous secretion, and certain cells together with their contents are capable of producing light when no longer living. Mention can be made of *Pholas*, certain of the insects, myriapods, and many of the worms. A fact of significance and too little noted is that certain tissues and cells have the power of producing light in a lifeless condition. Thus manuscript written with the luminous material obtained from *Luciola italica* gives off light when it is dampened. The light organs of *Lampyris noctiluca* lose their luminosity when thoroughly dried and kept in a vacuum. But, according to Bongardt, if after a year's time they are taken out and moistened with a drop of distilled water the light reappears. If filter paper is impregnated with the secretions of certain myriapods, it can, after two months' time, be made luminous by moistening. It is impossible in such instances to talk longer about "living cells" or "living cell contents," for it is impossible to describe as living the luminous material from an insect that has been dried and kept for a year in a vacuum. In such instances we are no longer dealing with a vital but with a purely chemical process; we are dealing with a substance which produces light in the presence of water and free oxygen.

In the case of luminous plants no such thing as a luminous excretion exists, though such is erroneously stated to be the case, for the light exists only within the cell. In other words, it has never been seen outside of the living plant cell, and to that extent luminosity in

plants must be spoken of as a genuine *vital* luminosity. But in the same way not long ago alcoholic fermentation was held to be inseparably connected with living yeast cells, while to-day, thanks to the brilliant biochemical discoveries of Buchner, we know that it is due to a certain material—the ferment zymase—which can of itself, although a lifeless substance, bring about the fermentation. We can suppose the same to be true for photogen. Although the isolation of such a luminous material has not as yet been accomplished, the failure is probably due to the material being present in such very minute quantity, to its extreme instability, and its destruction through the death of the cell. What photogen really is, and whether the giving of light represents a process of fermentation—these questions can not at present be answered. The future investigator must unearth these facts. To directly or indirectly prove the existence of photogen; to, if possible, isolate it from the cell, and then render it luminous—such efforts, in the light of other biochemical facts, appear to me most tempting and by no means unpromising.

Whoever has observed the swarms of fireflies flying through the darkness of the night like wandering stars, or the intense light of pure cultures of bacteria and the higher fungi, must involuntarily have been impressed by the peculiarity of these "living" lights. And therefore it is easy to see that at a time when the science of physics has surprised us with unexpected revelations, appearing at first like marvels, that we should with redoubled activity turn our attention to the nature of this light coming forth from life, and seek to discover its physical, chemical, and physiological activities.

I wish, first of all, to call attention to a noteworthy difference between the character of this light in the animals and in the plants. If we leave out of account the Peridineæ and confine ourselves to the plants alone, we see they are always steadily luminous. The bacteria and higher fungi give forth light for days, weeks, months—indeed, under some circumstances, as when supplied with abundant nourishment, for years, without cessation, day and night, while the animals, with few exceptions, shine only a short time, a few seconds or minutes, and mainly in response to some external irritation; so that the light gives the impression of a flash or spark. The light of the fungi is of a white, green, or blue character, and, contrary to earlier statements, never undulates like the light of phosphorus; never is inconstant or glimmering, but is in all cases quiet, steady, and constant, whether viewed with the naked eye or through the microscope. As a rule, its intensity appears to be low, and yet there are bacteria so intensely luminous that they can be seen on a bright day in the corner of a room without the eyes being accustomed to the darkness. A remarkable object in this respect is *Bacterium phosphoreum* (Cohn) Molisch, the luminous bacteria of butcher's meat, and, to an even

greater extent, *Pseudomonas lucifera* Molisch, a photobacterium which two years ago I discovered in marine fish, the light intensity of which surpasses that of any luminous bacteria heretofore known.

To R. Dubois is due the credit of having first attempted to utilize bacterial light in the form of a lamp, and I have renewed Dubois's attempt with the two already mentioned intensely luminous bacteria, and have constructed a bacterial lamp on the following plan: In a Florence flask, having a capacity of from 1 to 2 liters, is put from 200 to 400 cubic centimeters of salt-peptone-gelatin. It is then stopped with cotton wool and sterilized. When cool, but before the gelatin has quite solidified, it is infected with a culture, fresh and luminous, of *Bacterium phosphoreum* or *Pseudomonas lucifera*, a platinum needle being used. The flask is held horizontally and slowly rotated, so that the gelatin forms a coating on the entire inner surface of the flask and then hardens. After being kept for one or two days in a cool room, the entire inner surface of the flask is covered with colonies of bacteria, so that it gleams with an exquisitely beautiful bluish-green light, and presents with its soft, steady brilliancy a splendid appearance. I have lately found that the luminous power of such a lamp can be considerably augmented by applying the infection to the gelatin in parallel lines about 1 centimeter apart, running from the bottom to the neck of the flask, and adding to the gelatin 1 to 2 per cent of peptone and about one-half per cent of glycerin. Such a lamp will continue luminous in a cool room for about fourteen days, and when the eye is accustomed to the darkness will give light enough to see the face of a watch, the scale of a thermometer, or to read coarse print. Such a flask is visible on a dark night at a distance of 64 paces, and could in an emergency be utilized as a night lamp. Inasmuch as dead luminous flounders are successfully used as bait by fishermen on account of their light, a lamp of this kind could be made to serve as a valuable lure in catching fish.

My investigations warrant me in stating that in the future it will probably be possible, by means of exact formulas of nutriment and by selective breeding, to so increase the intensity of this exceedingly cheap source of light, so free also from heat rays, that on account of its cheapness, its long and uninterrupted luminosity, its freedom from danger, and its lack of heat it can be turned to practical account in powder magazines, in mines that are not too warm, and in other places.

In connection with the investigations of F. Ludwig and Forster, I may state, in regard to the luminous bacteria and mycelial fungi, that their light spectra are continuous, without dark lines, and, as a rule, simply luminous spectra—that is to say, on account of their low intensity they are colorless; that the spectrum of the already named bacteria shows a more decided trend toward the violet end of the

spectrum than that of the higher fungi; and that in regard to the light of fungi (and this is also true for insects) the green rays dominate the weaker yellow and blue rays. I have actually succeeded in distinguishing colors through the spectroscope in the intense light of the previously mentioned *Pseudomonas lucifera* Molisch—green, blue, and violet. This is the first established case where colors have been seen through the spectrum in the light of a plant.

It is possible to state, on account of the spectroscopic composition of fungous light, that it may be made to act on photographic plates. In fact, the researches of various investigators—as Von Haren, Norman, Forster, Barnard, and especially R. Dubois—have taught us that photographs can be taken by bacterial light. If one uses intensely luminous bacteria, such as are at my disposal, it is possible to make photographs of bacteria colonies by their own light by an exposure of five minutes, and if bacteria lamps are employed, to make good pictures of various objects, such as busts, thermometers, and printed matter. In the last instance, however, to secure sharp pictures, the time of exposure must be several hours. On the other hand, if merely an impression upon the plate is desired, a single second of time is sufficient to secure an image of a luminous-streak culture. All pictures so far produced have been the result of light from colonies or mass cultures. But it appears to me not at all improbable, in view of the practically unlimited sensitiveness of photographic plates, that hereafter it may be possible to photograph a single bacterium cell by means of its own light, in the same way as we have succeeded in rendering visible by means of the photographic plate stars in the heavens which are invisible to the naked eye.

The discovery of Röntgen-Becquerel rays and of the emanations proceeding from radioactive elements make opportune the thought that rays of particular quality may also exist in bacterial light. Still the assertion made by R. Dubois that bacterial light has the power of penetrating opaque bodies, like wood and cardboard, is based upon an illusion brought about through the direct action of the wood or paper material on the salts of silver. On the same basis, I am able to explain the remarkable, and from the standpoint of physics utterly puzzling, statements of the Japanese investigator, Muraoka, in regard to the light of the firefly. Fungous light—and the same is true of the light of the firefly—acts upon the salts of silver like ordinary daylight, and is incapable of penetrating opaque objects.

It seems to me to be not without interest that bacterial light also brings about physiological results in plants. Heliotropic sensitiveness is, according to Wiesner, of remarkable intensity, especially in the case of the etiolated seedlings of certain plants. Such plants can discriminate better than the human eye between the most minute differences in light intensity and may therefore with justice be con-

sidered as excellent physiological photometers. This extraordinary light sensitiveness induced me to test experimentally the heliotropic power of bacterial light. In fact this light can bring about positive heliotropism in various seedlings, such as the lentil, the pea, and the vetch; and in fungi, as *Phycomyces* and *Xylaria Hypoxylon*. We have here a striking spectacle, that of one plant influencing another in its movements; the bacteria, by their production of radiant energy in the form of light, compelling the stem of a plant to extend its growth almost directly toward the source of illumination. Bacterial light does not, however, show itself capable of causing the production of chlorophyl, probably because the light is not sufficiently intense for this process.

We come now to the question whether so striking a phenomenon as this development of light in plants gives indication of being of any practical benefit to them. Zoologists seem to agree that light among the animals is of great importance. For when we consider the instantaneous and explosive generation of light, the sudden expulsion of a luminous secretion and the wonderful construction of a light-producing apparatus in animals inhabiting the darkest depths of the sea, we can have no doubt that such constructions are of service to the organisms, and that a definite use is served by this light-development in the case of many zoological forms. Thus these creatures may, by means of their light, either allure or frighten, or may illuminate their surroundings in order to more easily and successfully capture their prey.

The question in the case of plants is far more difficult to answer. The idea has been advanced that the light capacity of the bacteria may be a means of their distribution. The light of those bacteria occurring in decaying sea animals is said to attract certain animals along the seashore to feed upon these and by scattering the bacteria to aid in their dissemination. I agree with Beijerinck that, as sea currents, waves, and the sand along the shore bring about the dissemination of these bacteria in the most admirable manner, the beforementioned opinion is untenable.

There may be some doubt in the case of luminous mushrooms; in fact, a well-known biologist, Von Kerner, has expressed the opinion that the light of the mushroom points out the way for fungus gnats and fungus beetles, which lay their eggs in the mycelium and spore-bearing tissues of these Hymenomycetes; so that these creatures are in this way of service to the fungus by transporting its spores. At first sight this theory seems to have much in its support, but on closer examination we find there is not a little against it. Thus, in the case of the mushroom *Agaricus melleus*, it is difficult to understand why the gills, which bear the spores and are easily penetrated by insects, are not luminous, while the myceleum, growing under

tree bark or in the wood, is luminous. The luminous fungus threads growing in phosphorescent wood produce, as a rule, no fruit-bearing organs whatever. If the idea of this light of the myceleum were to allure insects or maggots, the result would be simply the destruction of the fungus, for by attracting these animals it would not be disseminated, but fed upon, and thereby destroyed, so that its light would be its ruin. Or if the light of the plant were to serve the purpose of enticing animal forms at night, it is not easy to understand why the plant is not luminous merely at night instead of uninterruptedly by day and by night—that is, at times when the light is wholly imperceptible to these animals. In the case of plants the question is a radically different one from that in the case of animals, and under these circumstances it seems to me better to forego speculations and simply to rest on the fact that at the present time we are unable to give any plausible teleological explanation of luminousity in the Fungi; perhaps, indeed probably, because it is nothing more than an inevitable consequence of the transforming of substances in the luminous Fungi.

If, in conclusion, we glance at our problem from the standpoint of dynamics, it is seen that, in company with various forms of energy in the plant, as heat, electricity, and chemical energy, radiant energy can also be produced in the form of light. A wondrous factor! The green cell in its minute microscopic laboratory, the chlorophyl grain, lays hold upon the energy emanating from the sun and transforms the living force of the light ray into chemical energy. Thereby is produced from the carbonic-acid gas of the atmosphere, with liberation of oxygen, organic matter—a storehouse of potential force. This organic matter enters as food into luminous animals and luminous plants, and there by transmutation produces once more heat and light.

Truly a cycle from light to light in the plant! In fact, the light of the living organism is governed by the energy of the sun. When the light of the glowworm, hidden in the grass, pours forth, directing by its lantern the way for its amorous mate; when the *Noctiluca* or *Peridineæ*, disturbed by the ship's keel or whipped by the waves, suddenly gleam forth: when the sea crabs on the floor of the ocean illuminate the darkness with their organs of light, or when luminous bacteria in decaying flesh or shining mushrooms in old forests flood their surroundings with magic twilight, this light of the organism is fundamentally nothing other than the radiating energy of the sun caught up by the plant and transformed into light. It is the newborn sunlight of the plant.

NOTES ON THE VICTORIA LYRE BIRD (MENURA VICTORIÆ).[a]

By A. E. Kitson, F. G. S., Melbourne.

DISTRIBUTION AND DISPERSION OF THE LYRE BIRD.

The Victoria lyre birds are restricted to the densely timbered, moist, hilly, and mountainous parts of eastern Victoria, for they must have abundance of moisture, and food consisting of insects, grubs, worms, etc. The Melbourne to Sydney railway may be taken as the approximate western limit of these birds. They have not been found to the west of that line, nor even nearly up to it in many parts. The reason apparently is that no densely timbered and scrubby humid ranges, with permanent creeks in them, occur to the west of this line on the northern side of the main divide, for neither Futter's Range nor the Mokoan Range near Benalla possesses these characteristics. The main divide itself, where the railway crosses it at Kilmore Junction, at an altitude of 1,145 feet, is rather low, and is not—apparently never was—densely scrubbed. Again, although eminently suitable country for these birds is comprised by the Macedon Ranges and those in the Blackwood district, near and on the main divide, also by the Otway Ranges, no lyre birds are found there. In the case of the last, the reason is undoubtedly its isolation. It is completely cut off from the other hilly and mountainous districts of Victoria by the great volcanic plains of the western district, which would form an effectual barrier to the dispersion of the lyre bird southward, even if it were present on the main divide to the north. The bird is so shy that, unless abundant cover be quite close at hand, it will not, under ordinary circumstances, venture into the open forest country, much less cross wide tracts devoid of arboreal vegetation. It is not so obvious why the lyre bird is not present in the thickly timbered and scrubby country of the Macedon Ranges, but apparently this also is due to its comparative isolation. On the east it is separated by a wide dissected volcanic plain, forming a natural barrier. The only practicable bridge of dispersion exists in the main divide itself, which from Wandong on the railway takes a general northwesterly course

[a] Reprinted by permission, with the author's corrections, from The Emu, Melbourne, Victoria, Vol. V, part 2, October, 1905.

to Mount William, thence southwesterly and southerly to Mount Macedon. About Mount William itself there was, in its original state, a small area which might have been suitable for lyre birds, but on the portions between Wandong and Macedon the want of sufficient moisture and scrub is perhaps the reason of their absence. The birds seem to have spread over southeastern Australia from New Guinea by following through Queensland and New South Wales the mountains that form the watershed between the Darling-Murrumbidgee basin and the Pacific Ocean; and this within comparatively recent time, considered from a geological point of view.

It is a matter for wonder that in suitable country lyre birds have existed in such numbers as they have done. The native carnivorous fauna destructive to them comprise the dingo or wild dog (*Canis dingo*), the "tiger cat" (*Dasyurus maculatus*), and the "native cat" (*D. viverrinus*). These animals, especially the first two—which are much less numerous than the "native cats"—frequent lyre-bird country. These birds build their nests in spots usually accessible to dingoes, and easily so to the climbing "cats." They have almost invariably only one young one a year, and yet in most of Gippsland and the northeastern district lyre birds exist in much greater numbers than many of the other larger birds which nest in much less dangerous situations, such as the gray magpie, king lory, wonga-wonga, and bronze-winged pigeons, laughing jackass, and black cockatoo. The lyre bird is a day bird and roosts in trees at night, so except at nesting time it is practically safe from attack. It is a strong, active bird, and could, even if attacked by a "cat" in a tree, either free itself or drag the "cat" to the ground in its first struggle. But it is comparatively helpless when in the nest, and certainly the young are completely so. One fact, however, aids in its protection. The nest is usually not easily seen, especially if the female bird is inside with her tail raised over her head, as is her wont, thus nearly filling up the entrance and breaking the noticeable black cavity of the empty nest.

Near the source of the King River I have seen the birds going to roost in tall green trees. They can not fly upward like an ordinary bird, but rather partially jump upward in a slanting direction with their outspread wings aiding them by soaring, not flapping. To get into these tall young trees, ranging up to nearly 100 feet in height, they went up by stages, taking advantage of short and long tree ferns and the branches of smaller trees.

HOME OF THE LYRE-BIRD, ON THE FAR UPPER YARRA.

NESTS OF THE LYRE-BIRDS IN TREES.

DESTINY OF THE LYRE BIRD.

But the days of the lyre bird are numbered unless it develops the habit of nesting in trees or spots inaccessible[a] to its far more dangerous enemy, an introduced one, the European fox. Scattered feathers and occasional feet are frequently met with in some parts of the country and attest the depredations of the fox, which has now spread over nearly the whole, if not the whole, of the State, and has moreover, developed the faculty of ascending slightly leaning trees.

As regards South Gippsland the lyre bird is doomed to extinction, and that by the agency of man. The mass of hilly country between the valleys of the Latrobe on the north; the Tarago, Lang Lang, and the Bass on the west; the Powlett and Tarwin and the narrow strip between Foster and Merriman Creek on the south and southeast, was a large tract, covered with an extremely dense vegetation and in a continuously moist or wet state before settlement took place. It was united to the main mass of the mountain system of eastern Victoria by a narrow elevated tract of volcanic and similarly timbered country between Warragul and Longwarry. In every gully and on every spur the lovely notes of the lyre bird could be heard, and evidence of its occupation could be seen on every hand. Thousands of these birds must have sported about this country, making the otherwise rather silent forest a huge natural concert hall. Now, alas, the march of settlement, with its breechloaders, forest spoliation, and bush fires, has brought about a sad change from a naturalist's point of view. With the disappearance of the scrub goes the lyre bird, and as the country gets cleared from various sides, so patches only of scrubby country are left. These become the temporary home of such of the outcasts as have escaped the gun, the clearing, and the fire, till they, in their turn, become felled and burnt, when the lyre birds disappear.

NEST, EGG, AND YOUNG.

During my geological survey of the Victorian coal-fields area in South Gippsland in the year 1900 I was camped on the Foster River near Jumbunna, on the edge of a belt of natural forest of an extremely dense character. This scrub was the home of scores of lyre birds, whose lovely notes could be heard all through the day.

Several nests of these birds were found, and as many observations made concerning the birds and their habits as time and opportunity permitted. One nest was situated in the side of one of the short, deep channels ("blind creeks") that drained the swampy portion of the river flat. As is customary in South Gippsland, the timber had

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[a] Reference to Plate II will show that lyre birds occasionally build in trees.—*Eds.*

been taken "in the face"—i. e., all the scrub and trees up to, say, 4 feet 6 inches in diameter had been felled, but as they had not then been burnt they lay in hopeless confusion, forming a tangled mass of logs, branches, and scrub, through which young scrub was growing. It was, therefore, an awkward place for stock, or even human beings, to get into—a fact that some of the birds had apparently recognized by building their nests in it. Across the river lay the natural forest forming the feeding and sporting ground of the birds, and containing some nests also. I found the nest in question one morning by noticing the female bird fly, or rather float, noiselessly away from the place on my approach. This is a common practice with the lyre bird. A young bird, unfeathered save for tufts of down on its crown and upper back and a few young feathers just breaking forth on the crown, was in the nest. It screeched so vigorously on being disturbed that the female bird quickly appeared, making meanwhile a semi-clucking noise, somewhat similar to that of a domestic hen calling her chicks. Whenever the little one gave its whistling screech the mother made this noise and also gave vent to her own quaintly melodious notes, sounding like "Koo-wuk′, koo-wuk′, koo-wow′," with a growl-like roll on the *wow*, and "Qua-ack′, qua-ack′," some like the guttural of the common opossum. On calming down after the young birds stopped screeching she imitated various birds,[a] principally the tits, scrub wrens (*Sericornis*), coachwhip bird (*Psophodes crepitans*), king lory (*Aprosmictus cyanopygius*), magpie (*Gymnorhina leuconota*), gray magpie (*Strepera cuneicaudata*), laughing jackass (*Dacelo gigas*), black cockatoo (*Calyptorhynchus funereus*), butcher bird (*Cracticus destructor*), sparrowhawk (*Accipiter cirrhocephalus*), etc.—principally the first three. She then walked leisurely down the sloping log, stopping every now and then to scratch it—simply through force of habit, for it was quite dry and sound—and then jumped onto the ground and resumed her scratching. All this time she was giving a refined rendering of the liquid notes of the common magpie.

The place was a very unsuitable one for the camera, and, being alone, there was difficulty in getting the photograph of the adult bird (see plate III). She was very restless, and as a time exposure was necessary, I was compelled to focus the camera on a certain part of the log where she stayed for a second or two while walking down it. Then, as I could get no stick long enough to touch the young one from my post at the camera, I collected pieces of mud and earth, and threw bits of these into the nest. Whenever one hit the little bird a screech followed, and the mother was on the log like a flash, but keenly alert and ready to float into the scrub at the least sign of danger.

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[a] This is a very important note. Hitherto it was believed that only the male lyre bird mimicked.—*Eds.*

On one occasion September 22, 1900, when setting up the camera opposite the nest, I heard a slight sound, and, looking up, found the bird on the log within 2 feet of my head. I had not touched the young one, so it had not screeched, and the mother had, therefore, not betrayed herself sooner. All the while I was setting up the camera she moved about the log within a few feet of me, occasionally putting her expanded tail over her head and quietly warbling—an alert, observant, fearless spectator. Now and then the young bird gave its whistling screech, when the old one evinced great distress and moved to a position that gave her a view of the nest, though she never went near it all the time. Whenever I stooped or sat down on the ground she got suspicious and hopped round till seeing me, then walked up quite close to see what was being done. Of my whistling she took very little notice, of talking none at all, but started at once at a gruff noise like coughing.

One of her most graceful movements was walking along the swaying frond of a tree fern. As the frond bent under her weight she gradually reversed her position till she was hanging head downward, suspended by her claws, and quietly warbling the while. This bird was the most sensible of any of the kind that I have seen. She seemed to realize at once that I had no intention of hurting the young one, and though evincing every sign of great distress while her offspring was screeching, became quite reassured of its safety when the screeches ceased.

The bird frequently walked down the log while I was standing at the nest with my head within 2 feet of her. Once I touched her feet with my hand, and I think with a little time and patience I could have caught her. Several times I made a grab at her leg, but she only jumped and floated away to another log, without evincing any signs of fear. Again, to test her timidity, I shouted, waved my arms, and threw little sticks at her without frightening her from her position, and even when one stick hit her on the head she simply floated to another log and resumed her observations.

The entrance to the nest can be seen just on the right of the log under the tail of the bird and just to the left of the extremity of the blackbutt spray with large leaves.

The picture of the young bird (plate IV) shows it resting in my hat, surrounded with sprigs of tree fern (*Alsophila australis*), dogwood (*Cassinia aculeata*), blackbutt (*Eucalyptus pilularis*), musk (*Aster argophyllus*), and laurel (*Pittosporum undulatum*). It was very frightened when first taken out of the nest, but soon rested quite contentedly in the hat while being photographed.

When in the nest it commenced to screech immediately anything appeared in the entrance, and thrust itself back as far as it could, meanwhile keeping almost on its back, with its powerful feet pushed

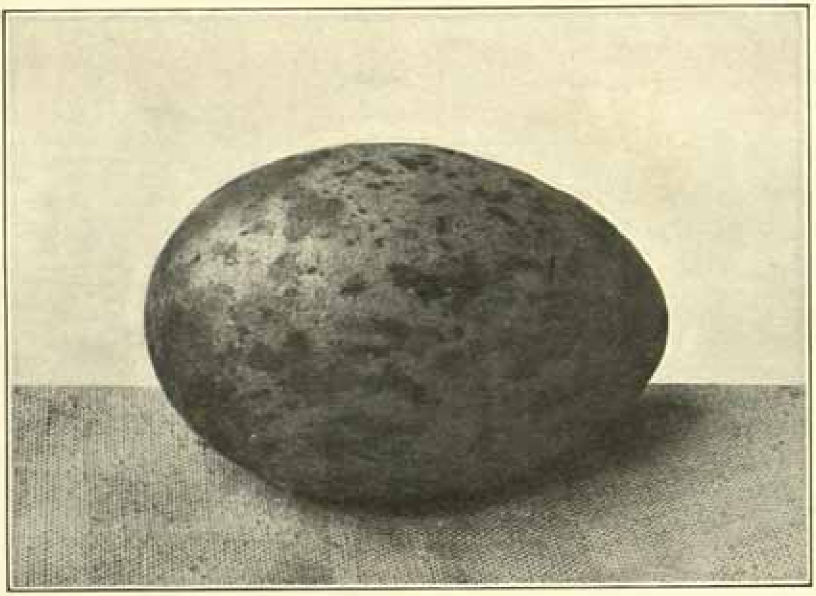
out in front, and screeching. As it grew older it sometimes pecked at my hand when thrust into the nest and always screeched. This, however, was never long sustained, except on movement of the hand, and it remained quite still if the hand were still.

I watched it carefully till it was nearly fledged, but one day I heard the distress signal several times in rapid succession. On reaching the place I found the poor creature dead in the nest. It had suffered no apparent injury, there were no signs of damage to the nest or of any struggle, and the only conclusion I could come to was that it had been bitten by a tiger snake (*Hoplocephalus curtus*). The nest was in the side of the gully, about 5 feet from the bottom, and easily accessible to animals and reptiles. The snake had, I think, put its head into the nest, been pecked by the bird, and after at once biting it had withdrawn and disappeared. I made careful search to confirm this view, but could not, as the place afforded no chance of seeing a snake track of any kind. Had a fox killed it, the bird would undoubtedly have been dragged out of the nest. The snake, as every bushman knows, is of a very enterprising nature and particularly partial to exploring nests of birds, whether on the ground or in trees and scrub. I have nearly tramped on one crawling along a scrub-suspended fallen tree, at a height of 10 feet from the ground, the snake being there probably with the dual view of getting direct sunlight and young birds, and I for less laborious and quicker progress than was practicable in the tangled vegetation on the ground.

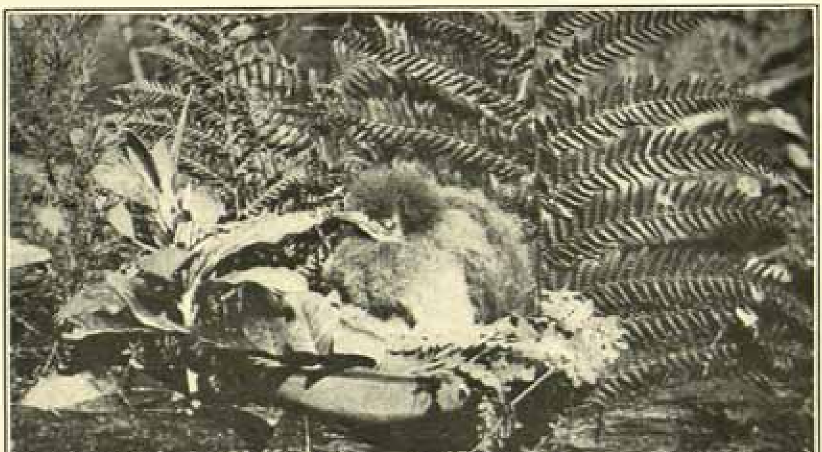
In the case of another nest near I found there was no sign of any old bird until the young one screeched on being touched. Then, like a flash, the female bird was on the spot, uttering notes somewhat similar to those of a "clucking hen." On seeing me she flew first into a tree fern, watching intently meanwhile, then onto the ground and scratched away, gradually working up almost to within kicking distance. All this time she quietly imitated three or four notes of the magpie and those of a few other birds. When any movement was made she jumped or ran away a few yards and resumed her quest for grubs. When the young one screeched rapidly several times in succession the mother, after giving her answering call, "koo-wuk′, koo-wuk′," made a noise like a woman in hysteria. She calmed down when the young one stopped its noise, and with a grating, purring noise floated down to the ground and resumed scratching.

The young one when found on August 11, 1900, was probably about two days old. It had down on the crown and upper back, the rest of it being bare, showing the whole of the skin to be of a bluish-drab color. The abdomen was an abnormal size and the vent large, characteristics of all the young found. On September 11, on my approaching the nest, the young one jumped out, but was caught, when it screeched and struggled violently, using its feet vigorously. It

LYRE-BIRD (FEMALE).



EGG OF THE LYRE-BIRD (NATURAL SIZE).



YOUNG (IN DOWN) OF LYRE-BIRD.

was most unwilling to enter the nest and acted like the other one when placed therein. On September 16 I again visited the nest with a view to photographing it, but, as feared, found it empty.

Another young one nearly full grown sat up silently in the nest when found, but when touched it struggled and screeched, using its claws freely. In this case the female bird came rushing up at once, but on seeing me darted back into the scrub and ran round the nest, making meanwhile her "koo-wuk′, koo-wuk′," and in addition the "clungk, clungk," or "buln, buln," that lyre birds make when undisturbed in the scrub. This nest was within half a mile of Jumbunna township, in an easily penetrable patch of scrub, which probably accounted for the timidity of the parent bird.

For the descriptions of nest, egg, etc., reference should be made to Mr. A. J. Campbell's and Mr. Robert Hall's descriptions in their publications.[a] Nevertheless, I shall give a few further personal observations. Nests have been found in various places. The one most favored by the bird in South Gippsland is the side of a deep channel or creek under a slightly overhanging bank, with ferns and leaves about (see plate v). Another favorite one is among the roots of a large fallen tree several feet from the ground with vegetation growing out of the contained earth. In the Baw Baw and Walhalla districts Mr. J. Easton tells me that a large proportion of the nests occurs in tall stumps of trees. All the nests are placed so that the bird can have a clear space through which to fly or float out of sight on the approach of danger.

It has been stated that once a lyre bird's egg has been touched by human hands the bird deserts the nest. However true this may be in individual cases, it by no means is general. On August 26, 1900, I found a nest in South Gippsland and handled the egg. Between this date and September 13 I handled the egg on six different occasions. On the last visit the egg was quite cold, and the nest appeared to have been deserted, but on again visiting it on the 15th a young one, apparently just hatched, was in it. The young bird was partially covered with down, as in the cases of those already mentioned. On September 23, 1900, the feathers were just showing through the skin on the top of the wings and the upper back. Further observations on this I had no opportunity to make, on account of leaving the locality. During this survey several abandoned nests, each with one egg, were found. In these cases I do not think that the nests had been voluntarily abandoned, but that the birds had been killed.

All the young birds mentioned in this article were sent to the National Museum, Melbourne, where they can be seen in the scenic case of the lyre birds.

[a] A. J. Campbell, Nests and Eggs of Australian Birds, pp. 510–523; Robert Hall, The Insectivorous Birds of Victoria, pp. 171–176.

DANCING GROUNDS.

These dancing grounds are open spaces, generally about 3 feet in diameter, situated preferably in a rather clear place in a patch of dense scrub. In some cases they are raised several inches above the general level of the surrounding ground, while in others there is little or no difference in level. The surface, which is flat, appears to have been scratched up by the birds, and the sticks, roots, and pieces of grass or creepers thrown to one side. Numerous examples have been noted in various parts of eastern Victoria, but in no case have I seen any evidence of a beating down of the surface. They all had a more or less freshly scratched appearance. On only one occasion have I been fortunate enough to see the birds dancing. This was on the top of Mount Wild Boar, about 8 o'clock on a foggy morning (March 19, 1896). When walking quietly alone along a track I suddenly heard and immediately saw two male birds performing on one of these grounds. They were alternately advancing and receding, turning, bowing, whirling, hopping, and running about round the ground. While doing this they raised and lowered their tails repeatedly. Sometimes they put their heads through their raised tails, and, turning them, seemed to be admiring the lyre designs thereon. At the same time they were, in rather subdued tones, whistling beautifully and mimicking all the forest birds. One female bird walked quietly round the dance, making a few short, hen-like notes, and pretended to pick up a grub here and there and to be unconcerned about the dance. She, however, cast occasional glances at the male birds, and was doubtless making her choice of a mate. I was in a hurry to search for a missing horse, and could not watch them for more than a few minutes, so quietly went past and left them undisturbed.

MIMICRY.

The lyre bird is an extraordinarily good mimic. No sound is too difficult for it to reproduce, and the imitation, in the case of all sweetly musical notes, is an exact reproduction of the originals, while of those of a harsh nature it is a highly refined imitation. Its rendering of the rich liquid notes of the gray magpie (*Strepera cuneicaudata*), the butcher bird (*Cracticus destructor*), the gray thrush (*Collyriocincla harmonica*), and the magpie (*Gymnorhina leuconota* and *G. tibicen*) is superb; similarly with the chirp and twitter of the small scrub wrens and tits. In the case of the laughing jackass (*Dacelo gigas*) the harsh, grating, laughter-like effort of this quaint bird is rendered in a manner so refined as to afford a pleasing contrast with the original. The swish of the coach-driver's whip, the sound of the saw and ax, which I have heard on the Blacks Spur and near Marysville, are perfect deceptions, and the rapidity with which the notes of various

PLATE V.

NEST (ON GROUND) OF LYRE-BIRD.

LYRE-BIRD (MALE).

birds are rendered, the gliding of one bird's notes into those of another, and the rendering of two or more simultaneously are nothing short of marvelous. The male bird is much the better and more powerful whistler, but the female is practically as good a mimic. I have no doubt that the lyre bird is a mocking bird, for, even supposing it to owe to heredity its faculty for imitating the birds of the forest, as has been suggested, it can have acquired the art of imitating sounds of human origin only since the settlement of the country in which it is found.

LYRE BIRDS IN CAPITIVITY.

It is generally supposed that these birds can not be reared and kept in captivity. Several attempts have, I believe, been made in the Zoological Gardens, Melbourne, but the birds have always died in a short time. There are several instances known, however, in which such attempts have been successful. The most notable one is that of a resident of the Woods Point district (Upper Goulburn), who, so Mr. O. A. L. Whitelaw tells me, reared several of these birds, which fed with the fowls and were quite tame. The owner decided upon proceeding to America to exhibit the birds as one of the curiosities of Australia, but before matters had been arranged all of them were poisoned, it was supposed, by some malicious person.[a]

Other instances have been cited of a lyre bird having been reared and kept for lengthened or brief periods of time[b] in the Drouin,

[a] Writing under "Nature notes" in The Argus of July 28, 1905, Mr. Donald Macdonald incidentally substantiates this fact. A correspondent, Mr. J. C. Mahan, of Woods Point, in giving some particulars about saving and keeping lyre birds in captivity, states: "When I found a nest I left the chicken for thirty days after it was hatched; then snared the old bird, and carried them with the nest to a large wire-netted aviary. The chicken was thus fed naturally by the mother. On one occasion I had a chicken in the nest for forty-two days. A bird that had been in my aviary for three or four years developed only three of the 'fronded feathers.' In my opinion the male bird does not reach its full plumage for eight years. I have never found more than 24 of the brown bars on a mature bird. It was a tedious and difficult task to accustom my birds to artificial food, and I lost thirteen before succeeding. The proof that I got the right system in the end was shown in the fact that after my birds had been maliciously poisoned they were opened and found to be lined with healthy fat, as the saying is. The late Mr. A. C. Le Souëf offered me £40 for the collection, and later Jamrach's agent offered £115 a pair for three domesticated pairs, to be delivered in London. I was going to accept this offer, when all my birds were poisoned; then I lost heart and gave it up. If the national park is ever established some lyre birds should be turned down there. With the right conditions they would breed in captivity. The experience of my own aviary satisfied me as to that."—*Eds.*

[b] Mr. F. P. Godfrey in The Emu (Vol V., p. 33) mentions Mr. S. McNeilly, of Drouin, having had a male lyre bird in a state of domestication for twenty years. A photograph of this particular bird is herewith given. (See Plate VI.)—*Eds.*

Loch, and Omeo districts. Personally, I think it would be impracticable to keep a bird in captivity even after rearing it unless it had access to some scrub affording shelter and a supply of insects.

GENERAL NOTES.

Though lyre birds are chiefly found in the dense scrubby forest, they at times can be seen in fairly open country, but in such cases there is dense scrub at hand, and they disappear into this on the first approach of danger. In South Gippsland, where I have seen and heard hundreds of these birds, I never once saw them singing in cleared land, or even in open forest. Moreover, in no instance have I seen them feeding or running about on open ground. On one occasion I noticed about eight of them cross a narrow strip of cleared ground, about 5 chains wide, from one patch of scrub to another. They did this just before dusk by running quickly, jumping over logs, and floating, one after the other. During the great bush fires in South Gippsland in 1898 hundreds of lyre birds were burnt or starved, and I have been told by settlers that in the Jeetho district some of these birds came out of the burnt scrub and fed among the fowls near the farmhouses. This was doubtless owing to the destruction of insect life. It would indicate that they could in necessity become graminivorous birds. Mr. J. W. Bainbridge informs me that two lyre birds have become so tame near Mrs. Manfield's Temperance Hotel, at the foot of Mount Buffalo, that Mr. Manfield has photographed one of the pair perched on the fence near the place.

Lyre birds may be seen at altitudes from 100 feet above sea level in the dense gullies of South Gippsland to those of close on 6,000 feet, or as high as arboreal vegetation ascends, in the Australian Alps. In November, 1890, when returning to Harrietville from Mount Feathertop (6,303 feet), in the Australian Alps, I saw between twenty and thirty male and female lyre birds on the stunted snow gums (*E. pauciflora*) on the high ridge running from Feathertop and separating the Ovens River from Snowy Creek. They were at an altitude of about 5,700 feet and near the timber line. It was nearly sunset when I was surprised to hear a medley of melodious sounds, as if all the birds of the bush were singing their best and loudest. Being alone and on foot, I was in their midst before they noticed me, but to my surprise they not only remained jumping about the trees, or with heads inclined watched me from the branches, but many of them continued their unsurpassable mimicry of other forest birds. I regretted that approaching darkness did not allow me to stay and watch them longer. At altitudes of from 5,000 feet to the timber line I have seen these birds, or evidence of them, on the high

Gibbo Range, Mount Wild Boar, Mount Bogong, Mount Stirling, in Benambra, Victoria, and on the high timbered spurs of Mount Kosiciusko, New South Wales.[a] Once, when camped, on March 20, 1896, on the summit of Mount Wild Boar, at an altitude of over 5,000 feet, I was awakened shortly after sunrise by beautiful and spirited whistling outside the tent entrance. On jumping up I found a male bird peering into the tent from a branch only a few feet away. After putting the camera together as hastily as circumstances permitted I had the mortification of seeing the bird glide away into the thick scrub just as I was about to take the photograph. Mr. Bainbridge informs me that he has heard during the winter a lyre bird whistling on Mount Buffalo at an altitude of 3,500 feet and quite close to snow.

Lyre birds are very inquisitive when found in districts or places where they have not been molested by man. On passing through such country one is sometimes escorted for some distance by these birds, which pass from tree to tree along the line of march. I have been informed by Messrs. W. Baragwanath, jr., and J. Easton, that once when they were surveying a line on the flanks of Mount Baw Baw a female bird came close up to the chain, watched it intently, and followed it as it was dragged along. Every time they made a noise the bird gave the well-known alarm whistle and darted into the scrub, to return almost immediately and repeat these tactics for some time. On another occasion, in a creek near Mount Useful, a male bird viewed them from blackwood trees 60 to 70 feet high and disappeared only after several sticks had been thrown at him. On other occasions they have brought these birds close up to themselves by whistling the birds' own notes, in the same way that the king lory can be decoyed.

Unlike some of the native birds which give their songs at certain times through the day, lyre birds may be heard in their haunts any time from dawn till dusk, regardless of the nature of the weather. On a misty day, when steady, light rain is falling, they may, perhaps, be said to be heard to the greatest advantage.

Lyre birds are inveterate scratchers and are almost unceasingly at such work, somewhere or other in the bush. They must do a great deal of good by destroying myriads of insects destructive to vegetation. Unwittingly they also do a certain amount of harm, by partially obliterating tracks, filling up side cuttings and survey trenches, and uprooting or burying survey pegs. Some years ago

[a] Hitherto *Menura victoria* has been recorded for Victoria only, but it is natural to suppose that the same species is found in the ranges extending over the border of New South Wales. It is probable that *M. superba* is not found south of the Blue Mountains. If it exist farther south, it would be interesting to find where the two species inosculate, if not intergrade.—*Eds.*

I remember seeing a recently made track over the Bogong Pass, in Victoria, which had been rendered impracticable for horse traffic though being filled up in some places with masses of rock, logs of wood, and other débris. These had rolled down the steep sides of the mountain on account of their supports of humus and soil having been scratched away by these birds. Again, it is often impossible to exactly locate a survey trench or peg in lyre bird ("pheasant," as it is called by selectors) country, sometimes even shortly after they have been placed there. This causes some difficulty when the blaze (ax-cut mark) on the tree has been destroyed by bush fires. This habit of scratching among decayed vegetation and soil may account for the abundance of lice which Mr. W. Bragwanath, jr., informs me, are to be found on most of these birds in the Baw Baw district of Gippsland.

I have spoken of the flight of lyre birds as a floating. As far as I have noticed they do not rise upward in the air like a soaring bird, and can not make a proper upward flight. But in going to a lower place they simply jump off a log or rock into the air with their wings outspread, and float or glide through it down a slope into a gully, sometimes taking advantage, every here and there, of a log or rock from which to get an additional spring. In a few seconds they can descend several hundreds of feet with very little apparent motion of the wings. It is an interesting sight to see the dark brown form of a departing lyre bird as it hops on a fallen tree, floats under a tree fern, or jumps off into space—silent, save for its first shrill whistle of alarm. While lyre birds are fond of tree-fern gullies and dogwood (*Cassinia aculeata* and *C. longifolia*), "native hop" (*Daviesia latifolia*), and "wild hop" (*Goodenia ovata*) slopes and ridges, they are very partial to the patches of "blanket wood" (*Senecio bedfordi*). This plant grows into small trees with lateral branches, and large, thick leaves, arranged more or less horizontally, thus forming a canopy. The ground beneath is usually not covered with ferns and small plants, but with decayed leaves and twigs, while the branches form convenient perches for the lyre birds. There are thus open spaces between the foliage and the ground, and the birds are fond of moving about in them, hence the scrub is called locally "pheasant scrub."

My thanks are tendered to Messrs. A. J. Campbell, D. Le Souëf, and F. P. Godfrey for six of the photographs which illustrate this article.

THE INFLUENCE OF PHYSICAL CONDITIONS IN THE GENESIS OF SPECIES.[a]

By Joel A. Allen.

Among biologists who accept the modern theory of evolution as the only reasonable hypothesis available for the explanation of the diversity of structure among organized beings, there is a wide difference of opinion as to what are the leading causes of differentiation. The doctrine of natural selection, or the survival of the fittest, has recently been brought prominently forward as the key to this complex problem, and is upheld by a large class of enthusiastic adherents, who accept it as the full solution of the whole question. By others the conditions of environment are believed to be far more influential in effecting a certain class of modifications, at least, than the necessarily precarious influence of natural selection, which must take its origin in isolated instances of variation in favorable directions, and depend for its continuance upon these fortuitous advantages being inherited by the descendants of the favored individuals in which they originate. The modifying influence of conditions resulting from geographic or climatic causes was long since noticed, and for nearly a century has been considered by many writers as explanatory of much of the diversity existing not only in the human race but among animals. It has, however, remained until recently vaguely grounded, being based more in conjecture than on observed facts. Scarcely, indeed, have two decades passed since the real nature and extent of geographical variation among animals, and even as yet among only a few species, began to receive careful attention, while only within the last fifteen years has any attempt been made to correlate the observed differences with the climatic or geographical conditions of habitat. Only within recent years have the differences in general size, and in the relative size of different parts, been ascertained by careful measurement, and the differences in the character of the tegumentary covering (as the pelage in mammals) and in color, in indi-

[a] Reprinted, with note and bracketed additions by the author, from the Radical Review, 1, 1877, pp. 108–140.

viduals of the same species inhabiting distant portions of a common habitat, been duly recorded. In the work of registering these instructive data, it has fallen to Americans to take a leading part, large credit in the matter being due not only to the activity of our professional biologists, but to the liberality of the General Government in attaching competent natural history observers and collectors to the numerous surveying parties it has sent out during the last twenty years to explore the till then practically unknown geography and productions of our western Territories.

The combined fruits of their labors, together with those of the agents and correspondents of the Smithsonian Institution, have resulted in the accumulation of an amount of material far exceeding that elsewhere accessible to single investigators, representing, as it does, at least two of the vertebrate classes of animals from the whole North American continent so fully that generalizations may be made from their study which could not otherwise have been reached for many years and for which no similar facilities for any other equal area as yet exist. The recent investigations of American mammalogists and ornithologists have been in consequence largely directed to the subject of geographical variation, and their publications teem with tabulated measurements and records of variations in form and color that accompany differences in the climatic or geographical conditions of habitat. Among the results that have followed are the discovery of numerous interesting geographical varieties or subspecies, and the demonstration of the complete intergradation of many forms, often quite widely diverse in color, size, and proportion of parts, formerly regarded (and properly so as then known) as unquestionably distinct species, which discoveries have of course necessitated a large reduction in the number of recognized "specific" or nonintergrading forms. But most important of all has been the correlation of local variations with the conditions of environment, and the deduction therefrom of certain laws of geographical variation. Upon these have been based hypotheses that go far toward explaining many of the phenomena of intergradation and differentiation observed among existing animals. In the present paper will be given not only a summary of the results thus far attained, but enough of the details of the subject to show the nature of the evidence on which rest the conclusions already reached. These results, it is claimed, show that other influences than natural selection operate powerfully in the differentiation of specific forms, and that geographical causes share more largely in the work than naturalists have heretofore been prepared to admit—at least to consider as proven.

As is well known, animals vary greatly in respect to the extent of the areas they inhabit. While a few species are nearly or quite cosmopolitan, many others are restricted to single small islands or to

limited portions of a continent. Not a few range over the greater part of whole hemispheres, while by far the larger number are confined within comparatively narrow limits. Of the numerous species of mammals and birds inhabiting North America, none are equally common throughout the whole extent of the continent. The habitats of a few only extend from the Barren Grounds of the Arctic regions to Mexico, and from the Atlantic coast westward to the Pacific; one or two only among the mammals range over the whole continent from Alaska to Central America, while some occupy merely the extreme boreal parts of the continent. The latter, in many cases, range also over the Arctic and sub-Arctic regions of the Old World. Others extend from Arctic America southward to the United States. Still others occupy only the middle or more temperate latitudes, being unrepresented in the extreme north or the extreme south. Others, again, first appear in the middle or more southerly parts, and range thence southward far into the Tropics. A large number are restricted to the region east of the Rocky Mountains; others are confined to a narrow belt along the Pacific coast; and others still to limited areas of the great Rocky Mountain Plateau. In general, their distribution accords with climatal regions or zones, their respective ranges being limited in part by latitude and in part by geographical barriers, as treeless, arid plains, or high mountain ranges. The northern and southern boundaries of the habitat of a species are found to agree, not generally with the arbitrary parallels of the geographer, but with isothermal lines, these being more or less different for each species. The geographical distribution of a species is thus mainly determined by climatic or other physical causes, though in part, doubtless, by its organic constitution. In most cases species that are wide ranging are the most variable, as would naturally follow from their being subjected, in the different portions of their habitats, to widely different environing circumstances.

Hence such species are often found to run into numerous local races, some of them greatly differing from others, but still inseparably connected by individuals inhabiting the intervening regions. Over districts slightly diversified, even if of large extent, species generally preserve comparative constancy of character, while, conversely, local races are of frequent occurrence in regions of alternating valleys, mountain ranges, and table lands, and more especially is this true if the highly diversified region be situated in the warmer latitudes. Small islands, remotely situated from other lands, have usually many species peculiar to themselves, their differentiation being proportionate to the geologic antiquity of the islands and their remoteness from larger land areas. In islands of recent origin and not widely separated from continental lands, the ancestral stock of the species is still often

clearly apparent, the forms thus differentiated through insular influences not having passed beyond the varietal stage; in other cases they are specifically different from their nearest continental allies, or may even have advanced far toward generic distinctness, while their origin may still remain tolerably apparent.

Plasticity, or susceptibility to the influences of physical surroundings, often differs even among quite closely allied species, as those of the same family or even genus, and different species are evidently affected differently by the same circumstances. Variability in color may or may not accompany variability in size or in the character of particular organs. Generally, however, a species which varies greatly in one feature varies to a similar degree in many others. Species having a wide geographical range not only commonly run into a greater or less number of local races, but they generally present more than the average amount of strictly individual variation, as though species ranging widely in space were originally more plastic than those having more circumscribed habitats, and were thus able more easily to adapt themselves to their surroundings; they are also more persistent, their fossil remains being far more frequently met with in the quaternary deposits than are those of the more local and generally more specialized forms.

Geographical variation, as exhibited by the mammals and birds of North America, may be summarized under the following heads, namely, (1) variation in general size, (2) in the size of peripheral parts, and (3) in color, the latter being subdivisible into (a) variation in color with latitude and (b) with longitude. As a rule, the mammals and birds of North America increase in size from the south northward. This is true not only of the individual representatives of each species, but generally the largest species of each genus and family are northern. There are, however, some strongly marked exceptions, in which the increase in size is in the opposite direction, or southward. There is for this an obvious explanation, as will be presently shown, the increase being found to be almost invariably toward the region where the type or group to which the species belongs receives its greatest numerical development and where the species attain the largest size, and are also most specialized. Hence the representatives of a given species increase in size toward its hypothetical center of distribution, which is in most cases doubtless also its original center of dispersal. Consequently there is frequently a double decadence in size within specific groups, and both in size and numerically in the case of species when the center of development of the group to which they belong is in the warm temperate or tropical regions. This may be illustrated by reference to the distribution of the higher classes of vertebrates in North America. Among the species occurring north of Mexico there are very few that may not be supposed to have had

a northern origin; and the fact that some are circumpolar in their distribution while most of the others (especially among the mammals) have congeneric Old World allies further strengthens the theory of their northern origin. Not only do individuals of the same species increase in size toward the north, but the same is true of the species of the different genera. Again, in the exceptional cases of increase in size southward, the species belong to southern types, or, more correctly, to types having their center of development within or near the intertropical regions, where occur not only the greatest number of the specific representatives of the type, but also the largest.

For more detailed illustration we may take three families of the North American Carnivora—namely, the Canidæ (wolves and foxes), the Felidæ (lynxes and wild-cats), and the Procyonidæ (raccoons). The first two are to some extent cosmopolitan, while the third is strictly American. The Canidæ have their largest specific representatives the world over, in the temperate or colder latitudes. In North America the family is represented by six species,[a] the smallest of which, speaking generally, are southern and the largest northern. Four of them are among the most widely distributed of North American mammals, two, the gray wolf and the common fox, being circumpolar species; another, the Arctic fox, is also circumpolar, but is confined to high latitudes. The three widest-ranging species—the gray wolf, the common fox, and the gray fox—are those which present the most marked variation in size. Taking the skull as the basis of comparison, it is found that the common wolf is fully one-fifth larger in the northern parts of British America and Alaska than it is in northern Mexico, where it finds the southern limit of its habitat. Between the largest northern skull and the largest southern skull there is a difference of *about 35 per cent of the mean size!* Specimens from the intermediate region show a gradual intergradation between these extremes, although many of the examples from the upper Missouri country are nearly as large as those from the extreme north.

The common fox, though occurring as far north as the wolf, is much more restricted in its southward range, especially along the Atlantic coast, and presents a correspondingly smaller amount of variation in size. The Alaskan animal, however, averages about one-tenth larger than the average size of specimens from New England.

[a] The gray wolf (*Canis lupus* [=*C. occidentalis* and allied forms]), the prairie wolf (*C. latrans* [now treated as a group of a dozen or more closely related species and subspecies]), the Arctic fox (*Vulpes lagopus* [now separated into several forms]), the common fox (*V. alopex* [=*V. fulvus* and numerous related forms]), the kit fox (*V. velox* [now subdivided into several forms]), and the gray fox (*Urocyon virginianus* [=*U. cinereoargenteus*, with a dozen or more subspecies]).

In the gray fox, whose habitat extends from Pennsylvania southward to Yucatan, the average length of the skull decreases from about 5 inches in Pennsylvania to considerably less than 4 in Central America—a difference equal to about 30 per cent of the mean size for the species.

The Felidæ, unlike the Canidæ, reach their greatest development, as respects both the number and the size of the species, in the intertropical regions. This family has but a single typical representative—the panther (*Felis concolor*)—north of Mexico, and this ranges only to about the northern boundary of the United States. The other North American representatives of the family are the lynxes, which, in some of their varieties, range from Alaska to Mexico. They form, however, the most northern as well as the most specialized or "aberrant" type of the family. While they vary greatly in color as well as in the length and texture of the pelage at different localities, they afford a most remarkable exception to all laws of variation in size with locality; for a large series of skulls, representing localities as widely separated as Louisiana, northern Mexico, and California on the one hand and Alaska and the Mackenzie River district on the other, as well as various intermediate localities, reveals no appreciable difference in size throughout this wide area. The true cats, however, as the panther and the ocelots, are found to greatly increase in size southward or toward the metropolis of the family. The panther ranges from the Northern States southward over most of South America. Skulls from the Adirondack region of New York have an average length of about 7¼ inches, the length increasing to 8¾ in Louisiana and Texas, from beyond which points there is lack of data. The ocelot (*Felis pardalis*) finds its northern limit near the Rio Grande of Texas, and ranges thence southward far into South America. The average size of Costa Rican examples is about one-fifth greater than that of specimens from the Rio Grande.

The Procyonidæ are chiefly represented in tropical America, a single species—the common raccoon (*Procyon lotor*)—being found in the United States, and thence northward to Alaska [=British Columbia]. Here again the increase in size is southward or toward the metropolis of the family—Pennsylvania specimens averaging about one-tenth smaller than Costa Rican examples.

The common otter (*Lutra canadensis*) affords another example of increase in size southward among our Carnivora, although belonging to a family essentially northern in its distribution. The otters, however, form a distinct subfamily, which attains its greatest number of species in the warmer regions of the earth, and hence offers not an exception to but a confirmation of the law of increase toward the center of distribution of the group to which it belongs.

Instances of increase in size northward among the Carnivora of North America are so generally the rule that further space need not be taken in recounting examples in detail. It may suffice to state that the badger (*Taxidea americana*), the marten (*Mustela americana*), the fisher (*M. pennanti*), the wolverine (*Gulo luscus*), and the ermine (*Putorius ermineus* [= *longicauda, cicognanii, noveboracensis*, etc.])—all northern types—afford examples of variation in size strictly parallel with that already noticed as occurring in the foxes and wolves.

To refer briefly to other groups, it may be stated that the Cervidæ (deer family) are mainly rather northern in their distribution; that the largest species occur in the colder zones, and that individuals of the same species increase rapidly in size toward the north. Some of the species in fact afford some of the most striking instances of northward increase in size, among which are the common Virginia deer and its several representatives in the interior of the continent and on the Pacific slope. It is also noteworthy that the most obviously distinctive characteristic of the group—the large, annually deciduous antlers—reaches its greatest development at the northward. Thus all the northern species, as the moose, the elk, and the caribou, have branching antlers of immense size, while the antlers are relatively much smaller in the species inhabiting the middle region of the continent and are reduced to a rudimentary condition—a simple slender sharp spike, or a small and singly forked one—in the tropical species, the antlers declining in size much more rapidly than the general size of the animal. This is true in individuals of the same species as well as of the species collectively.

The Rodentia (the squirrels, marmots, spermophiles, mice, and their affines) offer the same illustrations in respect to the law of increase in size as the species already mentioned, the size sometimes increasing to the southward, but more generally to the northward, since the greater number of the species belong decidedly to northern types. There is no more striking instance known among mammals of variation in size with locality than that afforded by the flying squirrels, in which the northern race is more than one-half larger than the southern; yet the two extremes are found to pass so gradually the one into the other that it is hardly possible to define even a southern and a northern geographical race except on the almost wholly arbitrary ground of difference in size. The species, moreover, is one of the most widely distributed, ranging from the Arctic regions (the northern limit of forests) to Central America.

Among birds the local differences in size are almost as strongly marked as among mammals and, in the main, follow the same general law. A decided increase in size southward, however, or toward

the warmer latitudes, occurs more rarely than in mammals, although several well-marked instances are known. The increase is generally northward and is often very strongly marked. The greatest difference between northern and southern races occurs, as in mammals, in the species whose breeding stations embrace a wide range of latitude. In species which breed from northern New England to Florida the southern forms are not only smaller, but are also quite different in color and in other features. This is eminently the case in the common quail (*Ortyx virginianus*), the meadow lark (*Sturnella magna*), the purple grackle (*Quiscalus purpureus*), the red-winged blackbird (*Agelæus phœniceus*), the golden-winged woodpecker (*Colaptes auratus*), the towhee (*Pipilo erythrophthalmus*), the Carolina dove (*Zenædura carolinensis*), and in numerous other species, and is quite appreciable in the blue jay (*Cyanurus cristatus*), the crow (*Corvus americanus*), in most of the woodpeckers, in the titmice, numerous sparrows, and several thrushes and warblers, the variation often amounting to from 10 to 15 per cent of the average size of the species.[a]

As a general rule certain parts of the organisms vary more than does general size, there being a marked tendency to enlargement of peripheral parts under high temperature or toward the Tropics; hence southward in North America. This is more readily seen in birds than in mammals, in consequence mainly of their peculiar type of structure. In mammals it is manifested occasionally in the size of the ears and feet and in the horns of bovines, but especially and more generally in the pelage. At the northward, in individuals of the same species, the hairs are longer and softer, the under fur more abundant, and the ears and the soles of the feet better clothed. This is not only true of individuals of the same species, but of northern species collectively, as compared with their nearest southern allies. Southern individuals retain permanently in many cases the sparsely clothed ears and the naked soles that characterize northern individuals only in summer, as is notably the case among the different squirrels and spermophiles.

In mammals which have the external ear largely developed, as the wolves, foxes, some of the deer, and especially the hares, the larger size of this organ in southern as compared with northern individuals of the same species is often strikingly apparent. It is more especially marked, however, in species inhabiting extensive open plains and semidesert regions. The little wood hare, or gray "rabbit" (*Lepus*

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[a] The modern equivalents of several of the technical names in this paragraph are as follows: *Ortyx* [=*Colinus*] *virginianus*; *Quiscalus purpureus* [=*quiscula*]; *Zenædura carolinensis* [=*Zenaidura macroura*]; *Cyanurus* [=*Cyanocitta*] *cristata*; *Corvus americanus* [=*brachyrhynchos*].—*Author's note*, 1906.

sylvaticus),[a] affords a case in point. This species is represented in some of its varieties across the whole breadth of the continent and from the northern border of the United States southward to Central America, but in different regions by different geographical races or subspecies. In addition to certain differences of color and general size, the ears vary still more strongly. In the form inhabiting the Great Plains, commonly known as the little sagebrush hare (*L. sylvaticus nuttalli*), the ears are considerably longer than in the eastern variety and increase in size from the north southward, reaching their greatest development in western Arizona and the desert region farther westward and southward, where the variety of the plains proper passes into still another variety characterized mainly by the large size of its ears, which are in this race nearly twice the size they attain in the eastern variety. In the large long-eared "jackass" hares of the plains the ear likewise increases in size to the southward. In *Lepus callotis*,[b] for example, which ranges from Wyoming southward far into Mexico, the ear is about one-fourth to one-third larger in the southern examples than in the northern. The little brown hare of the Pacific coast (*L. trowbridgei*) presents a similar increase in the size of the ear southward, as does to a less extent the prairie hare (*L. campestris*). Not only are all of the long-eared species of American hares confined to the open plains of the arid interior of the continent, but over this same region is the tendency to an enlargement of the ear southward stronger than elsewhere. It is also of interest in this connection that the largest-eared hares of the Old World occur over similar open, half-desert regions, as do also the largest-eared foxes. On our western plains the deer are represented by a large-eared species. Among the domestic races of cattle those of the warm temperate and intertropical regions have much larger and longer horns than those of northern countries, as is shown by a comparison of the Texan, Mexican, and South American breeds with the northern stock, or those of the south of Europe with the more northern races. In the wild species of the Old World the southern or subtropical are remarkable for the large size of their horns. The horns of the American pronghorn (*Antilocapra americana*) are also much larger at southern than at northern localities.[c] Naturalists

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[a] The group here referred to as *Lepus sylvaticus* has in recent years been divided into some twenty-five or more forms, mostly with the rank of subspecies.—*Author's note, 1906.*

[b] *Lepus callotis*, as now recognized, does not occur north of Mexico; in place of this name may be substituted *Lepus texianus* and its subspecies.—*Author's note, 1906.*

[c] The deer tribe, in which the antlers increase in size toward the north, offer an apparent exception to the rule of increase in size of peripheral parts toward the Tropics. The antlers of the deer, however, are merely seasonal appendages,

have also recorded the existence of larger feet in many of the smaller North American mammalia at the southward than at the northward among individuals of the same species, especially among the wild mice, in some of the squirrels, the opossum, and raccoon, as well as in other species.

In birds the enlargement of peripheral parts, especially of the bill, claws, and tail, is far more obvious and more general than in mammals. The bill is particularly susceptible to variation in this regard, in many instances being very much larger, among individuals of unquestionably the same species, at the southward than at the northward. This accords with the general fact that all the ornithic types in which the bill is remarkably enlarged occur in the intertropical regions. The southward enlargement of the bill within specific groups may be illustrated by reference to almost any group of North American birds, or to those of any portion of the continent. As in other features of geographical variation, the greatest differences in the size of the bill are met with among species having the widest distribution in latitude. Among the species inhabiting eastern North America we find several striking examples of this enlargement among the sparrows, blackbirds, thrushes, crows, wrens, and warblers; in the quail, the meadow lark, the golden-winged woodpecker, etc. Generally the bill in the slender-billed forms becomes longer, more attenuated, and more decurved (in individuals specifically the same) in passing from the New England States southward to Florida, while in those which have a short, thick, conical bill there is a general increase in its size, so that the southern representatives of a species, as a rule, have thicker and longer bills than their northern relatives, though the birds themselves are smaller. There is thus not only generally a relative, but often an absolute, increase in the size of the bill in the southern races. The species of the Pacific coast and of the interior afford similar illustrations, in some cases more marked even than in any of the eastern species. More rarely, but still quite frequently, is there a similar increase in the size of the feet and claws.

The tail, also, affords an equally striking example of the enlargement of peripheral parts southward. Referring again to the birds of the Atlantic coast, many of the above-named species have the tail absolutely longer at southern localities than at northern, and quite often relatively longer. Thus, while the general size decreases, the length of the tail is wholly maintained, or decreases less than the general size; but in some cases, while the general size is one-tenth or more smaller at the south the tail is 10 to 15 per cent longer than in the larger northern birds. Some western species are even more re-

being annually cast and renewed, and are thus entirely different physiologically from the horns of bovines, which retain a high degree of vitality throughout the life of the animal.

markable in this respect, and in consequence mainly of this fact the southern types have been varietally separated from the shorter-tailed northern forms of the same species.

Variations in color with locality are still more obvious, particularly among birds, in which the colors are more positive, the contrasts of tint greater, and the markings consequently better defined than is usually the case in mammals. The soft, finely divided covering of the latter is poorly fitted for the display of the delicate pencilings and the lustrous, prismatic hues that so often characterize birds. Mammals, however, present many striking instances of geographical variation in color.

As already stated, geographical variation in color may be conveniently considered under two heads. While the variation with latitude consists mainly in a nearly uniform increase in one direction, the variation observed in passing from the Atlantic coast westward is more complex. In either case, however, the variation results primarily from nearly the same causes, which are obviously climatic, and depend mainly upon the relative humidity or the hygrometric conditions of the different climatal areas of the continent. In respect to the first, or latitudinal variation, the tendency is always toward an increase in intensity of coloration southward. Not only do the primary colors become deepened in this direction, but dusky and blackish tints become stronger or more intense, iridescent hues become more lustrous, and dark markings, as spots and streaks or transverse bars, acquire greater area. Conversely, white or light markings become more restricted. In passing westward a general and gradual blanching of the colors is met with on leaving the wooded regions east of the Mississippi, the loss of color increasing with the increasing aridity of the climate and the absence of forests, the greatest pallor occurring over the almost rainless and semidesert regions of the Great Basin and Colorado Desert. On the Pacific slope north of California the color again increases, with a tendency to heavy, somber tints over the rainy, heavily wooded region of the northwest coast.

Geographical variation in color among mammals, for reasons already stated, is generally, but not always, manifested merely through the varying intensity or depth of the tints. It is, however, often strongly marked. The common chickaree, or red squirrel (*Sciurus hudsonius*), for example, which ranges from high northern latitudes southward over the northern portion of the United States, shows an increase in the color over the middle of the dorsal surface from pale yellowish or fulvous to rufous. The fox squirrel of the Mississippi Valley (*Sciurus niger, ludovicianus*), which ranges from Dakota southward to the Gulf of Mexico, has the lower parts, at the northward, very pale yellowish white, which tint gradually in-

creases in intensity southward till in Louisiana it becomes deep reddish orange, the dorsal surface also becoming at the same time somewhat darker. Excepting the fox squirrels and a Pacific-coast variety of the chickaree, all the squirrels living north of Mexico have the lower parts white, while those inhabiting tropical America have the lower parts fulvous, deep golden, orange, or even dark brownish red, specimens with the belly white being exceptional, though occasionally occurring in several of the species.

Mammals tend strongly to run into melanitic phases, which are especially developed at particular localities or over limited regions, but whether or not the result of geographical influences is not clearly evident. The whitening of the pelage in winter at the north in a considerable number of species of mammals and in one genus of birds, and not elsewhere, is, on the contrary, a strictly geographical phenomenon, but seems to be the result of other than the ordinary causes of geographical variation in color. Its occurrence in some species and its absence in others closely allied to them is a fact not readily explained. It shows, however, how differently different animals are affected by the same influences. The change to a white winter livery is more complete in the higher latitudes, where the whiteness pervades the pelage to a greater depth and continues for a longer period, the change being only partial in the southern representatives of species that exhibit this seasonal change of color.

In respect to southward increase in color among birds, a few examples only out of the many almost equally striking can be here given. These will be chosen from widely different groups and will represent localities remotely separated, as well as very diverse styles of coloration. In comparing, for instance, New England examples of the common quail with others from southern Florida the colors are found to be so much stronger and darker in the southern birds as to give the appearance of their being entirely distinct species, particularly when the smaller size and larger bills of the southern race are also considered. While in the northern birds the color of the dorsal surface is gray and rufous, slightly varied with black, the gray is wholly wanting in the the southern type, the rufous is much stronger, and the black markings are very much broader. The lower surface is varied by transverse bars of black and white, but while in the northern birds the white bars are twice, or more than twice, the width of the black ones, in the southern birds they are often of equal width; or the black bars may be the broader, with much more black bordering the white throat patch, giving, on the whole, a very much darker aspect to this region of the body. Yet when a series is brought together from many intermediate localities, there is found to be a complete intergradation between the most extreme phases. In the common towhee the style of coloration is entirely different

from that seen in the quail, the colors being chiefly massed in large areas, with white markings on the wings and large white spots at the ends of the outer tail feathers. In this species southern specimens differ from northern ones in the black of the upper parts and the chestnut of the sides being more intense, while the white markings on the wings and tail are greatly reduced in area. In the northern bird, four of the outer pairs of tail feathers have a large white spot near the end, while in the southern form only three pairs are thus marked.

In the purple grackle the plumage (in the males) is everywhere black, with, at the north, greenish or bronzy reflections; in the southern or Floridan form the black is more intense, and the reflections are steel blue and purple, with iridescent bars across the middle and lower parts of the back. In the northern form the female is dull brownish-black, with little or no iridescence, while in the southern form the female is nearly as lustrous as the northern male. The two types differ so widely, not only in color, but, as previously noticed, in size and in the form of the bill, that, without the connecting specimens from intermediate localities, no ornithologist would hesitate to regard them as entirely distinct species; and they were, indeed, at one time so regarded. The red-winged blackbird has, excepting its red wing patches, also a lustrous black plumage throughout, and presents a similar range of variation in general color with the preceding; while the red of the wing patch becomes much darker at the southward, and its creamy-white border seen in the northern form changes to yellowish-orange in the southern.

The common blue jay, and the long-crested jays of the Rocky Mountain region, may be cited as illustrations of southward increase in brilliancy or intensity of coloring where the prevailing tint is blue; the green Mexican and Rio Grande jays of a passage from yellowish-green tints into bright yellow; the yellow-throated warblers (genus *Geothlypis*), several of the flycatchers (genera *Myiarchus* and *Tyrannus*), and the meadow lark, as examples of increase in the area and intensity of yellow; several of the woodpeckers (genera *Centurus* and *Sphyrapicus*), the cardinal finches (genus *Cardinalis*), and some of the tanagers (genus *Pyranga*), of a similar increase of red; the goldfinches (genus *Chrysomtris*), and most of the species above named, of increase in extent and purity of black areas. The Rocky Mountain jays have, at the northward, a large portion of the plumage rather dark ashen, which farther southward becomes bluish ash, and still farther south culminates, in the Central American States, in blue. In the genus *Geothlypis*, the Maryland yellowthroat (*G. triches*), which ranges over the whole United States, and thence far southward, has at the northward the abdomen whitish; more to the southward, yellowish; and, in the West Indies, Mexico, and

northern South America, runs into races in which the abdomen is bright yellow. At the same time the black markings about the head increase in extent and purity and the general size becomes larger, the group having its metropolis in the tropical regions. In consequence of these variations in color and size this species at the southward becomes differentiated into several more or less well-marked subspecies (formally accorded full specific rank), which are connected by an unbroken series of intergradations.

In the great-crested flycatcher (*Myiarchus crinitus*) of the United States the yellow of the abdominal region is much the stronger in the southern birds, while the same is true of several of the western species of the same genus, which at the southward also pass into several recognizable subspecies.

The western goldfinch (*Chrysomtris psaltria*) affords a well-known instance of increase of black. This species is found in the western half of North America from about the parallel of 40° southward to Ecuador. The northern form has the black of the upper parts mainly restricted to the head, wing, and tail, the rest of the dorsal surface being olive green. In northern Mexico the back begins to be more or less clouded with black, which tint increases in extent in Central America till it wholly replaces the olive green, while in northern South America it becomes more intense and lustrous. In northern specimens the tail is marked with white spots, which either decrease greatly in size or become wholly obsolete in the southern races. The extremes, as may well be imagined, are widely diverse in their coloration and, though formally regarded as entirely distinct species, have been found so thoroughly to intergrade that it is impossible to draw any lines of separation between the several races. Lawrences's flycatcher (*Myiarchus lawrencei*) affords also a striking example of southward increase in the area and intensity of black. At the northward this species has a grayish-black crown, which gradually passes southward into a form with the crown wholly deep black. With the increase southward of the area and intensity of black markings there is also in this, as in other species, a general increase in the intensity or depth of the other accompanying tints.

The red-bellied, or Carolina, woodpecker (*Centurus carolinus*), a common bird of the United States, shows a strong increase of red on the head and lower surface of the body at the southward, in which this tint is not only much brighter, but also much more extended in the south Florida birds than in those from the Northern States. At the same time it presents, in common with other species of the same family, a marked southward decrease in the size of the white transverse bars and spots of the dorsal plumage.

In the southern portion of the Mississippi Valley the variation is

in a tropical direction, and is merely due to the more northward extension there of tropical influences. In passing to the plains and the Great Basin west of the Rocky Mountains, however, an entirely different phase of color variation is met with. Here, as a general rule, there is a loss of color, this region being characterized by the presence of subdued or faded tints in the representatives of species having a nearly continental range. The transition, however, is as gradual as is that of the climatic conditions, the paleness beginning near the eastern border of the Great Plains and increasing westward, reaching its extreme phase in the arid wastes of the almost wholly rainless districts of the far Southwest—south Nevada, Arizona, and the contiguous region westward and southward. In respect to this part of the subject it is hardly necessary to say more than that the representatives of continental species found here are uniformly much paler than those inhabiting the adjoining regions; that in many cases the paler forms were originally described as distinct species, and are commonly recognized as varietally distinct, though found to inseparably intergrade with the neighboring darker forms. In addition to the general paleness there is often an increase in the areas of white and in some cases an accession of new ones.

The wooded, mountainous districts embraced in this region also give rise to peculiar local phases of color variation, to give a detailed account of which would too greatly extend the present paper. The tendency is mainly toward the development of more or less well-marked rufous or fulvous phases of coloration, with sometimes an accession of red, while not a few species have more than the usual amount of black. A most striking instance of increase of red at western localities is seen in the yellow-bellied woodpecker (*Sphyrapicus varius*)[a] which, in some of its forms, ranges in the breeding season over the more northern and elevated wooded portions of the continent. In its eastern form the male has merely the chin, throat, and crown red, while in the female the red is restricted to the crown. In rare instances there is a trace also of a narrow red nuchal band. In the Rocky Mountain form, however, there is always a red nuchal band, the red on the throat is more extended in the male, and a small area of red appears also on the throat of the female. In the form met with in the Cascade Range the red begins to spread over contiguous portions of the plumage, while in the form occurring along the Pacific coast the red overspreads the whole head, neck, and breast, through which, however, the markings of the eastern birds can generally be readily traced. Here we have, at one end of the series, the red confined to a few distinct patches about the head, while at the other it

[a] In 1877 *Sphyrapicus varius* included *S. ruber* as one of its subspecies, now generally held to be a distinct species.—*Author's note, 1906.*

extends over the whole anterior half of the body. Yet the intergradation between the two has been so fully traced that these diverse forms are now held by competent authorities as merely local races of a single species.

Another case of the increase of red over the same region is afforded by the golden-winged and red-shafted woodpeckers (genus *Colaptes*), in which yellow in the eastern form is replaced by red in the other; in the middle region of the continent the species being largely represented by individuals in which are variously combined the special characteristics of the two forms. In the present case the black cheek patch of the eastern form is replaced by a red one in the western. Traces of the characteristics of the western type occasionally appear in the most eastern representatives of the eastern type, and, conversely, features of the eastern bird appear in the most western representatives of the western, showing at least their close affinity and probable community of origin.

The Pacific coast region from California northward is characterized by a great accession of color, all the continental species being here represented by forms much darker even than on the Atlantic coast. Here the coloration is duller than at the southward, though perhaps equally strong, the general tendency being to fuscous or dusky tints. We consequently find among the mammals and birds of the United States three strongly marked phases of color differentiation among representatives of the same species, characterizing the three most strongly marked climatal regions—a bright, strongly colored form east of the Great Plains, a pallid form over the dry central region, and a deeply colored fuscous form over the rainy, heavily wooded region of the northwest coast. Examples of this differentiation are afforded by apparently all the species whose habitats extend entirely across the continent, the several local forms being in some species only more strongly marked than in others. Among mammals illustrations are afforded by different species of squirrels, hares, mice, lynxes, deer, etc., and among birds by six or eight species of sparrows, a number of woodpeckers, several flycatchers, thrushes, and warblers, the meadow lark, various hawks, owls, etc. Generally these several geographical forms were originally described as dstinct species, and many of them are still thought worthy of recognition by varietal names. As intermediate links began to be discovered they were at first looked upon as the result of hybridity between the supposed distinct species whose characters they respectively combined, but eventually such links were found to be too frequent and too general over the areas where the habitats of the several forms come together to render such a supposition longer tenable, it finally appearing evident that they were only the connecting forms between merely local races or incipient species.

The local races of any given region, as compared collectively with those of contiguous regions and the manner of their mutual intergradation, point plainly to some general or widely acting cause of differentiation. This is indicated by the constancy of the results, so many species, belonging to numerous and widely distinct groups, being similarly affected. Will the fortuitous, spontaneous results of natural selection yield a satisfactory explanation of these phenomena, or must we seek some more uniform and definitely acting cause? To briefly summarize the results above detailed, we have a somewhat uniform increase of size in some given direction, affecting many species simultaneously and similarly over the same areas. We have a frequent enlargement of peripheral parts, affecting not a few, but many, species, and all in a similar manner, though in varying degrees. We have a very general increase in the depth or intensity of colors southward, a general loss of color in approaching the central arid portions of the continent, and again an excessive increment of color under still different climatic conditions and over a different area. We find the increase of size among the individuals of any given species to be quite uniformly in the direction of the center of distribution of the group to which the species belongs, this being especially well marked in mammals. We find the increase in the size of peripheral parts, as the external ear and the length of the pelage in mammals and the size of the bill and length of the tail in birds, to be in the direction of the regions where these parts meet, respectively, their greatest development—the increase in color (especially among birds) toward the region where are developed the richest and most lustrous tints; the loss of color in the direction of the region where the greatest general pallor prevails.

We find again that the enlargement of peripheral parts correlates with increase of temperature; the southward increase of color with an increase of atmospheric humidity and temperature, and consequently with the protective influences of luxuriant arboreal vegetation and clouds: and, conversely, the loss of color accompanying excessive aridity, a scanty vegetation, and an almost cloudless sky, the conditions, in short, of all others the most powerfully effective in the blanching of color; and again, the somber, dusky, tints of the northwest coast accompanying the most humid conditions of climate and the conditions generally most favorable for the protection or preservation of color. Are these merely accidental coincidences, or are they the evident results of cause and effect? Because the white winter livery of some of the northern species is more protective against cold than darker tints would be, or aids in concealing them in some cases (as in the hares and ptarmigans) from their enemies, or in other cases (as in the ermines and the arctic fox) tends to aid them in stealing unperceived upon their prey, are they to be regarded

as unquestionably the beneficial results of the working of natural selection? Because the dull gray tints of species inhabiting the semiarid regions of the interior harmonize well with the general gray aspect of their surroundings, is this concordance the result again of the operation of the law of natural selection, the less favorably colored having been weeded out in the struggle for existence? Are the heavy, dull colors of the humid region of the Northwest the result, again, of the necessary influence of natural selection in perpetuating only the individuals whose colors best accord with their somber conditions of environment? Has the same action brought about the bright, rich coloration of birds, insects, and other animals under the warm, humid conditions of the hotter parts of the earth, preserving the ratio of brilliancy of coloration with that of the conditions that everywhere most favor such differentiation? Finally, is the exact correlation of the changes in coloration with the gradual change of climatic conditions in passing from one geographical region to another the result in like manner of the long-continued weeding out of the less favored? Or are these modifications severally due to the *direct* action of the conditions of environment?

In answering these questions it may be well to glance first at the nature of the theoretical origin of differentiation through the influence of natural selection as expounded by the leading advocates of the theory. As is well known, all the individuals of a species found at the same locality (differences resulting from sex and age aside) are not all cast in the same mold, but differ constantly, the average range of purely individual variation in general size and in the size of different parts ranging (in birds and mammals) from 8 to 15 or 20 per cent of the average size for the species, with a corresponding amount of variation in color. These variations are found to tend in every conceivable direction, and it of course follows that some of them must be in directions exceptionally favorable to the species. The theory of modification by the action of natural selection only supposes that the stronger or otherwise more favored individuals transmit their favorable qualities to their offspring, and that the latter, in consequence of their inherited advantages, multiply more rapidly than their less favored relatives; that these favorable deviations from the parental stock become in subsequent generations more pronounced, and that the original form is eventually overpowered and supplanted by its modified descendants. From the same original stock may be conceived to arise, even simultaneously, other forms diverging in different, though still favorable, directions, these in turn giving rise to several lines of descent, occupying perhaps different portions of the habitat of the original species, where they also multiply and become dominant, and eventually pass on from the stage of incipient species to more or less widely differentiated types.

These premises being admitted—and they are certainly within the bounds of reasonable conception—only the element of time apparently is requisite for the development of an endless variety of unstable forms, constantly increasing in number and following divergent lines of development, and thus capable apparently of giving rise to all the diversity of organisms at present peopling the earth.

But there are many adverse circumstances with which the favored forms have in the outset to contend and to which in the majority of instances they must succumb. These are, first, the minuteness of the first favorable divergence, the isolation of the individuals in which it appears, and consequently the impossibility of such individuals pairing with others similarly favored, and the consequent tendency of the offspring to possess the favorable characters in a less rather than in a greater degree than the parent, and to be absorbed into the original stock. Secondly, in case the incipient advantages are perpetuated, as it is necessary to suppose, the new offshoot must originate from a single point and spread thence gradually to contiguous regions as its representatives slowly multiply.

But it is supposed, again, that new forms are not always thus gradually evolved from minute beginnings, but sometimes—perhaps not infrequently—arise by a *saltus;* that individuals may be born widely different from their parents, differing so widely and persistently as not to be so readily absorbed by the parental stock. In proof of this instances are cited of new species apparently appearing suddenly and of varieties thus originating under artificial conditions resulting from domestication. Granting that new forms may thus arise, although as yet few facts have been adduced in its support, they are necessarily at first local and in no way accord with the observed geographical differences that characterize particular regions and which affect similarly many species belonging to widely different groups.

The direct influence of climatic or geographical conditions upon animals is, in the main, ignored by the leading exponents of the doctrine of natural selection. To quote Mr. Darwin's own words on this point:

> The action of climate seems at first sight to be quite independent of the struggle for existence; but, in so far as climate chiefly acts in reducing food, it brings on the most severe struggle between the individuals, whether of the same or of distinct species, which subsist on the same kind of food. Even when climate—for instance, extreme cold—acts directly, it will be the least vigorous, or those which have got the least food through the advancing winter, which will suffer most. When we travel from south to north or from a damp region to a dry, we invariably see some species gradually getting rarer and rarer and finally disappearing, and the change of climate being conspicuous, we are tempted to attribute the whole effect to its direct action. But this is a false

view; we forget that each species, even where it most abounds, is constantly suffering enormous destruction at some period of its life from enemies or from competitors for the same place and food, and, if these enemies or competitors be in the least degree favored by any slight change of climate, they will increase in numbers, and, as each area is already fully stocked with inhabitants, the other species will decrease. When we travel southward and see a species decreasing in numbers, we may feel sure that the cause lies quite as much in other species being favored as in this one being hurt. So it is when we travel northward, but in a somewhat lesser degree, for the number of species of all kinds, and therefore of competitors, decreases northward; hence in going northward or in ascending a mountain we far oftener meet with stunted forms due to the *directly* injurious action of climate than we do in proceeding southward or in descending a mountain. When we reach the Arctic regions or snow-capped summits or absolute deserts, the struggle for life is almost exclusively with the elements. That climate acts in main part indirectly by favoring other species we may clearly see in the prodigious number of plants in our gardens which can perfectly well endure our climate, but which never become naturalized, for they can not compete with our native plants nor resist destruction by our native animals.[a]

While there is perhaps little reason to question the general correctness of the above-quoted generalizations, they have little bearing upon the question of the modification of species by the direct action of climatic conditions, but relate mainly to such unfavorable climatic influences as tend toward the extinction of species or to the circumscription of their ranges. Indeed, the phenomena of variation detailed in the foregoing pages were almost wholly unknown at the time the earlier editions of the Origin of Species were published, and have hardly as yet become the common property of naturalists. Gradual decrease in size southward in hundreds of species inhabiting the same continent, or a gradual increase or decrease in color in given directions on a similarly grand scale, are facts but recently made known, and have not as yet been very fully discussed by evolutionists of the purely Darwinian school. Mr. Darwin, indeed, in referring to the "effects of changed conditions" upon animals, alludes to facts of a similar character—as the alleged brighter colors of European shells near their southern limit of distribution and when living in shallow water, and the more somber tints of birds that live on islands or near the coast under overcast skies as compared with those of the same species living more in the interior, etc.—but is in doubt as to how much should be attributed even in such cases "to the accumulative action of natural selection and how much to the definite action of the conditions of life." "Thus," he says, "it is well known to furriers that animals of the same species have thicker and better fur the farther north they live; but who can tell how much of this difference may be due to the warmest-clad individuals having been favored and preserved during many generations and how much to the

[a] Origin of Species, 5th ed., pp. 80, 81.

action of the severe climate? For it would appear that climate has some direct action on the hair of our domestic quadrupeds." [a] Since, however, it happens that some species do not vary at all, although living under the most opposite climates, he is thereby inclined "not to lay much weight on the direct and definite action of the conditions of life," though he fully admits "that strong arguments of a general nature may be advanced on the other side." "In one sense," he adds, "the conditions of life may be said not only to cause variability, but likewise to include natural selection, for the conditions determine whether this or that variety shall survive." [b] But he says again: "I believe that natural selection generally acts slowly in effecting changes *at long intervals of time and only on a few of the inhabitants of the same region.*" In a later work, however, he refers to the variation in color with locality seen in many species of birds in the United States, and says explicitly, in reference to northern and southern localities, "this seems to be the direct result of the difference in temperature, light, etc., between the two regions." [c]

There is, however, a vast amount of unquestionable proof of the direct and constant action of climate and other conditions of life upon animals, and that such geographical variations as the thicker and softer fur of mammals inhabiting cold regions, smaller size and brighter colors at the southward, etc., do not require the action of natural selection, in its strict and proper sense, for their explanation. It is well known, for instance, that a flock of fine-wooled sheep when taken to a hot climate rapidly acquire a coarser and coarser fleece, till, in a few generations, it nearly loses its character of proper wool, and becomes simply hair; that the change affects simultaneously the whole flock, and is not brought about by one or two individuals acquiring a coarser fleece and through their descendants modifying the character of the herd. Furthermore, in the case of sheep, it is well known that certain countries are very favorable to the production of a fine fleece, and that fine-wooled breeds, even by man's aid, can not be perpetuated in other regions. Again, it is a fact of common observation that in birds and mammals colors become more or less faded toward the moulting season simply by the direct action of the elements, the tints of the fresh and the long-worn plumage or pelage being more or less strikingly different in the same individuals, and that this contrast at different seasons is more marked in arid than in moist regions, through the greater bleaching effect of a dry heated atmosphere and the more intense dazzling sunlight of regions that are not only cloudless, but lack the protection afforded by abundant vegetation.

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[a] Origin of Species, pp. 166, 167.

[b] Origin of Species, p. 168.

[c] The Descent of Man, 2d. ed., p. 225

While so much is claimed by the writer as due to the direct action of climatic causes, it is admitted also that habits and food and other conditions of life than those resulting from climate have a marked effect in determining modifications of form and color among animals. A scarcity of a favorite kind of food will undoubtedly force species to subsist upon the next best that offers, which may be so different as to modify certain characters and fit the species to live upon the less desired food. A change of food may lead to modification of dentition, the muscles of mastication, and the organs of digestion and, correlatively, of other organs or parts of the body; the modification, however, arising simultaneously among all the descendants of the individuals thus driven to a change of diet, instead of appearing first in a single individual and becoming perpetuated in its descendants alone. Entomologists have found that, among insects of the same species, the forced or voluntary use of different food plants gives rise to modifications of color and structure, and hence result in what have been termed phytophagic varieties or subspecies, and that man can also effect such changes at will by simply changing the food of the species. Again, the geological character of a country is well known to have a marked effect upon the size and color of animals inhabiting it, as is strikingly illustrated among molluscous animals, whose abundance, and even presence, is largely dependent upon the constituents of the soil. Over regions of the United States, for example, where the underlying rock is noncalcareous the species are both few in number and sparsely represented, while in other regions, where limestone abounds but which are in other respects essentially the same, the species are far more numerous and far more abundantly represented. In respect to the fresh-water mussels, those of the same species from different streams are easily distinguishable by differences in the thickness of the shell, in color, shape, and ornamentation, so that the character of the shells themselves affords a clew to the locality of their origin. At some localities the species tend to become tuberculous or spinous, this being particularly the case toward the southward; at other localities they acquire a very much thickened shell, or different colors, the same characteristics appearing simultaneously in quite diverse species, and thus becoming distinctive of particular localities. In regard to mammals, measurements of large series of the skulls of minks, martens, squirrels, and other native species show that the representatives of these species living in northern New England and northeastern New York are smaller than the representatives of the same species occurring in the limestone districts of Pennsylvania and the States more to the westward, and the same is true of the different kinds of domestic cattle. This is in opposition to the law of decrease in size southward that elsewhere and generally characterizes these same species, and seems obviously related to the geological character

of the country at these localities; small size, in opposition to a general law, occurring over northern noncalcareous districts, and larger size more to the southward, where the underlying rock is limestone. In this case the difference obviously results from the direct action of the conditions of habitat upon every individual rather than from "slowly effected changes" originating in "only a few of the inhabitants" of these respective districts.

Use and disuse of organs, through changes of habit resulting from changed conditions of environment, must result in some modification of the organ involved. As an example may doubtless be cited the passerine birds of some of the smaller, remotely situated islands, as the Guadeloupe and Galapagos groups, where recent investigations have shown that most of the species differ similarly in several features from their nearest allies of the mainland, and of which they are unquestionably insular forms. These differences consist in the greater size of the bill, shorter wings, longer tails, and darker colors. The sedentary life necessitated by the confined habitats of species thus situated would naturally act more or less strongly on the organs of flight, and a reduction in the size of the wing would follow, not necessarily through the roundabout process of natural selection, through the modification originally of a single individual, but by the direct action on all the individuals alike of the changed conditions of life.

It is doubtless unnecessary to further multiply examples of the modification of animals by the direct action of the conditions of life. The subject is one that can be but imperfectly treated at best in a short paper like the present. The illustrations have here been drawn from a limited geographical field and mainly from among the two higher classes of vertebrates. There are, however, abundant indications that other fields and other classes would yield results equally confirmatory of the direct action of physical conditions in the evolution of specific forms among animals and plants. Changes in environing conditions will, however, go but a short way toward explaining the origin of the great diversity of structure among existing organisms; the character of the food, habit, or the increased use or the disuse of particular organs may explain many of the modifications, leaving a large share of the work to as yet unknown causes. Natural selection, as sometimes defined, is made to cover all causes of differentiation, it being stated by Mr. Darwin himself that if organic beings undergo modification through changes in their conditions of life "uniformity of character can be given to their modified offspring solely by natural selection preserving similar favorable variations." In its strict sense, variation by natural selection results only through favorable differences appearing at first in single isolated individuals, which transmit these favorable qualities to their offspring, in virtue

of which they multiply till they outnumber, crowd out, and finally destroy the less-favored form from which they originated.

It is hardly conceivable, for example, how the peculiar structure seen in the woodpecker, the kingfisher, the swift, the heron, or the duck, or the peculiar dentition and correlated characters of the rodents, the ruminants, or the shrews and moles, as compared with the Carnivora, can have been initiated by the direct action of climatic conditions, however much other conditions of environment may have favored the development of these diverse types.

Having thus far mainly detailed merely facts and coincidences relating to the subject of variation with locality, it may be well in conclusion to consider more fully some of the possible or probable causes of purely geographical variation. In regard to geographical variation in color, it seems evident that high temperature, conjoined with moisture, favors increase of color, and especially the acquisition of lustrous tints, while moisture alone favors simply increase in depth or the production of dull, heavy, and especially fuscous phases of coloration; on the other hand, that aridity and exposure favor the loss of color. The latter is due apparently no less to the influence of a dry and often intensely heated atmosphere than to the direct action of light intensified by the reflection of the sun's rays from almost verdureless sands. That the latter conditions act powerfully in blanching color there is most abundant proof. Hence we have the necessary correlation of increase of bright rich tints of coloration with the increase of atmospheric humidity. In respect to the enlargement of peripheral parts at the southward, it is obvious that a high temperature favors the more rapid circulation of the blood in these parts, while, as is well known, a low temperature produces the opposite effect and necessarily retards their development.

With the decrease in size among birds, there has been observed a decrease of vivacity and deterioration of song, which may reasonably be attributed to the enervating influence of a high temperature. Since the northern types of animals reach their highest physical development toward the northward, it seems fair to suppose that decrease in size southward may be directly due to the enfeebling influences of increase of temperature, since certainly it can not be attributed, in the majority of cases at least, to greater scarcity of food, for in many instances just the reverse obtains. This supposition is in accordance with the known effects of similar climatic conditions upon the northern races of man, which reach their greatest vigor and highest intellectual status under temperate conditions of climate, and deteriorate, both physically and mentally, on removing to intertropical regions. Again, the mammals and birds of the United States reach their maximum size within the United States

under the stimulating climate of the region drained by the upper Mississippi and upper Missouri rivers, being, as a rule, larger here than in corresponding latitudes more to the eastward. The decrease in size toward both the northern and southern borders of the habitat of a given species or genus, of which there are many marked instances, further shows that size varies with the varying conditions of habitat and reaches the maximum only where the conditions are most favorable to the life of the species.

Much has been written respecting the influence of climate on man, and many speculations have been indulged in in relation to the part the conditions of life have taken in bringing about the diversity at present existing among the different races. A striking parallelism is often observable between the leading features of geographical variation among animals and the physical differences that obtain among nations or races of men inhabiting the same areas and subjected to the same influences. While civilized man is, in a measure, less the subject of such influences than the lower animals, he is not wholly above them. Certain regions more favor both physical and intellectual development than others, and these prove to be, as would be expected, the milder temperate portions of the globe, where the struggle for a mere vegetative existence is reduced to a minimum.

The influence of different climatic conditions upon members of the same nationality find exemplification in different parts of our own country, and are so obvious as to be the subject of frequent observation and comment. The same original stock is found to gradually develop certain peculiar physical and mental characteristics when placed under diverse conditions of climate, certain localities more favoring intellectual growth and activity than others, just as certain regions are characterized by the frequent occurrence of particular diseases which in other regions are exceptional. While humidity and a high temperature, when combined, are found to be enervating and deteriorating, a clear, dry atmosphere favors vigor of both mind and body. But the subject of the influence of climatic conditions upon man is too vast to be entered upon in detail in the present connection. The study of man from a geographical standpoint, or with special reference to conditions of environment, offers a most important and fruitful field of research, which, it is to be hoped, will soon receive a more careful attention than has as yet been given it.

In conclusion, a few words seem called for concerning the question, What is a species? as well as in respect to the bearing of the general facts above detailed upon the evolution of specific forms.

As is well known, the belief that species were distinct and immutable creations was long the prevailing one among naturalists. Yet the question of what constitutes a species is one about which endless

discussions have arisen, and one respecting which the most discordant opinions have been held by naturalists equally eminent in their respective fields of research. The amount and kind of difference necessary to characterize a species has been variously defined; forms that some have considered as specific others have regarded as merely varieties, and the reverse. In certain groups of organisms intermediate forms have been constantly met with, constituting steps of easy intergradation between quite diverse types. Such forms have been and still are held by some writers as varieties of a single species and by others as constituting a group (genus or subgenus) of distinct but nearly related species. Through the frequent discovery of such intergradations, however, the instability of so-called "species" has been made manifest and the contrary doctrine of the stability or fixity of species refuted. Indeed, naturalists now generally agree that the terms "variety," "species," "genus," "subgenus," "family," "subfamily," "superfamily," and the like, are but conventional and more or less arbitrary designations for different degrees of differentiation—convenient formulæ for the expression of general facts in biology. Not a few high authorities even maintain that the differences which characterize these several groups are of the same nature, differing only in degree, in opposition to others who hold that they are based on different categories of structure, or on differences of *kind* rather than of degree. The falsity of the latter view is shown more and more clearly with the increase of our knowledge of the structure and affinities of animals.

While formerly species were considered as necessarily characterized either by differences of a particular kind, or by a certain amount of difference, the present tendency is to regard neither as a sufficient criterion, the test of specific diversity being merely absence of intergradation, in other words, breaks in the continuity of closely allied beings. Local races, or geographical forms, are thrown together under one specific designation whenever they are found to intergrade, however diverse may be their extreme phases of differentiation. The term species is now made to cover groups which were, not many years since, frequently regarded as subgenera, or even genera, the forms then supposed, in numberless instances, to be "good species," now ranking merely as subspecies. The reduction in the number of species has necessarily entailed a considerable reduction in the number of currently accepted genera, which in turn are limited by hiati rather than by any given amount or particular kind of difference. It was formerly urged against the theory of evolution that its advocates could point to no instance of the gradual change of one species into another, and that, until this was done, the theory was untenable. Among the species of North American vertebrates recognized as valid

ten years ago, hundreds of instances can now be cited of thoroughly proven intergradation, forms then regarded as unquestionable species being found to be but connected phases of one and the same specific type, which assumes, at remote localities, under the evident action of climatic agencies, phases widely diverse, which gradually merge the one into the other through the individuals inhabiting the intervening districts. So long as species are based on the absence of intergradation, and biologists have found no other satisfactory criterion for their limitation, there can of course be no passage of one species into another. Let, however, some of the connecting links become extinct, and these now intergrading forms would be resolved into distinct species. In this way insular and other local forms are passing beyond the so-called varietal stage, and species are similarly tending to generic distinctness. That varieties may and do arise by the action of climatic influences, and pass on to become species, and that species become, in like manner, differentiated into genera, is abundantly indicated by the facts of geographical distribution and the obvious relation of local forms to the conditions of environment. The present more or less unstable condition of the circumstances surrounding organic beings, together with the known mutations of climate our planet has undergone in past geological ages, points clearly to the agency of physical conditions as one of the chief factors in the evolution of new forms of life. So long as the environing conditions remain stable, just so long will permanency of character be maintained; but let changes occur, however gradual or minute, and differentiation begins. If too sudden or too great, extinction of many forms must result, giving rise to breaks in the chain of genetically connected organisms. In the deep abysses of the sea, where the temperature is low and stable, where the conditions of life must have remained almost unvaried since the early geological periods, the same low organisms still exist that were the prevailing forms of life when life first dawned upon the earth. The recent explorations of the depths of the sea have gone far to prove that stability of organic forms is in direct ratio to the stability of the conditions of existence, while the facts of geographical distribution show that change of structure and diversity of life are directly related to the physical conditions of habitat.

NOTE.—During the twenty-nine years that have passed since the original publication of this article great advances have been made in our knowledge of the mammals and birds of North America, to which this paper primarily relates. Nearly every part of the continent has since been explored in great detail by well-trained collectors, employing new methods and greatly improved devices, especially for the capture of the smaller rodents and insectivores, which in

the earlier days proved so elusive. With the consequent immense increase of material, of much better quality and from innumerable localities, the point of view in regard to species and subspecies has greatly changed, resulting in changes of nomenclature. Aside from the technical names there is little in the article that I should modify were it to be now rewritten. All that it contains concerning geographic and climatic variation, and the influence of physical conditions in the genesis of species and subspecies, is still satisfactory. In the present reprint, the only changes found really desirable consist in the correction of a few typographical errors, and modifications here and there of technical names, to bring them more nearly in harmony with present nomenclature. These changes are for the most made in footnotes or by words inserted in brackets.

J. A. Allen.

American Museum of Natural History,
New York City, February 1, 1906.

PARENTAL CARE AMONG FRESH-WATER FISHES.

By Theodore Gill.

The belief long prevailed that fishes are indifferent to their eggs and young and leave them entirely to the care of Mother Nature. One who was more excellent as a man of letters than as a naturalist, but who wrote, nevertheless, a very readable work on Animated Nature, expressed the general belief once dominant. Oliver Goldsmith, in 1774, told his readers that "fishes seem, *all* except the whale kind, entirely divested of those parental solicitudes which so strongly mark the manners of the more perfect terrestrial animals."[a] Many to the present time entertain that belief.

More than a score of centuries before Goldsmith, however, the greatest naturalist of antiquity, Aristotle, told of a kind of fish, inhabiting the largest river of Greece, the Macedonian Achelous, which, in the person of the male parent, exerted the greatest care of both eggs and young. That account, however, was overlooked or neglected, and even regarded with skepticism and as fabulous. The strange history of that fish—known to Aristotle as the glanis—will be told at length in later pages of this article. Its truthfulness has been vouched for, not by later observers of itself, but by studies of related fishes having analogous habits in a quarter of the world unknown to and undreamed of by Aristotle. Although the most detailed history of any fish by any ancient writer is connected with it in the philosopher's History of Animals (*Περι ζωων ἱστοριας βιβλια*), no reference to it appears in any modern popular work.

Many important details respecting the life histories and parental care of a large number of other fishes have been published from time to time and may be found in the publications of various societies or

[a] Many years before Goldsmith wrote, Linnæus (1758) had recognized the impassible gap between true fishes and cetaceans and combined the latter and the viviparous hairy quadrupeds in the class of mammals, but Goldsmith urged that, "Although all our modern naturalists have fairly excluded them from the finny tribes, and will have them called, not fishes, but *great beasts of the ocean*," "yet, notwithstanding philosophers, mankind will always have their own way of talking; and for my part," continues Goldsmith, "I think them here in the right." This thought indicates how little of a naturalist Goldsmith really was.

other periodicals, but such are closed books to most persons. Any-one who looks for information in the popular works on natural history of the day must inevitably be disappointed at the meagerness of the information given. Even in the voluminous German work, so well known as Brehm's Tierleben, the information is meager for almost all fishes, and especially meager for American forms. The sources of knowledge have not been discovered by the compilers of such works, but he who might judge from the paucity of data that no others could be found would be much deceived. To uncover some of the interesting details hidden in comparatively little known journals and other works is the object of the present article, which is devoted to the record of facts about the mating and breeding habits of some among many remarkable species. It is hoped that the information given may indicate points to be observed in the history and economy of other species, as well as of those already noticed. There is, indeed, an urgent call for corroboration and amplification of most of the histories given, as well as for discovery of the natural history of other species.

The species which manifest care for their young are so numerous that the present article must be restricted to those which are inhabitants of fresh water. Such are better known than the marine forms, as they are more easily observed and within the range of observation of a more numerous population. Considerable is known, however, of the habits of many of the dwellers in salt water. Parental care has been especially observed in the marine pipefishes, sea-horses, Pegasids, Solenostomids, Sparids (e. g., *Catharus*), Labrids (Wrasses), toad fishes, gobies, blennies, sculpins or Cottids, lumpfishes, Gobiesocids, etc. Doubtless analogous care will be found to be exercised by many more when fishes shall have been more thoroughly studied.

Naturally the most common or frequent mode of care is the simplest, consisting of little more than selection of a site for the deposit of the female's eggs and subsequent guardianship of those eggs by the male. The concomitants of such selection are various. In the case of the American sunfishes, black basses, and crappies, the place selected is cleared of stones and weeds, and in the cleared places the eggs are laid. Some of the sunfish-like Cichlids and the North American catfishes, as well as the Grecian glanis, exercise similar means with slight modifications. Another kind of catfish, living in North Australia (Queensland), lays her eggs in the center of a selected area of a river bed, and, after having fertilized them, the fish accumulates stones from the surrounding area and piles them in a heap over the eggs. Other modifications of a general plan appear to be executed by other fishes, but the details remain to be investigated.

Oral gestation or carriage of eggs within the mouth of the parent fish is practiced in a number of unrelated species. In Siluroid catfishes it is associated with enlarged size of the eggs, as in most Tachisurines and one of the Pimelodines (*Conorhynchos*), and is confined to the males. The Malapteruroid, or electric catfish, is also said to be an oral egg carrier. In other fishes the eggs of the egg carriers are not essentially different from those of normal habits, and many related species do not have the peculiarity.[a] Such egg carriers are Cichlids of America (*Geophagus*) and of Africa (*Tilapia*, *Tropheus*, *Ectodus*, etc.), as well as species of the marine genus *Chilodipterus*, one of the Apogonids.

It is especially noteworthy that among the Cichlids are exceptions to the rule that the care taker is a male. In several cases it has been verified that the egg carrier is a female and presumably, of course, the layer of the eggs. From evidence so far accumulated it would seem that the sex of the care taker is coincident with specific characters, and that when the care taker is a female the male is not. At least, in a recent article (L'incubation buccale chez le *Tilapia galilaea* Artedi, 1904), J. Pellegrin showed that all four individuals of the species examined which had eggs in the mouth were females, and he could find no male egg carriers. Boulenger previously had found eggs in the mouths of females only of *Tilapia nilotica* and other Cichlids of the genera *Ectodus*, *Tropheus*, and *Pelmatochromis*. On the other hand, the sex of the egg carrier of *Tilapia philander* was determined by so competent an authority as A. Günther to be male. Further, Lortet named a Cichlid *Tilapia paterfamilias*, which was declared by Pellegrin to be specifically identical with *Tilapia simonis*. Lortet gave his name, because he considered the egg carrier to be the male, while Pellegrin confirmed, by dissection, the sex of a specimen of the same species to be female. Evidently, then, there is necessity for further observations as to the sex of the egg carriers of African, as well as the American, Cichlids.[b]

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[a] The eggs of some of the ovigerous Cichlids are very large. According to Boulenger (T. Z. S., XV, 18), "the mouth and pharynx of" a female *Tropheus moorii* contained "four eggs of very large size, the vitelline sphere measuring 4 millimetres in diameter, with an embryo in an advanced stage of development. The eggs of the fifteen-spined Stickeback, hitherto regarded as the largest Teleostean egg in proportion to the size of the animal, measures only 3 millimetres in diameter." The egg-carrying *Tropheus* was only about 4 inches long.

[b] The above remarks are left just as they were printed, but on the same day as the proof of this article was received from the printing office a "Fourth Contribution to the Ichthyology of Lake Tanganyika," by G. A. Boulenger, fresh from the press, was also received, containing the much-needed "further observations." Doctor Boulenger records that Doctor Cunnington, the latest explorer of the ichthyology of the lake, had been "so fortunate as to considerably extend the list of Cichlid fishes in which the parents protect their

One of the most singular devices for protection of the eggs is the formation of bubbles of air rendered tenacious by a viscous secretion of the mouth. This might seem to be so specialized a method that there would be no independent repetition by representatives of a very different group. In fact, however, the method, or an analogous one, has originated anew time and time again. It is manifest, so far as known, in its simplest form in the fish-of-paradise (*Macropodus viridi-auratus*), which makes a floating nest of a mere conglomeration of bubbles, but other species of the same family (Osphromenids) evolve nidamental receptacles little more complicated, and among them is the celebrated Gourami. The nests earliest described, in which air bubbles formed an essential element, were those of Hassars (Callichthyids of the genus *Hoplosternum*), but in them the air or "froth" was used in combination with vegetable material ("fallen leaves or grass"). The large floating nest of the African *Gymnarchus*, recently described by Budgett, may, perhaps, be partly buoyed up by aeriform secretions. The future investigation of the structures involved in the secretion of such bubbles will undoubtedly yield most interesting results.

More specialized than any of the methods of parental care hereinbefore noticed is one manifested by certain American fishes. Those fishes are of a family named Aspredinids, peculiar to the fresh waters of South America and distantly—and very distantly—related to the catfishes of the north. In them it is the female that assumes charge of the eggs, and she does it in a strange and truly characteristic manner. After the eggs have been discharged from the ovaries (and presumably after they have been fertilized), the mother presses her belly and breast over them and they become attached thereto; then the areas of attachment of the skin become elevated into cupules round the eggs, like the cups of acorns round the nuts, and not only so, but strangulation ensues between each cupule and the general skin of the belly, so that the eggs and cupules are borne upon stalks or peduncles, and so they remain till the eggs are hatched and the

offspring by giving them shelter in the mouth and pharynx. This mode of nursing is illustrated" by examples of seven additional species of six genera. "The natives" round the lake "say it is always the female, in the cases where one of the parents takes the eggs in the mouth," that is the carrier. This belief has now been confirmed by Boulenger for no less than ten African genera; in fact, whenever he had been able to test the sex of the egg carrier it was "invariably the female who thus carries the eggs. This was in contradiction to statements made by Lortet and by Günther, who ascribed the habit to the male in the species of the same genus with which they had dealt." Of course it is easy enough to tell by dissection whether a fish is a male or a female, and the authors in question probably neglected to take the proper means to ascertain the sex, but took it for granted that the nurse was a male. See for further data the paragraphs on the Cichlids hereafter.—October 25, 1906.

embryos leave, after which the skin returns to its former condition. The only analogue to this occurs in certain anurous batrachians, but in such in a less specialized condition and on the back.

The most specialized of all the care takers are the sticklebacks, or Gasterosteids. These have an important organ (the kidney and its adjuncts) especially modified histologically to yield a thread analogous to that developed by spiders and used for binding the objects selected for a nest. So far as known none of the related fishes has the same structural peculiarity, but it is quite possible, if not probable, that their nearest relatives of the North Pacific—the Aulorhynchids—may have a similar history. It is scarcely within the range of possibility that an analogous structure like this should have been independently developed a second time in unrelated fishes.

One remarkable, and to some astonishing, fact is the want of correlation that may sometimes exist within a natural family between structural features and habits. This is strikingly manifest in the typical catfishes or Silurids. Neither of the parents of the well-known wels of central and western Europe appears to care for eggs or young, but the male of its near relation of Macedonia—the glanis—assumes a special charge of his consort's labor. Opposite ways of making their nests are practiced by the North American catfishes on one hand and certain Australian ones on the other. Enlargement of the eggs is manifested in another group and is associated with their reception and carriage by the male in his mouth.

In the last English work on fishes, the Cambridge Natural History,[a] it is declared that, "with the exception of the pelagic *Antennarius*, which builds its nest in the sargasso weed in mid-ocean, nest building and parental solicitude for the young are confined to fresh water fishes and to marine forms with demersal eggs. Pelagic ova must necessarily be beyond the scope of parental care." The so-called *Antennarius* is no exception; the species meant is not a true *Antennarius*, but belongs to a distinct though related genus—*Pterophryne*. Its history is a truly remarkable one and it has been more widely noticed as a nest-building fish than any other except the *Gasterosteids*. In truth, however, it does not build a nest at all. The whole story is the result of a misidentification of the eggs of a fish. In 1872, the celebrated naturalist, Prof. Louis Agassiz, attributed egg-bearing masses of gulf weed (sargassum), which he found in the gulf stream, to the *Pterophryne* which was abundantly associated with them. His equally able son, Dr. Alexander Agassiz, a decade later (1882), made known the remarkable egg raft which floated the eggs of a relative of the *Pterophryne*—the angler (*Lophius piscatorius*). This discovery may have led to thought, but

[a] Cambridge Natural History, Vol. VII, p. 414 (1904).

did not discredit the earlier identification.[a] In 1905, however, Dr. E. W. Gudger and Dr. Hugh Smith both caught females of *Pterophryne* in the act of emission of egg rafts like that of the angler. Of course the parent of such eggs and egg rafts could not be the maker of the nests attributed to the *Pterophryne*. What fish, then, was the maker of the nests? The only eggs like those found in the nests are those of some flying fishes (Exocœtids). We are forced, therefore, to assume that a flying fish had laid her eggs on a frond of the sargassum, and that they had been fertilized by the male. These eggs have bipolar bunches of very long filamentary tendrils, and such have mechanically grasped and brought together the finely divided branches of the sargassum, with the result that subglobular masses have been formed in which the eggs are protected. They

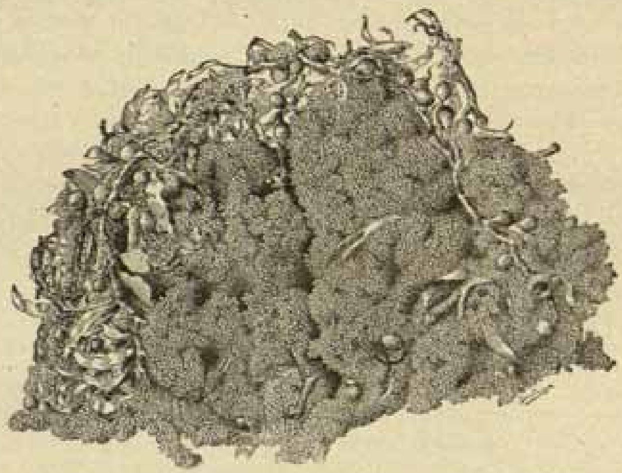


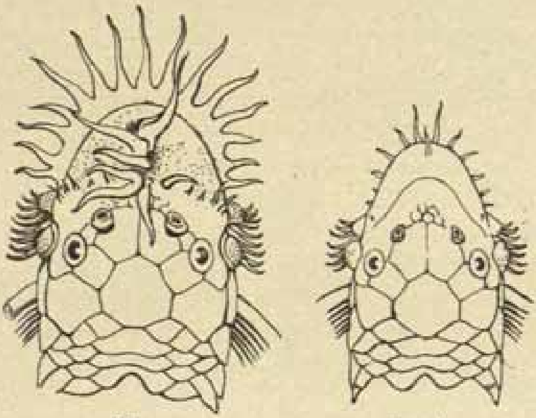
FIG. 1.—Alleged nest of *Pterophryne*. After A. Agassiz.

answer every purpose of a nest, but are they nests? If so considered we must admit that the eggs and not the fish make a nest!

Some of the fishes to be noticed in the following pages have the males gaudily colored and larger than the females. The relations of the sexes to each other with regard to color and size are noteworthy, inasmuch as they have been generally misunderstood. One eminent ichthyologist (Doctor Günther), in an "Introduction to the study of fishes" (p. 656), dogmatically declared that "with regard to size, it appears that in *all* teleosteous fishes the female is larger than the male," and Darwin was assured by him that he did "not know a sin-

[a] As Professor Agassiz did not notice any filaments on his eggs, I thought it possible that some real eggs of a *Pterophryne* may have drifted on the outside of an egg mass, but Doctor Agassiz kindly sent me a couple of eggs from the outside and they proved to have bipolar filaments and consequently to be eggs of flying fishes.

gle instance in which the male is larger than the female."[a] Yet in the very chapter containing this assertion Darwin represents three species of fishes selected by Günther in which males are figured of larger size than females; they are named *Callionymus lyra* (fig. 29), *Xiphophorus helleri* (fig. 30), and *Plecostomus barbatus* (fig. 31). These species, be it remarked, have the sexes trenchantly differentiated, the males in two cases being marked by a superior brilliancy of coloration and exuberance of fins and in the other (*Plecostomus*) by a bristly armature of the head. The instances of increased size of the male are, in fact, numerous; in almost all cases when the males are decidedly differentiated from the females by brilliancy of color or other secondary characters the rule is that they are larger than the females. Like other rules, this may be subject to exceptions, but the rule is based on extensive observations. A couple of figures made



Male. Female.

FIGS. 2, 3.—*Ancistrus occidentalis*.

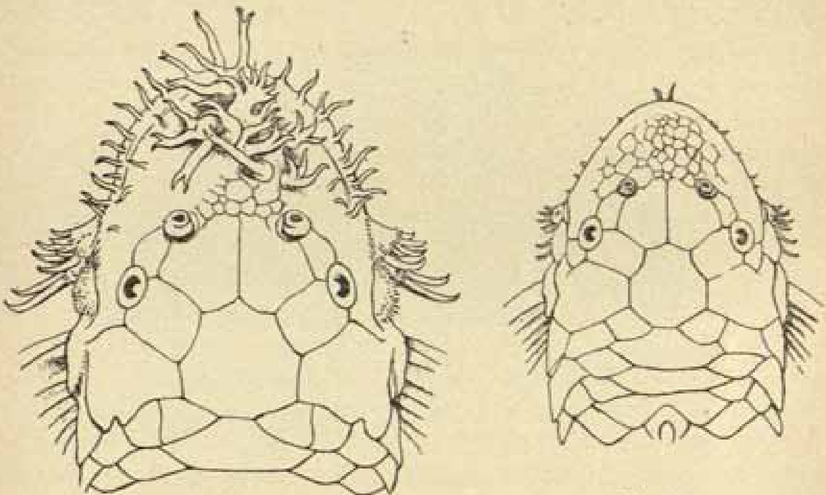
simply to illustrate sexual differences for Mr. C. Tate Regan's Monograph of the Loricarioid Catfishes of America and reproduced here exemplify the rule. Of a kindred species, *Pseudancistrus barbatus*,[b] the sexes are illustrated in Darwin's work.

During the consideration of the social economy of these fishes the question must often recur, How did the parental instinct manifested originate? It was easy enough in olden time to give an answer which would be regarded as all sufficient in those days; it was a specific instinct implanted by an omnipotent creator in every case. In these days of evolutionary belief, however, such an answer is equivalent to no answer. The instinct must be regarded as a development of an aptitude inherent in the fish itself.

[a] Darwin, The Descent of Man, N. Y., 1881, p. 335.

[b] *Plecostomus barbatus* Günther, Darwin; *Ancistrus barbatus*, Regan.

Probably few naturalists or psychologists will be prepared to concede the possession of a sentiment of antiselfish altruism by any of these lowly forms. The attribute of parental care must therefore be regarded as an outcome of selfishness, or, if you will, self-love,[a] a result of the sense of proprietorship. The eggs are the fish's own, and therefore they and the resulting larvæ are to be cared for as such. Perhaps it may be urged that the attention of the parental fishes is of the same nature as that of the hen to her young. We are not prepared to deny it. It may even be conceded, and yet the claim that the sentiment is the offspring of self-love can still be maintained. In fact, there is a regular gradation of self-love into the ennobled sentiment which impels the human mother to sacrifice her life cheerfully for *her* child and the degraded passion which emboldens the miser to



Male. Female.

FIGS. 4, 5.—*Ancistrus chagresi.* After Regan.

suffer death rather than lose *his* gold. It is the basis of the courage of the farseeing martyr for his religion, for he is willing to sacrifice the present for an illimitable future.

Wonder may be entertained that one and the same method of care should have originated independently many times, but this will diminish on reflection. When the sense of proprietorship in the eggs has been established protection by hiding them or clearing away of foreign substances that would interfere with them would not unnaturally follow. The mouth is used by many fishes for carrying, and the instinct to take up the eggs into the mouth for protection would be a natural consequence which might be, and repeatedly has

[a] See Whately's Morals and Christian Evidences, XVI, sec. 3 (Am. ed., 1857, p. 129); Ward's Dynamic Sociology, I, 679.

been, developed into a habit. These and other provisions for the care of the eggs do not make excessive demands on our receptive capacity or imagination. It is only when we consider the case of the sticklebacks that the combination of aptitudes for nest making impresses us. In them complexity is carried to an extreme. There is a sympathetic development of the kidneys and the testes; there is the synchronous response of both to external stimuli; there is the reaction of both on the brain and of the brain to external conditions; there is the elaboration of the wonderful thread which is used to bind the nest materials; there is the instinct to use the thread; there are, finally, the regular aptitudes and impulses which are shared with the majority of fishes. Such an accumulation and convergence of structural, physiological, and psychological characters almost force upon us a rejection, as explanation, of natural selection or sexual selection. The development manifested in the Gasterosteids is, indeed, one of the greatest wonders of the evolution of animal life. Nevertheless, it may not seem so extraordinary if we extend our researches beyond the class to which they belong.

Naturally the elaboration for the perpetuation of the species in the Gasterosteids is unique in the class of fishes, but there is to some extent an analogous provision, although not so complicated, for the animal economy in certain other classes, as in the case of the webs of most spiders and the cocoons of some insects, as notably the silkworms. Mollusks and Annelids furnish other illustrations. Of course in those cases the analogous secretions are not produced by homologous organs, but by very different ones, very different from each other as well as from those of the sticklebacks.

As this article is intended to summarize existing knowledge respecting the breeding habits of some of the fishes in question, the original words in which the facts are recorded are given in most cases—in fact, wherever it could be done without interference with the mode of treatment or sequence adopted for the narration. The text, however, is by no means confined to information respecting the nests and breeding habits. Most of the species are little known or even quite unknown to many persons and yet are very interesting for other reasons than their parental instincts. Consequently quite detailed accounts of their habits in general as well as their places in nature are added. The illustrations are mostly borrowed and are derived from various sources, as will be indicated in connection with the respective figures. Among the original illustrations are those of a fish longest known—the Glanis of the ancient Greeks, never before figured.

THE DIPNOANS.

In and confined to the Southern Hemisphere are three very peculiar types of aquatic animal life. One from South America was first described in 1836 as a reptile related to the siren of the north and named *Lepidosiren;* another, from Africa, not long after (1841), was made known as a true fish, and on account of its simple and supposedly primitive fashion of limbs styled *Protopterus.* For a long time it was a matter of dispute between naturalists whether the two were reptiles or fishes, and no relationship was recognized between them and any other forms, recent or fossil. At last, in Australia, in 1870, was discovered the third type, and then it became evident that not only had they all relatives in the past, but all their relatives were of the past, and the very distant past. The most recent of those extinct forms, so far as known, lived not only in old Europe and America, but also in Africa, Asia, and Australia. They enjoyed a world-wide distribution during the Jurassic period and thus early in geological history disappeared from the surface of the earth. Some, of course, must have survived to transmit their blood and likeness to

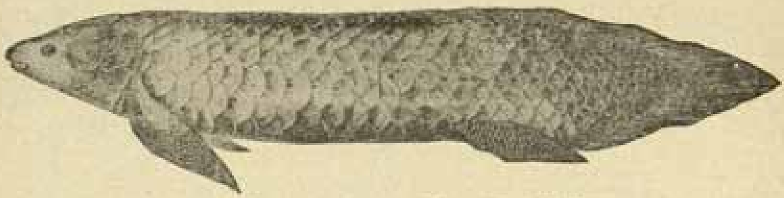


FIG. 6.—*Neoceratodus forsteri.* After Günther.

their living relatives, but their fossil remains have not yet been found. There is an extraordinary gap between the oldest of the living types (of very late Tertiary age) and the hosts that once ranged over the globe. The three types are the *Lepidosiren* of South America, the *Protopterus* of Africa, and the *Neoceratodus* of Australia. They and their distant relative, *Polypterus*, are immeasurably the nearest of kin to the stock from which alike fishes and reptiles originated. Two are remarkable for the provision which they make for their eggs and young. It is most fitting, therefore, that they should be the first to illustrate parental care among fishes.

The three genera are now segregated into a group named Dipnoi or Dipneusti, and often called lung fishes, which has been variously estimated to be of subclass, ordinal, or even class value. Here the subclass valuation may be accepted as expressing best the taxonomic importance of the distinctive characters of the group. Among living fishes the only ones that are at all related to the Dipnoans are the Polypterids or Bichirs of Africa. These are the representatives of a

great group or subclass named Crossopterygians which were characteristic or even predominant fishes of ancient times from the Devonian to the Jurassic period. One of the most striking external features of the Crossopterygians was the prolongation of the axes of the paired fins and the consequent lateral or fringelike arrangement of the rays along the axes. It is to this characteristic that the name crossopterygian (or fringe-finned) alludes.

During the same remote period in which the ancient Crossopterygians flourished lived also fishes so much like those forms that they were confounded with them in the same group by so good a naturalist as Huxley and by many others. They likewise had lobate paired fins, but later it was found that instead of a distinct suspensorium for the lower jaw there was no distinction between the suspensorial elements and the cranium, and that all formed one piece with which the lower jaw directly articulated. There were no distinct upper jawbones. The heart of the living representatives has the same kind of antechamber as that of the Crossopterygians although otherwise different.

It was a long time before the facts thus epitomized became known and appreciated. The histories of the ancient forms and the recent ones were long told as those of beings entirely unrelated. That of the living ones is as interesting as it is curious.

Two very distinct families of Dipnoans are represented in the modern world, one (*Ceratodontids*) confined to northern Australian rivers and the other (*Lepidosirenids*) common to South America and Africa.

In 1836 a great naturalist-collector, Johann Natterer, discovered in the Amazon basin an animal of which he sent two specimens to the Imperial Austrian Museum, and by the custodian of the museum (Fitzinger) it was described as a *reptile* related to the North American *Siren* and called *Lepidosiren paradoxus*. Several years later (1841) Thomas Weir sent two specimens of another animal, taken from the Gambia River, West Africa, to London. This species was described by Owen and considered to be a true *fish* related to the eels and was at first called *Protopterus annectens*, but later it was referred by its describer to the same genus as the South American animal. Owen thought the two belonged to a peculiar "family" and made "the nearest approach in the class of fishes to the Perennibranchiate reptiles." In fact, none of the old authors had any real appreciation of the relations of either animal.

Quite a warfare was carried on for some time about the question whether the animals were reptiles (amphibians) or fishes, but long ago it was decided in favor of the piscine relationship of the Lepidosirenids.

The *Ceratodontids* are a family of ancient lineage and, indeed, were for a long time supposed to have died out in the early Mesozoic period.

In 1870, however, the startling intelligence was published that a living species of *Ceratodus* had been discovered in Queensland. The skepticism with which this announcement was at first received was soon quieted by detailed examinations, comparisons, and descriptions. It was later admitted that the living fish was indeed different generically from any early extinct species known (and named *Neoceratodus*), but it was nearly related to the ancient members of the family. The family is of even greater interest and importance than the Lepidosirenids, but as the species is not a special caretaker of eggs or young, no notice of it is called for here and we pass on at once to the Lepidosirenids.

THE LEPIDOSIRENIDS IN GENERAL.

The Lepidosirenids are much further removed from the ancient lung fishes than the Ceratodontids, and so far no extinct members have been discovered.

The shape is anguilliform and the paired fins are reduced to little more than the stems, the rays being atrophied or lost. The teeth in number are the same as in most of the order, a pair of palatine and pair of vomerine teeth above and in opposition a corresponding pair of molar teeth in the lower jaw. The pneumatocœle is manifest in the form of a pair of entirely distinct lungs.

In the living animals, according to Professor Lankester, the body is covered by "soft vascular connective tissue, in addition to a well-developed epithelium," and consequently "no scales at all or parts of scales are visible on the surface of the body of a fresh or well-preserved specimen." The scale-like areas which are "marked out on the surface of the body" are in fact lozenge-shaped areas "outlined by the greater abundance along their margins of the large branching pigment cells of the connective tissue, which overlies as a uniform and continuously flat layer the subjacent scales."

Two genera of Lepidosirenids are represented by living species—in Africa *Protopterus*, with three known species, and in South America, *Lepidosiren* with one. Superficially they resemble each other so much that some have referred both to the same genus, but the anatomical differences are numerous and some of them striking. In *Lepidosiren* there are only four slits between the branchial arches, in *Protopterus* five; the scapular arch is connected with the cranium in *Lepidosiren* only by a ligament, but in *Protopterus* there is an osseous connection by a bone called the "supraclavicle." The body of *Lepidosiren* is also more slender than in *Protopterus*, the ventral fins farther back, and the dorsal fin considerably shorter.

THE PROTOPTERES.

Of the three described *Protopteri* the earliest known, *Protopterus annectens*, has the widest range, extending from the streams of tropical Africa, north of the Kongo basin, and from near the west coast to the Nile. *Protopterus æthiopicus* is a species of the White Nile, and *Protopterus dolloi* of the Kongo River. The last is distinguished for its slender body and many ribs (54) thus simulating the *Lepidosiren*.

The Protopteres live mostly in shallow, muddy waters or swamps which dry up during the rainless season. They spend most of the time at the bottom, and in an aquarium one may "seek the darkest corner" and squeeze itself "along one of the perpendicular angles of the case." At length it will arouse itself from this lethargy and move about for exercise or for food. J. G. Wood (1863) was "much struck with the exceeding grace of its movements, which indeed very strongly resemble those of the otter." During its progress "the peculiar screwlike or spiral movement of the limbs is well exhibited."

The open air has to be resorted to more or less for respiration.

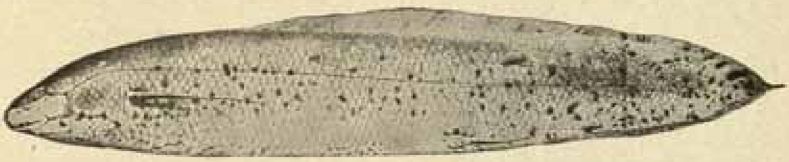


FIG. 7.—*Protopterus annectens*. After Lankester.

McDonnell has recorded his experience with the fish. "At first it used to come to the surface for air every three to five minutes, and, taking it in with open mouth, sink from the surface; small bubbles then generally escaped from the gill apertures, and frequently, before again coming up for more air, a large quantity was expired, bubbling up from the branchial outlets." That the fish "has the power of voluntarily closing the opercular opening was proved by the following maneuver." "The animal, burying its nose in the fine gravel in the bottom of the vessel, used rapidly to gulp up the gravel and throw it out through the gills with a strong stream of water. It could at will vary this operation by throwing the jet from the right or left aperture." After the owner had the animal "for some months," however, "and it had again become used to the aquatic respiration, it did not come to the surface for air oftener than from ten to twenty minutes."

As the water disappears, the fish burrows into the mud, contracts the body, and secretes a great quantity of mucilaginous matter which forms a cocoon around it, and thus it may remain interred until future rain dissolves the mass and liberates it. But provision is made

for respiration meanwhile, for the vital functions are only partly suspended. A tube is elaborated, lined with the same mucus which forms the lining of the cocoon from the mouth of the fish to the surface, and through this the Protoptere derives sufficient air to support its aerial respiration. The presence of a fish in a cocoon may be readily detected by introducing a straw into this tube. If the fish be alive, quite a sharp cry may be immediately heard which is produced by the sudden expiration of the air from the lungs. Boulenger, like Dubois, remarks that nothing surprises a person who has not been forewarned more than to hear the sound that may issue from a clod of earth of small size.

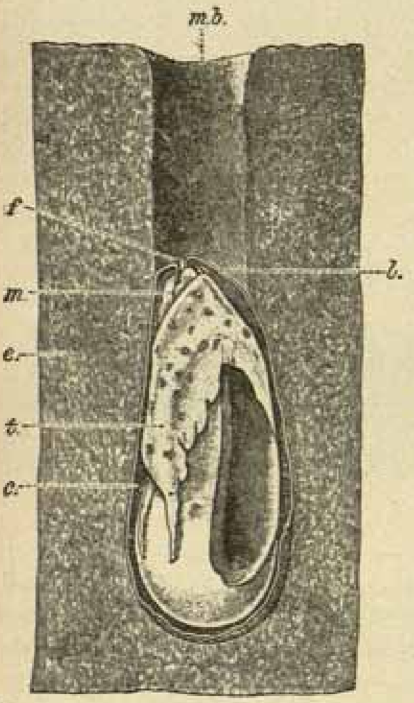


FIG. 8.—Protoptere in cocoon. *c*, cocoon; *e*, earth; *f*, funnel leading to mouth of fish; *l*, lid; *m*, mouth; *mb*, mouth of burrow; *t*, tail. After Parker.

The Protopteres under certain conditions, indeed, give utterance to decided sounds. Doctor McDonnell received a cocoon "dug up on the banks of the Gambia," and proceeded to liberate the inclosed fish. He pushed a straw into the air hole so as to touch it, whereupon it squeaked so loudly as not only to give unmistakable evidence of its existence, but to make the doctor quickly draw back "his hand, in fear lest" he "might be bitten," and while the cocoon was being sawed and broken open "the animal repeatedly produced vocal sounds," which McDonnell regarded as "unquestionably voluntary." But "after having been placed in water it was not again heard to produce any vocal sound; on being occasionally taken out of the water it made no other sound than the smacking made by eels and other fishes." The sounds were really involuntary and, as Boulenger has explained, "produced by the sudden expiration of the air from the lungs," reenforced by the walls of the cocoon acting as a sounding board.

The Protopteres are very voracious and indulge in a great variety of food. They mostly feed on tadpoles as well as grown up frogs, fishes, crustaceans, insects, and worms, but they likewise will eat boiled rice and beans. In captivity they have been mostly fed on

beef. According to J. G. Wood (1863) "the mode of eating was very remarkable. Taking the extreme tip of the meat between its sharp and strongly formed teeth it would bite very severely, the whole of the head seeming to participate in the movement, just as the temporal muscles of the human face move when we bite anything hard or tough. It then seemed to suck the meat a very little farther into the mouth and give another bite, proceeding in this fashion until it had subjected the entire morsel to the same treatment. It then suddenly shot out the meat, caught it as before by the tip, and repeated the same process. After a third such maneuver it swallowed the morsel with a quick jerk. The animal always went through this curious series of operations, never swallowing the meat until after the third time of masticating." In other words, the animal subjects its food to a kind of chewing process.

If left free in water where other fishes occur, they are very much at home and exercise a choice of food at the expense of many a coinhabitant. "A fish may be quietly swimming about suspecting no evil" and a Protoptere "rise very quietly beneath it until quite close to its victim" and then make "a quick dart with open mouth" and seize "the luckless fish just by the pectoral fin, and with a single effort" bite "entirely through skin, scales, flesh and bone, taking out a piece exactly the shape of its mouth." With this plunder the Protoptere will sink to the bottom and there chew as is its wont. It never chases its victim or takes a second bite. But when, in an aquarium, the keeper offered a Protoptere a frog attached to the end of a stick it acted differently. "No sooner did the frog begin to splash than the fish rose rapidly beneath it, seized it in its mouth, dragged it off the stick like a pike striking at a roach, and sunk to the bottom with its prey. Not a vestige of the frog was ever seen afterwards." It was naturally inferred that "the poor victim was gradually chawed up like the beef with which the creature was formerly fed."

Another peculiarity in ingestion of food was observed by McDonnell (1860). He had "seen an active little minnow an inch and a half or two inches from the mouth of the" Protoptere "suddenly sucked in and devoured. The prey is drawn into the mouth with immense rapidity by depressing the hyoid bone, and making a gulp rather than a snap."

They are very quarrelsome, and Boulenger declares that it is almost impossible to preserve many together in an aquarium without their maiming their fellows or amputating fins or tail. It is to be remarked in this connection that those parts are readily regenerated, but not to the same size or shape as the original, and consequently much variety may be observable in those respects.

The nests and eggs of the Protoptere were looked for for a long time before they were found. At length Mr. J. S. Budgett, in 1901, had the good fortune to find them during his expedition to the

FIG. 9.—Nest of the *Protopterus* of the Gambia. After Budgett.

Gambia region. One day his native head fisherman, Sory, approached him "in a great state of excitement to say that he had found the children of the cambona," the native name of the Protoptere. "It was scorching mid-day, in the height of the rainy season, the temperature 99° in the shade." But Budgett hastened to the swamp, and "there, about 10 yards from the water's edge, on dry ground, was an oval-shaped hole filled with water, and in the water was a great commotion, the surface of the water being con-

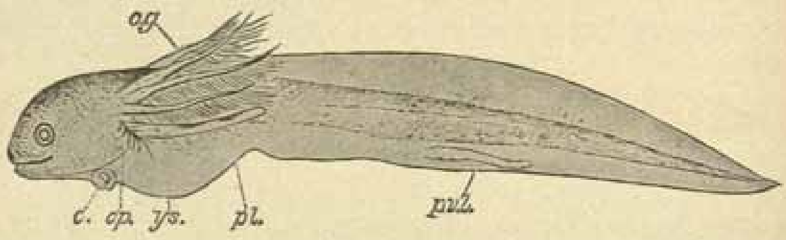


FIG. 10.—Larval *Protopterus* on the seventeenth day. *c*, Cement organ; *c.g*, cutaneous gill; *op*, operculum; *p.l*, pectoral limb; *pv.l*, pelvic limb; *y.s*, yolk-sac. After Budgett.

tinually lashed from side to side by the tail of a cambona, the head of which was way down under the ground. On being startled the cambona disappeared downward, and the fisherman putting his hand into the hole drew forth a handful of larval Protopteri." Having learned where to look for nests, Budgett found no difficulty in finding others and supplying himself with material.

Special care is taken of the young. "Throughout the period of the larvæ being in the nest, the male *Protopterus* stays with them and

guards them jealously, severely biting the incautious intruder." The nests are irregular in shape and about a foot deep. "There was never any lining and the eggs were laid on bare mud. All the males found in nests measured about eighteen inches in length." This, however, is by no means near the maximum of size attatned.

The rate of growth varies with circumstances. One noticed by Wood was 10 inches long and weighed "a few ounces" when received in London, and in three years grew to a length of 30 inches and a weight of 6¼ pounds. "The rapidity of its growth," Wood thought, "may be accounted for by the fact that it had fed throughout the entire year instead of lying dormant for want of water during half its existence, and its size was apparently larger than it would be likely to attain in its native state."

The Protopteres are highly esteemed by the African negroes, and they take advantage of their knowledge of the habits of the fishes to secure a supply. They readily discover the presence of cocoons in the dried-up swamp and dig them up with the surrounding earthy covering, and these clods may be kept for future use. The flesh is "very soft and white." Long ago the edibility, or rather savoriness, of the flesh was appreciated by whites. As far back as 1860 Doctor McDonnell described it as "excellent as an article of food," and being "highly palatable, somewhat resembling turbot; a considerable quantity of yellow granular fat is diffused among the muscles, to which, no doubt, is due in some degree its savory qualities."

THE LEPIDOSIREN.

The habits of the only generally recognized Lepidosiren are analogous to those of the Protopteres. It lives in stagnant pools and watery hollows in swamps by the side of a river, but not in the river

FIG. 11.—*Lepidosiren paradoxa.* After Göldi.

itself. Doctor Bohls was "unable to say from actual observation that the Lepidosiren can live in the dry mud of the pools, but as the swamps do dry up when the weather is hot and little rain falls, they must either die or pass through a period of nonaquatic life."

This is probably effected by burrowing and hiding in "the lower regions of the mud," and they "thus survive the drying up of the pools." Kerr was able to trace the career of one individual more fully.

"On the approach of the dry season it ceased to eat entirely: the muscles especially of its tail underwent fatty degeneration." It became still more sluggish than was its wont, "remaining in its

burrow, and as the waters completely dried up it remained in the mud, breathing air by means of an air hole." It, however, appeared to make nothing so specialized as the cocoon secreted by the Protoptere.

As a rule, the Lepidosiren is a sluggish animal and wriggles among the dense vegetation which it affects. It acts as if it were almost blind, "merely distinguishing light and shade," and is very sensitive to vibrations in the water. "A remarkable point" also, at least of the young, was observed by Kerr. "During the night the black chromatophores all shrank up, so that the creature was of a nearly pure white with round yellow spots." With the return of daylight the characteristic color is resumed. "At dawn the creatures are still pale, but gradually darken, until about sunrise the normal deep color is re-attained."

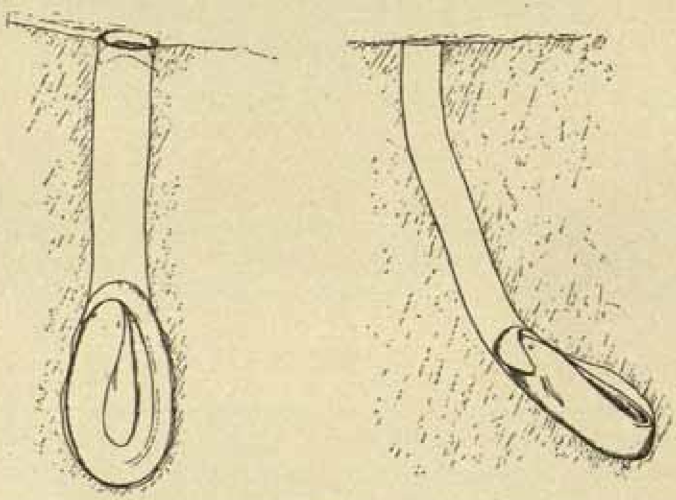


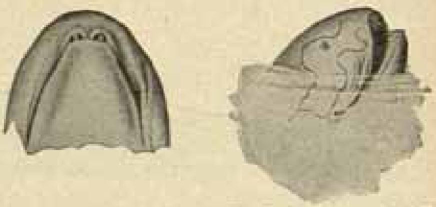
FIG. 12.—Views of two dry-season burrows of *Lepidosiren*. After G. Kerr.

The Lepidosiren is carnivorous and feeds mainly on "marsh snails," or gastropods of the family of apple snails or Ampullariids, one of which grows as large as a man's fist and has a dense shell which the powerful teeth of the Lepidosiren are well fitted to crush. It by no means confines itself, however, to mollusks, for specimens have been "caught with a hook baited with fish," so that the Lepidosiren occasionally at least feeds on fishes. Vegetable matter, too, was found "in the alimentary canal of the Lepidosiren together with the remains of the snails," but Doctor Bohls thought it "probable that this may have been swallowed accidentally and not as food." Kerr, however, thought that it deliberately fed "on masses of confervæ." "During the rainy season, life being easy and food extremely abundant, the Lepidosirens eat voraciously; fat is stored up in great quantities in their tissues. This is especially the case in the

tail region, where the large masses of lateral muscles become in great part replaced by orange-coloured fat. As the dry season comes on and progresses so far as to cause the area of water to greatly diminish in extent, a change comes, and the Lepidosiren ceases entirely to feed."

The Lepidosiren has great power in its jaws, and "the bite of the animal is much feared by the Indians." There are few enemies strong enough to master it when adult, but, nevertheless, "few examples of the fish are taken in a complete condition; one of the limbs may be missing, or the tail injured (as often noticed also with Protopterus). The Jacare (*Alligator sclerops*) feeds on the Lepidosiren in these pools, and specimens were found with the whole region of the body posterior to the anus in a state of regeneration—the amputation having been probably due to the bite of an alligator."

Doubtless, however, part of the mutilation is due to attacks of the bloodthirsty Pirayas, and part also, according to Lankester, to the invasion of a parasite akin to that which is so injurious to the salmon (*Saprolegnia ferax*).



Head from below to show anterior nostrils. Head partly projected from water to breathe.

FIGS. 13, 14.—*Lepidosiren*. After Göldi.

The Lepidosiren has a sort of voice. Its discoverer, Natterer, long ago affirmed that "his Lepidosiren could give a cry like that of a cat. Those observed by Doctor Bohls gave out a sound when removed from the water, caused by expelling air through the narrow aperture of the branchial chamber." According to others, too, it sometimes "growls."

A Lepidosiren obtained at Obydos (a town in the State of Para) was sent to Doctor Göldi and was kept for some time alive in an aquarium at Para. "During the day and when undisturbed" the fish was "a quiet and passive creature, not changing its curled position for hours." Only once did it attempt to bite the fingers of its keeper. It remained "generally indifferent even when small living animals" were offered to it "with the pincers." It refused all food in the presence of observers, but as it became "in a better state of nutrition than when it arrived" and "decidedly fat and round" it must have taken food unseen. It was assumed to do so "when it burrows half the length of its body in the mud, as frequently seen."

For respiration it ascended "from time to time to the surface of the water, and put out a portion of its head." The operation lasted several seconds. In a large aquarium this was done only "at intervals of several hours," but in a smaller one much more frequently. "The respiration is sometimes singularly prolonged. When descend-

ing, a series of air-bubbles is generally expelled from the branchial apertures on each side of the anterior part of the body. The whole body is covered with a viscous or gluey substance, which fills the water with whitish flakes when the Dipnoan executes more rapid and violent evolutions."

The breeding season follows with the rainy season and "within the first few weeks after liberation from the mud," in which the Lepidosirens have been imprisoned during the dry season. On the approach of the breeding season the papillæ of the ventral limbs of the males grow out "into blood-red filaments one or two inches long." A sort of nest is made "in an underground burrow" excavated at the bottom of the swamp, and therein the eggs are laid by the female, but "apparently usually guarded by the male" alone.

The progress of eggs and young were watched by Kerr.

Eventually there hatched out a tadpole-like larva, devoid of pigments, the horny eggshell undergoing a process of digestion before splitting. The larvæ were remarkable for the extremely well-developed sucker and the

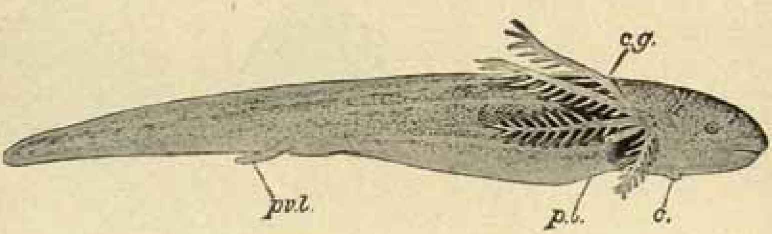


FIG. 15.—Larval *Lepidosiren* thirty days after hatching. *c*, Cement organ; *c.g*, cutaneous gills; *p.l*, pectoral limb; *pv.l*, pelvic limb. After Graham Kerr.

large external gills (strikingly amphibian characters said to be absent in *Ceratodus*). The external gills were four in number on each side. About six weeks after hatching the external gills atrophied, as did also the sucker; the creature assumed a much darker, almost black, colour, and its habits became much more active. The young Lepidosiren remained in its nest till about 60 mm. [about 2½ inches] long. For nearly three months it lived in the yolk in the walls of the enteron, but did not eat at all. About this time yellow spots appeared on the larva, and it remained so spotted till over one foot long. The young Lepidosirens had proportionately larger limbs than the adult, and used them much in irregular alternation in clambering through the mud.

The Indians in the neighborhood of its haunts depend largely on the Lepidosirens, as well as other fishes caught in the pools. The Lepidosiren can not be caught with nets (on account of the weeds), nor, commonly, by hook and line. They are mostly obtained by a spear or harpoon of about 8 feet in length. "The Indians plunge into the water in parties, prodding the bottom of the pools with these instruments." Doctor Bohls himself went out with a party of ten Indians. The ovaries of the Lepidosiren are preferred as an article of food to the salmon-like flesh, and are pressed into a kind of cake.

CROSSOPTERYGIANS.

During the later Paleozoic period and the succeeding Mesozic the predominant fishes were forms distinguished by the axial prolongation of the skeleton of the paired fins, pectoral as well as ventral. The species and genera were many, and they represented a number of families. They early disappeared—during the later Mesozoic—from the waters of countries later to be inhabited by civilized men, but in others the race or "phylum" must have been continued, for to-day relatives are still living in the fresh waters of the African continent, and there only. The last, though obviously akin to the ancient fishes, are not near relatives, but in some respects quite different. Modern naturalists concur in the opinion that many old forms and the new constitute a great comprehensive group to which the name of *Crossopterygians* (*Crossopterygii*) has been given. By some that group is called a subclass; by others a superorder or an order. In the belief that it is a natural group agreement is universal.

All, extinct and recent, had or have the paired limbs developed round an axial extension of the paired fin skeleton, so that the fins are "lobate." A distinct suspensorium of the lower jaw is developed, connected with the cranium by a simple suture. The skull is also characteristic in that the upper jawbones are not distinct, as in typical fishes, but continuous with the cranium as in Amphibians. The heart is preceded by an arterial muscular bulb, whose cavity is beset with several longitudinal rows of valves.

The cardiac character is of course known only from the living forms of the group, and they have been recognized as a distinct type (*Cladistia*). These *Cladistians*, which have been estimated by some ichthyologists as an order, are distinguishable by the peculiar pectoral fins. The base of each of those fins consists of a Y-shaped part articulating with a convex condyle of the scapular cartilage, and between the forks of the Y-shaped element is a broad cartilaginous plate. On the hind edge of this many ray-like bones or actinosts are set, and these support the pectoral fin.

It has been urged that this member manifests the nearest approach from the fish side to the fore limb of a terrestrial vertebrate. The "convex condyle of the scapula" is supposed to be homologous with the humerus, the Y-shaped element represents the radius and ulna, the intervening cartilage the material for the carpus, and the actinosts the metacarpals. The group is consequently one of singular interest to the morphologist. The interest is not lessened by the imperfection of the history of the group. While its ancient relatives died out countless ages ago in the explored regions of the earth, in Africa one branch of the group must have survived, and a number of species still represent the order and the subclass in many an African river. These representatives all belong to one family, called the Polypterids,

THE BICHIRS.

The family of Polypterids or Bichirs is peculiarly interesting, as, to a greater extent than any other recent group, it is intermediate between fishes and amphibians—that is, between vertebrates having fins and those with legs. The body is more or less elongated or subcylindrical and covered with oblique rows of enameled rhombic scales; the head is snakelike and protected by bony plates; the caudal fin rounded and continuous upward and forward with the dorsal fin; the dorsal furniture is especially remarkable; there are along most of the length of the back a row of spines (very different from the spines of other fishes) with whose hinder surfaces generally several raylike appendages articulate and a membrane is developed, thus resembling separate finlets. The anal is small and almost continuous with the caudal fin, and the ventrals are also far back; the pectorals are rounded and most prominent below the middle of the hinder margin.

The family has two very distinct genera—*Polypterus* and *Calamichthys*. Of the former one or more of 10 species are found every-

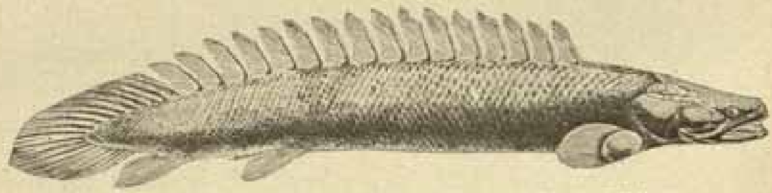


FIG. 16.—*Polypterus bichir*. After Geoffroy Saint-Hilaire.

where in tropical Africa; of the latter only one—a very elongated, eel-like form without ventral fins—occurs in a few rivers of western Africa.

The species of *Polypterus* are so much alike that they have been supposed by some to be variants of one species, but they are really well distinguished by differences in the number of dorsal spines (ranging from 5 to 18), size of scales, size of eyes, and other characters. The oldest known species (it was known to the ancient Egyptians, but was first described by Geoffroy Saint-Hilaire in 1809) is at one extreme with 15 to 18 spines, and one, described by W. O. Ayers, of Boston, in 1850, is at the other extreme, with 5 to 8 spines.

The habits of the Polypterids are characteristic. They are in the main bottom fishes and lethargic. But they are not confined to such places and conditions. Harrington found that they also live "in the deeper depressions of the muddy river bed," and there they are "active" swimmers and "not essentially bottom-livers or mudfishes." They are most active at nighttime, when "in search of food." But in shallow water they will lie for long periods on the mud at the bottom of the water, with the body a little upraised forward and

resting on the outspread pectoral fins, whose form is so well adapted to give a wide resting surface. At last they may deliberately move away, working the pectorals like a fan, the lower rays being the first deflected. If the water is foul, they will dart to the surface, take a mouthful of air, and then rapidly descend to the ground again. It is noteworthy that part of the air gulped down escapes by the spiracles behind the eyes.

The name pneumatocœle was coined as a common name for a viscus, which may be either an air bladder or a lung—that is, for the primitive diverticulum of the intestine, which was not specialized as one or the other. The pneumatocœle of the Polypterids is double on the floor of the abdominal cavity, and cellular; it is, indeed, a partly united pair of lungs, rather than an air bladder, and acts as a lung and not as a hydrostatic organ or air bladder. The emission of air instead of water through the spiracles is in harmony with this function as a lung. This approximation of the Polypterids to amphibians by its respiratory function is coordinate with another character of amphibians. In typical fishes the main instrument of propulsion is the tail and caudal fin, and the pectorals chiefly preserve its equilibrium; in the Polypterids the pectoral fins assume a large share in the function of progression, supplementing the caudal.

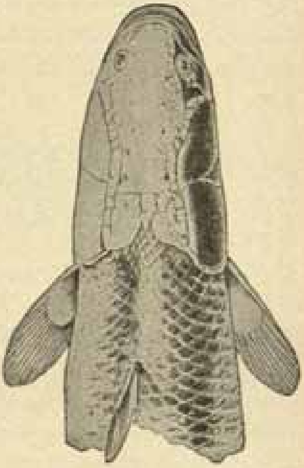


Fig 17.—*Polypterus bichir*. After Geoffroy Saint-Hilaire.

Although provided with real lungs, Polypterids do not appear to be able to live long out of water. At least Harrington complains that they "will not survive more than three or four hours out of water, and only then under the most favorable conditions—that is, covered with damp grass and weeds." This feebleness was a great obstacle to success in getting mature eggs and sperm at the same time.

Another characteristic in the actions of the Polypterids has been recorded by Harrington. "Peculiar in the swimming movements" is "the manner in which the head moves freely from side to side. This produces the appearance of a progression more or less snake or eel-like, although in general the powerful sweeps of the strong tail characterize the progression as fish-like."

The food of the Polypterids is limited by their ability of locomotion and ingestion; it consists mainly of small fishes and amphibians as well as crustaceans, but the variety is liberal. Harrington found that besides small catfishes, such as the "armoot, bayad, schilbe, and

schal, which were commonly used as bait," they eat "a great many other teleosts, as is evidenced by the more or less undigested remains in the stomachal pouch of such forms" as killie fishes, eels, and boltis. They apparently catch such fishes alive, and they are most attracted by "live bait;" the food is always swallowed whole. "Although catfish are usually taken head first, some fish were found in the stomachal pouch in a reverse position; their undigested remains are probably ejected through the mouth. The pouch is admirably adapted for resisting the very dangerous and strong spines possessed by the catfishes."

The spawning season commences nearly with the rainy season or the inundation of the Nile and may last several months, or from June to September. As the season for reproduction approaches, the habitual lethargy of the fishes diminishes, their movements become more sprightly, and males and females meet. The eggs become developed, and about as large as grains of millet; they are of a bright green color. The males also become more differentiated by the development of the anal fin. This is not only larger than in the female, but specially modified in form.

Another noteworthy circumstance is that "the males are smaller than the females and, although they are much less numerous, are generally taken in company with one or more females." Harrington obtained "only twelve males to fifty-eight females."

On account of the great interest connected with the relationship of the Bichirs, a number of expeditions have been sent or led to Africa for the purpose of studying the life history and especially the oviposition and development of the species. The first in the field were Americans—parties from Columbia University. In the spring of 1898 Dr. N. R. Harrington, then a "fellow in zoology" of the university, with Dr. Reid Hunt, went up the Nile in search of the Polypterids and remained till September 10. He found many fishes with eggs and spawn, but not the combination of the ripe products. Later Mr. J. S. Budgett undertook to visit equatorial Africa for the purpose of investigating the species, and in 1901 he published some important facts relative to the habits of some of the species. After several ineffectual attempts he succeeded in confining some fishes in four inclosures in a swamp off the Gambia River. He fed them with minced meat, and as soon as he put food into the water at one end of the inclosure some of the fishes "came hurrying through the grass from all parts and greedily devoured it, without the least appearance of shyness." He was unable, however, to obtain eggs from them or to effectually fertilize those from other individuals. He found that "the main difficulties in obtaining the eggs seem to lie in the fact that *Polypterus* probably makes no nest, and certainly lays but few eggs at a time, these being scattered, probably broadcast, throughout

the thick vegetation of the flooded grass-lands. The eggs are minute, and therefore the chances of finding them in a state of nature are small in the extreme."

In 1902 Budgett went to Uganda and returned by way of the Nile, in search of Polypterus. Below Murchison Falls, during August, he found Polypterus spawning and the fertilization of over a hundred ova was secured, but this, "the most promising attempt yet made to breed Polypterus artificially, again failed."

The youngest Polypterus yet found was an inch and a quarter long. It had external gills as "long as the head. It was a most beautiful object," above striped with black on a golden ground and with a golden stripe running from the snout onto the end of the stem of the external gill. It was "extraordinarily active, and, during the moments when it was at rest, supported the weight of its body on its pectoral fins, the blade of the fin being turned forwards and not backwards as is usually the case in the adult."

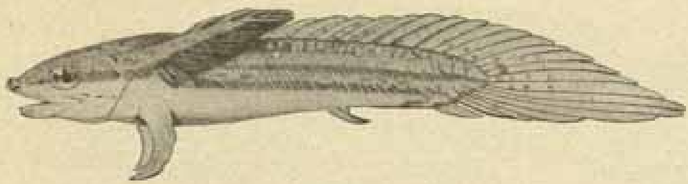


FIG. 18.—*Polypterus senegalus* larva, 1¼ in. long, in a very characteristic attitude. After Budgett.

At last, during a third voyage to Africa, in southern Nigeria in the months of August and September, 1903, Budgett succeeded in obtaining eggs and milt of *Polypterus senegalus* in proper condition and time. He was "able to fertilize a large quantity of eggs." The early development was found to be very similar to that of a batrachian—"astoundingly frog-like" was his first announcement—"the segmentation being complete and fairly equal and the process of invagination resembling that of the frog's egg. Prominent ventral folds are formed which arch over in the normal fashion."

A characteristic of the Polypterids is the development and retention for a long time of the peculiar external larval branchiæ or gills, one on each side, reminding one of similar structures in the Dipnoans. These have a featherlike form, with a tapering cutaneous axis bordered by rows of barblike filaments above and below, converging into a terminal portion; they originate behind the upper extensions of the branchial apertures. Their persistence is variable, and sometimes one may last much longer than the other, as in a specimen of the *Polypterus congicus*, nearly 9 inches (22 cm.) long, which retained the right gill but had lost the left one.

Here, for the present, the history of the Bichir's propagation ends. Four special expeditions have been made and two excellent naturalists—Harrington and Budgett—sacrificed their lives in the search for further details. Another and more fortunate explorer must arise before the full history of the fish is known and the extent to which provision is made for eggs and young.

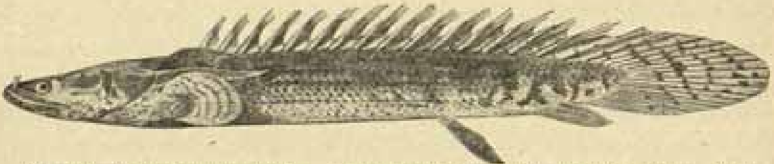


FIG. 19.—*Polypterus senegalus*. Young with persistent external gills. After Steindachner.

The Bichir is not only interesting from a scientific point of view, for it may be considered as a food fish and is by no means a bad one. Indeed, Geoffroy Saint-Hilaire claimed that its flesh is white and much more savory than that of the other inhabitants of the Nile. As the fish can not be readily cut with a knife, on account of its coat of mail, it is put whole in the fire, and can then, after the limbs have been cut out, be skinned and handled with ease.

THE BOWFIN OR AMIA.

One of the most interesting of the American fresh-water fishes is that most commonly known as the dogfish or mudfish, but to enable an

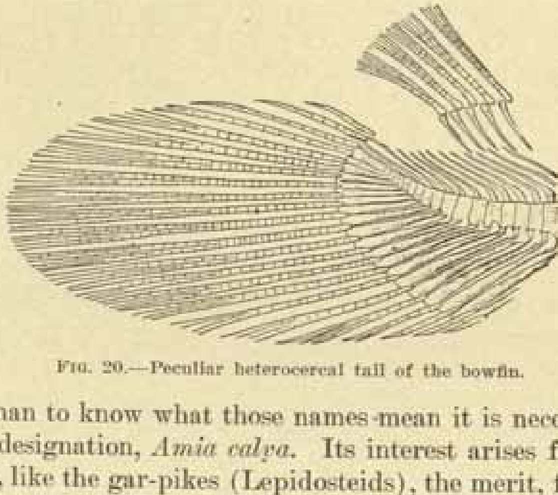


FIG. 20.—Peculiar heterocercal tail of the bowfin.

ordinary man to know what those names mean it is necessary to add the Latin designation, *Amia calva*. Its interest arises from the fact that it has, like the gar-pikes (Lepidosteids), the merit, for the zoologist, of being the only survivor of an ancient type of fishes, and thus preserving the records in flesh and bone of the details of structure as well as habits characteristic of one of the old types. It is at once

the representative of a peculiar genus (*Amia*), a peculiar family (Amiids), and a distinct order or suborder (Cycloganoids). But although now solitary and confined to some streams and lakes in North America, not long ago in geological history it had numerous relatives in many parts of the world, and a few survived in Europe till the Miocene period, when they had, as contemporaries there, species of Lepidosteids, as have those now living in America.

Although dogfish and mudfish are the names in widest use, there are many other popular names in more limited acceptation, such as bowfin, grindle, or, in more detail, "John A. Grindle," lawyer, marshfish and blackfish. Blackfish is the name current in the residence of the species nearest Washington and the coast cities; that is, about the Dismal Swamp of Virginia. But it and all the other compounds with fish are much better known to most persons and in literature in connection with other fishes, and consequently bowfin may be advantageously used here.

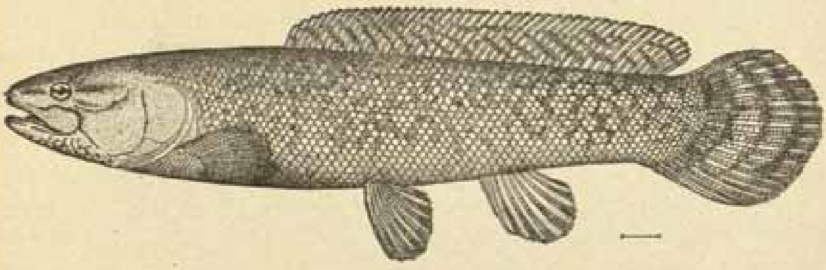


FIG. 21.—Bowfin (*Amia calva*).

The bowfin has attracted the attention of many persons, and by various zoologists it has been watched by day and night, as well as when feeding and breeding, and consequently its life history is quite well known. Chief of the historians of its doings are F. Fülleborn (1894), Whitman and Eycleshymer (1897), Bashford Dean (1898), and especially the latest, Jacob Reighard [a] (1903). From these we are able to derive an unusually satisfactory view of the fish. For details reference may be had to the writers just named, and a brief summary need only be given here.

The bowfin is a strong and well-armed fish, both as to the bony armature of the head as well as the teeth. It is one of the large fishes, when fully mature attaining a length of over 2 feet, often 2½, or even somewhat more. As usual among fishes, the females average larger than the males. The males, apparently, are much more numerous.

The geographical range of the bowfin is quite extensive, and yet restricted in a peculiar way. It is not found in the New England

[a] The quoted paragraphs not specially acknowledged are due to Professor Reighard.

States (except in Lake Champlain) nor in the waters, flowing eastward, of the Middle States, but it is an inhabitant of the Great Lakes (except Superior) and of the Mississippi basin, as well as of the Southern States up to Virginia and the Dismal Swamp.

Sluggish waters are its favorite haunts, and a couple of its names—mudfish and marshfish—indicate places in which they may be found. But, as Dean has recognized, "the general habitat of the fish varies at different seasons of the year. In summer it frequents deeper water; in spring it comes into the marshy shallows and makes its way through reedy places where the water is scarcely deep enough to cover the dorsal fin." For winter quarters, like the carp, it selects deeper water. Ayers found it "in schools closely huddled together in the bottom of pockets or shallow depressions of the gravelly beds" of Lake Oconomowoc (Wisconsin) "among the water weeds." In such places the fishes may "lie so close together that occasionally two individuals are impaled on the fish-spear by one throw." When disturbed by such intrusion, "they scatter from their resting-places, moving out a short distance to return quickly after the first few disturbances." Doubtless during the cold weather they cease to feed and live on the fatty stores they accumulated during the summer.

The bowfin is a more or less nocturnal animal, but stirring mainly about the beginning and end of night. After considerable observation, Dean concluded that it "is rather to be regarded as active at twilight. It takes the hook best shortly after sundown and during early morning." At such times it is "exceedingly active under natural conditions."

Voracity is characteristic of the bowfin, and smaller fishes and crayfishes are its chief prey. Some of its victims may be half as long as itself, but generally they are considerably smaller. Its approach to prey is rather slow and steady; but when near enough it quickly darts and seizes the object which it has neared. According to Hallock, one has "been known to bite a two-pound fish clean in two the very first snap." As a rule the object must show evidence of life to render it desirable. Dean at least "found no evidence that the dogfish eats fish, or, more accurately, *some* fishes, after they are dead," and "dead perch and sunfish remain untouched" where the fish "is very abundant." Nevertheless it sometimes takes advantage of "a rubbish heap in the water," and "scraps of meat and a lump of raw potato have been found in the stomach of one."

When warm weather sets in, the bowfin leaves its winter quarters and begins to make good the loss of flesh incurred during the winter. The impulse to perform their procreative duties is soon felt and the sexes show the effects. The females become heavy with ripening eggs, but retain the dull colors of winter. The males assume a bril-

liant livery; all their fins become a bright green and of the same hue as the pond plants among which they rove; the bronze of the back and sides is furbished up; the stripes on the cheeks show in bolder relief, and above all the spots at the base of the caudal fin grow vividly distinct; the spot of each side culminates in being velvety black, and its surrounding ring is of a bright orange or yellow color.

Striking and glaring as is the color of a male fish when isolated, it is quite otherwise when amid his natural surroundings. Then, Reighard testifies, "one is struck by certain resemblances between his colors and those of surrounding objects. All his fins are of a green like that of the aquatic vegetation and blend with it readily. The reticular markings on his sides bear a close resemblance to the shadows cast by the intercrossing leaves of the vegetation floating at or near the surface." This resemblance is so close that Reighard, "after prolonged examination at a distance of a foot or two," was unable to determine with certainty "which of the reticulations on the side of the male were due to pigment and which were shadows. They could only be distinguished through some slight movement of the fish. Moreover, the tail-spot bears a striking resemblance to certain refraction images that are commonly seen on the bottom in shallow water."

In April the mating is generally at its height. Males and females seek each other. Both resort to places fit for their future functions. Reighard tells that "the localities selected for nests are quiet bays or inlets, well-grown with water-plants and affording shelter for the nests in the form of stumps, bushes or fallen trees. Those localities are preferred in which the removal of the growing vegetation leaves a thick mat of fibrous rootlets for the bottom of the nest." Each nest is a saucerlike excavation from 1 to 3 feet in diameter and from 4 to 8 inches deep. The bottom of the excavation is usually of the kind of fibrous roots just noticed, "which, freed of all earth, form a thick spongy mass. Sometimes, however, the bottom is of gravel or sand, or even of black loam, and in two cases" observed by Reighard, it was of "the dead, brown, water-soaked stems or leaves of cattail or other similar water plants." Of course there are still other variants from the average nest.

The male unaided constructs a nest, and, according to Reighard, "works chiefly by night, not by day." There are, however, some exceptions, and Reighard records that "a half-completed nest found at 9 a. m. on April 23 was found completed in the afternoon of the same day." Reighard was convinced "that the male uses the snout in making the nests" from "the fact that in the nesting season the snout of the male is frequently covered with scratches where the epidermis has been removed, and the underlying connective tissue shows white beneath it. Probably the male in building the nest

breaks off the young shoots with the snout, or by the movements of the body, or by biting." Doubtless "he then sweeps the underlying rootlets clean of bottom ooze by the fanning movements of his pectoral and caudal fins. When he excavates into sand or gravel, the work is probably done largely, as in teleosts, by fanning with the caudal and pectoral fins. This much may be inferred from the fragmentary observations" recorded.

A nest is made without any selected mate and sometime in advance of finding or selection of one by its maker. Meanwhile the male stays beside it more or less persistently. "If the female does not appear, the waiting male ceases after a time to guard the empty nest," and leaves. More likely, however, a seeking female, a night

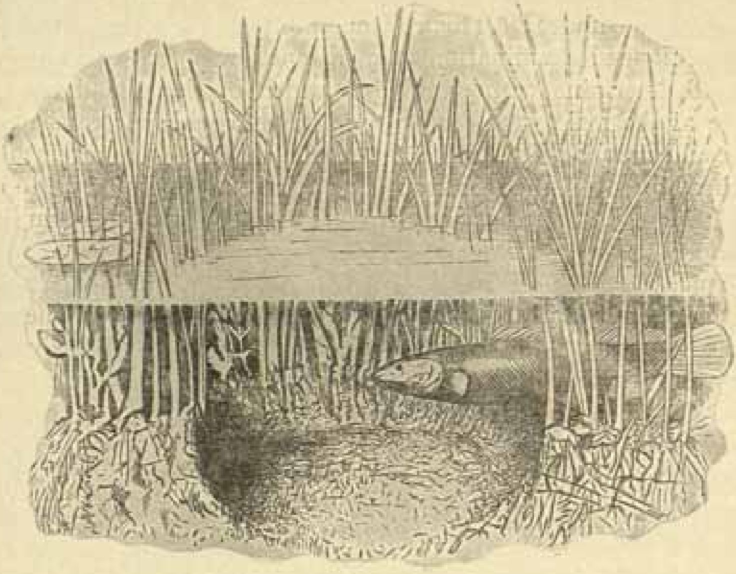


FIG. 22.—Nest of Bowfin. After Dean.

or two later, may find the nest and its maker. After a longer or shorter play, caressing and circling about, the two come together side by side, the one laying the eggs, the other fertilizing. On one occasion observed by Reighard, the preliminary play lasted "one hour and twenty minutes." After the first pairing, the two fishes may again play and come together as much as five or six times.

The stock of eggs thus provided is watched over assiduously by the male, but he is quite willing to admit another female to the nest, and not infrequently one enters and adds to the store. But while two, or even more, females may spawn in one nest, oviposition being intermittent, a female may also spawn in two or more nests. Under such circumstances the number of eggs in any nest may vary greatly, from a few to many thousands. In one case Reighard could only

find "twenty-five freshly laid" ones. Eggs "may be over the whole inner surface of the nest, on the bottom only, or on one side only. If fibrous roots are present, they are invariably on these."

The stock of eggs being provided, the male bowfin redoubles his guardianship and "lies for the most part motionless, or with only slight movements of his fins, but at intervals he moves over the nest and thus by the movements of his fins keeps the eggs free from sediment, which would otherwise smother them." All the time he is on the outlook for intruders, and especially against other males. One Reighard saw rushed at another male and "struck him with his head in the middle of the side and hurled him two feet from the nest." Generally there is no contest, for the rights of the nest maker appear to be respected, but occasionally too great aggressiveness on the part of the occupant or audacity of an intruder results in a regular battle. Whitman and Eycleshymer tell of one: Two males that claimed a female were unwilling to yield, one to the other, and "a fierce battle for supremacy ensued" between them. "They approached from opposite sides of the nest and locked jaws in a most ferocious manner. Their struggles were so violent that a cloud of muddy water soon arose and obscured them from view." Eventually one of the males was left about the nest, and his attentions were accepted by the female, who, "during the battle, had remained concealed at the side of the nest."

Vigilant though the watching may be, it is not entirely continuous during the period of incubation; Reighard found "that at many visits" males were not found over their nests "in spite of careful search through all the surroundings." The absences were most numerous in the morning and least so in the afternoon. But day after day the nest is guarded most of the time. Nine days elapse before the eggs are hatched and seven to nine more before the larvæ are prepared to leave the nest. The newly hatched larvæ are not quite a third of an inch (7 millimeters) long; those ready to take to free life are nearly half an inch (11 to 12 millimeters) long. By this time black pigment has developed and the whole body except the belly is "very dark greenish black or greenish brown." The swarm reminds one both of a swarm of tadpoles and a swarm of bees. First the larvæ are stationary and then they commence to move. "They swim together in a swarm which moves in a generally circular direction about the edge of the nest or just outside it. The larvæ, though not progressing continuously as individuals, form a swarm which nevertheless progresses, one way or another, with many internal irregularities." The course of a school from which its guardian was frightened away has been well epitomized and illustrated by Reighard.

"This swarm was among hummocks (dotted areas) and bunches of grass (lined areas), and when the observation began was at A.

Its subsequent movements, its subdivisions, and the frequent returns to the point B, where, without much doubt, either the school or the male had been for some time previously, and its final reunion with the male when, after fifteen minutes, he returned to the point C, may all be followed in the figure. These larvæ were about 20 millimeters long. The rate at which the schools move increases greatly with the age of the larvæ and doubtless also at any age with the conditions, such as abundance of food. In a school of larvæ of about 20 millimeters" Reighard "noted a rate of about 16 meters per hour. In

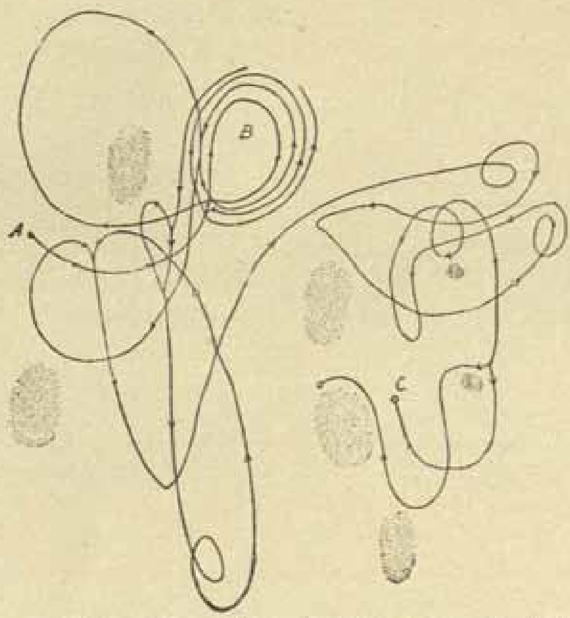


FIG. 23.—Diagram of movements of 20-mm. larval Bowfins during 15 minutes. After Reighard.

another case" he "found a school of larvæ of about the same size within 5 meters of the spot on which it was five hours earlier, another within 12 meters of its original location, and another within 30 meters."

By the middle of June, "when the larvæ are some 90 to 100 millimeters (about 4 inches) long, the schools are much spread out, consist of few individuals, and are moving with great rapidity." The male still continues with them. But by high summer all the swarms have broken up and the young dispersed to lead independent lives.

After complete dispersion and when the young fishes have to provide for themselves their habits are those of the species in miniature. When 3 to 5 inches long, the colors are quite striking; yellow, red, and green tinting the vertical fins and blackish bordering them, red dyeing the gill membranes, and three distinct bars bordered with lighter or orange running along the sides of the head, the uppermost through the eye, the lowermost along the jaws; later these fade out. When a year old they are about 10 inches long and like the parents in form and color. Most individuals probably do not reach sexual maturity till the third or fourth year.

The bowfin is not a favorite with epicures, and is, indeed, generally rejected and not ranked as a food fish at all. The flesh is soft and disagreeable.

CHARACINIDS.

The family of Characinids includes a very large number of species (about 300), confined to South (and middle) America and Africa; species are the sole American representatives of the carp-like fishes in the Southern Continent, but in Africa may be found side by side with the Cyprinids, especially Barbels. Nothing exact is known of the breeding habits of any of the species, but in 1901 J. S. Budgett recorded a noteworthy fact respecting a peculiar provision for the protection of the eggs and young of a common African species, the *Sarcodaces odoë*. According to him, in the flooded grass lands of equatorial Africa along the Gambia River, "the eye is frequently caught by masses of white foam floating on the surface of the water. On close inspection it is seen to be filled with numerous transparent ova," about 2½ millimeters in diameter. The fry hatched from the eggs "make their way through the foam * * * down to the surface of the water, and there the young larvæ hang holding to the surface of the water by a large adhesive organ situated on the front of the head." The blacks were well acquainted with the nature of the foamy nests, and told Budgett what they were, and were corroborated by his investigations.

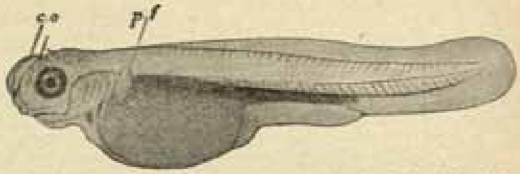


FIG. 24.—*Sarcodaces odoë* larva, just after hatching, showing the large adhesive cement organ (*c. o.*) borne on the front of the head and a pectoral fin (*p. f.*). After Budgett.

The peculiar fabrication of a foamy receptacle for the eggs is analogous to the provision made by some catfish-like forms—the Callichthyids—as well as the celebrated fish of Paradise (*Macropodus viridi-auratus*), a relative of the Gourami. This fact is especially noteworthy, as the three groups which make such similar nests are in no wise related, and all three differ from most of their relatives in their peculiar oviposition.

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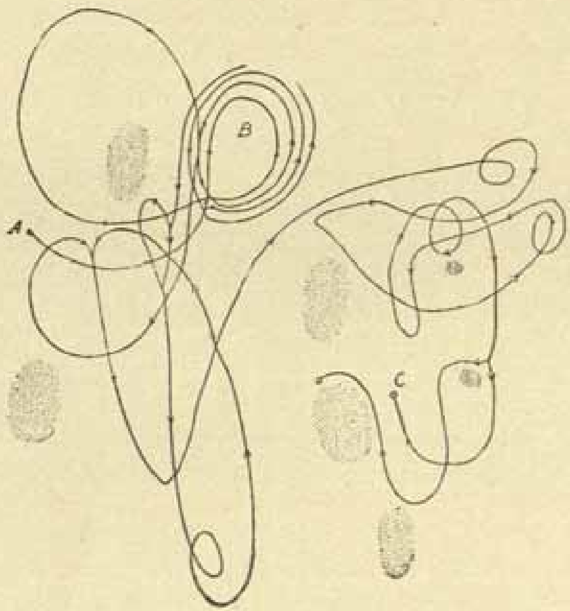

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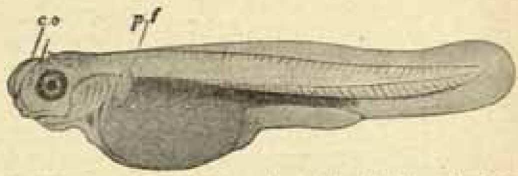

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In an article on "The nest-builders of the sea," by Dr. C. F. Holder, published in Harper's New Monthly Magazine for December, 1883 (LXVIII, 105), a figure is published of a "hanging nest of perai," representing a cocoanut-like object floating in the water, loosely suspended in the water from a palm-like tree, with two fishes close by. Doctor Holder can not, at present at least, give me the source of his information, but thinks it was "from some French journal." By perai, piraya or piranha is meant.

CYPRINIDS.

In the enormous family of the Cyprinids, or carp-like fishes, the species generally neglect their eggs after oviposition, but a few make special provision for them. One remarkable method is that exemplified by the Bitterling of central Europe, and illustrated in the Smithsonian Miscellaneous Collections (XLVIII, 203, pl. 53). Several American also take care of their eggs, especially the Horned Dace (*Semotilus atromaculatus*), the Black-headed Dace (*Pimephales promelas*), and the Stone-roller (*Campostoma anomalum*). Their nest-making habits have long been known, but imperfectly, and next winter (1907) a full account may be expected from Prof. Jacob Reighard, of Ann Arbor, who has been observing them for years, and has already published preliminary communications.

THE GLANIS.

Many centuries ago a fish was noticed inhabiting fresh waters in northwestern Greece that exercised particular care for both the eggs and young. The fish was especially an inhabitant of the river Achelous, the largest of Greece, and was then known as the *Glanis*. Aristotle gave more details respecting this fish than about any other. The mode of oviposition and the subsequent paternal care manifested for the eggs are described at considerable length in his History of Animals. The translation of his words from the Greek, due to Prof. Louis Agassiz, is the best that has appeared in English, and is therefore here reproduced with few modifications. Agassiz was probably assisted by the eminent Greek scholar, Professor Felton. Aristotle's account of the *Glanis* is not a continuous one, but distributed under no less than seven chapters, wherein various organs or functions are considered. The sections relative to the spawning habits and parental care occur in the sixth and ninth books.

In the sixth book (chap. 13, secs. 2 to 4) the manner of spawning is described as follows:

> The fresh-water fishes spawn in the still waters of rivers and lakes among the reeds, as the phoxinos (minnow) and the perke (yellow perch). The glanis and the perke give out their spawn in a continuous string, like the frogs; and,

indeed, the spawn is so wound up that the fishermen reel it off, at least that of the perke, from the reeds in lakes.

The larger glanis spawns in deep waters, some at the depth of a fathom; the smaller in shallower places, especially among the roots of willows or some other tree, and also among the reeds, or the mosses.

They copulate, sometimes a very large with a very small one, and bringing the parts together which some call the navel, and through which they discharge the seed, the females the eggs and the males the sperma. All the eggs that are mingled with the sperma become generally on the first day white and larger, and a little later the eyes of the fishes become visible. These at first, in all fishes as also in other animals, are early conspicuous on account of their size. And those of the eggs that the sperm does not touch, as in the case of sea-fishes, are useless and sterile.

But in these fertile eggs, as the fishes grow larger, a kind of husk separates. And this is the envelope that encloses the egg and the young fish. When the sperm has mingled with the egg the spawn becomes more viscous among the roots, or wherever it may have been deposited. And where the greatest quantity is deposited the male guards the eggs, and the female, having spawned, departs. The growth of the glanis from the egg is very slow, wherefore the male keeps

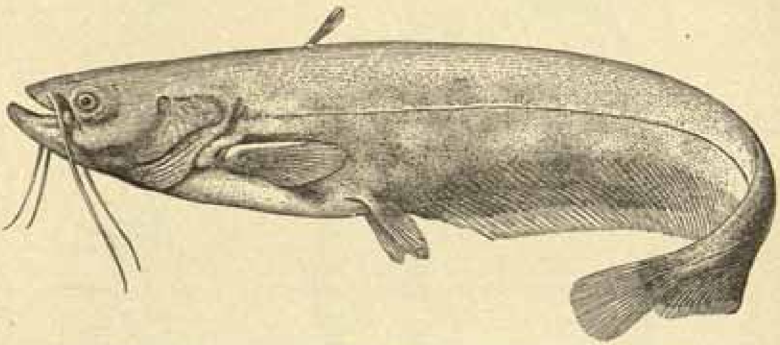

FIG. 25.—Aristotle's catfish (*Parasilurus aristotelis*). After Nature.

watch forty or fifty days, that the young may not be devoured by the fishes that happen to be in their neighborhood.

Aristotle incidentally adds, in subsequent paragraphs, that "the eggs of the glanis become as large as the seed of the orobos" (sec. 5)—that is, the millet—and that none of the fresh-water fishes "except the glanis watch their eggs" (sec. 6).

How the eggs are taken care of after spawning is told in a later book (Book IX, chap. 25, sec. 6):

Of the river fishes, the male glanis takes great care of its young. For the female, having brought forth, departs; but the male, where the greatest deposit of eggs has been formed, remains by them watching, rendering no other service except keeping off other fishes from destroying the young. He does this for forty or fifty days, until the young are sufficiently grown to escape from the other fishes. And he is known to the fishermen wherever he may chance to be watching his eggs; for he keeps off the fishes by rushing movements, and by making a noise and moaning. And he remains by the eggs with so much of natural affection that the fishermen, when the eggs adhere to deep roots, bring

them up to the shallowest place they can; but he does not even then leave his offspring, but if he chance to be a young fish he is easily taken by the hook, because he snaps at all the fishes that approach him; but if he is already accustomed to this, and has swallowed hooks before, he does not even then desert his young, but breaks the hook by a very strong bite.

In 1839 two of the greatest ichthyologists of the last century, Cuvier and Valenciennes,[a] regarded this account with great skepticism and recapitulate it, concluding with this opinion:

What Aristotle relates in detail, and in two passages, of the care which the male silurus takes of the eggs of his female, borders a little on the marvelous.

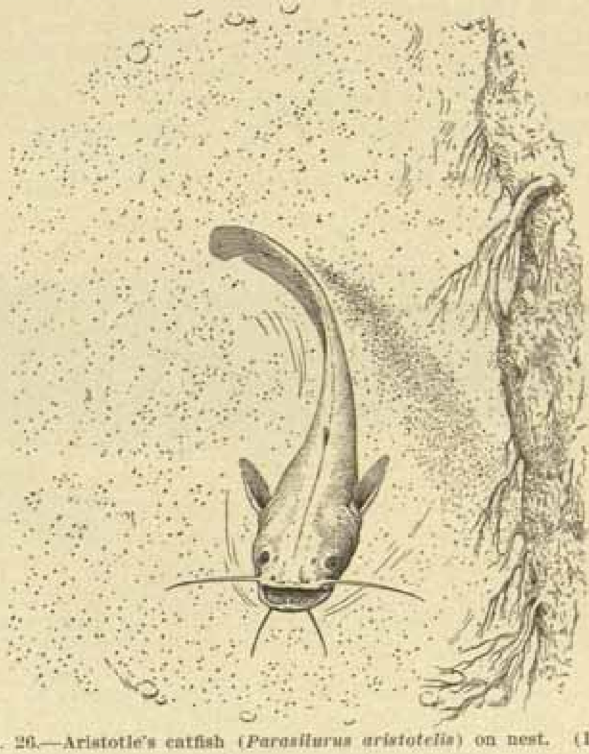

FIG. 26.—Aristotle's catfish (*Parasilurus aristotelis*) on nest. (Ideal.)

According to him, the large siluri deposit them in deep waters; the smaller among the roots of willows and other trees, among the reeds or even the mosses. The female, having laid them, leaves them, but the male guards and defends them; and, as these eggs are long in hatching, he continues this care forty or fifty days.

Skepticism was not at all unnatural in view of the fact that the French naturalists thought there was no doubt that the Aristotelian fish was specifically identical with the *Silurus glanis* of central Europe; "On ne peut douter que notre silure ne soit le Γλανίς d'Aristote," they exclaimed (p. 344). This opinion was confirmed,

[a] Histoire Naturelle des Poissons, t. 14, pp. 350, 351.

they thought, by the fact that the Silurus is called at the present day *Glanos* or *Glano* in Turkey. Fifty-six years later (1895) another eminent European ichthyologist (Prof. F. A. Smitt) declared that "the ancient account of Aristotle, that the male hatches the roe, is now regarded as dubious."

It may be here recalled that the *Silurus glanis* does not care for its eggs, but after depositing and fecundating them, the parents leave them to Dame Nature. The skepticism of naturalists respecting the statements of Aristotle was then quite natural as long as there was supposed to be no structural difference between the common silurus and the glanis of the Achelous.

From the fourth century before the Christian era a leap may be made to the latter half of the nineteenth and into a new world.

America is not inhabited by any species of the same group or even subfamily as the Glanis, but has numerous representatives of the same family and of a subfamily quite closely related to the Silurines. Species are found almost everywhere in the streams and lakes of eastern America and the valley of the Mississippi, and are generally known as catfishes. It was also long known that some at least exercised care of their eggs and young. It was therefore quite natural that Prof. Louis Agassiz should accept with implicit faith the account of the ancient naturalist and at the same time be skeptical as to the correctness of the identification of the Grecian fish with that which he had well known in central Europe. In 1856 he received specimens of a Silurid from the same river (Achelous) in Acarnania from which Aristotle had secured his Glanis, and these were evidently of the same kind as that described by the old naturalist; according to C. Felton, they even still bear a name, "Glanidi, formed, according to numerous analogies, from the genitive (Glanidos)" of glanis. The specimens, on comparison with some of the wels, were found to be quite different, the species was named *Glanis Aristotelis*, and an interesting account of them, in the form of translations from Aristotle, was presented to the American Academy of Arts and Sciences and published in their "Proceedings" (III, pp. 325–334).

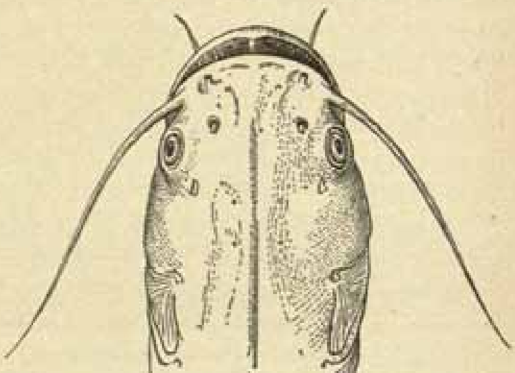

FIG 27.—Head from above of Aristotle's catfish (*Parasilurus aristotelis*). After Nature.

In this long account, however, no indication was given of any structural differences between the Grecian and German fishes, and consequently for half a century the species has been ignored by European naturalists. Indeed, in the latest English work on fishes (The Cambridge Natural History, Vol. VII, p. 593) the great ichthyologist, Dr. George Boulenger, expressly affirms that the "only European representative of the family," Siluridæ, is the *Silurus glanis*. Nevertheless, in 1890, in response to the present writer's demand for information, Samuel E. Garman published a description of the specimens collected and commented on in 1856, and called the species "*Silurus* (*Parasilurus*) *Aristotelis*." It appears that "from the young of *S. glanis* L. of equal length, they are readily distinguished by the possession of four barbels instead of six," as well as "by the difference in shape of those on the maxillaries—they being shorter, less compressed, and more threadlike, by the wide separation in the middle of the band of vomerine teeth, by a larger eye, by a greater slope to the sides of the head, by a smaller dorsal, by the smaller number of rays in the anal, and by the markings." The largest of Mr. Garman's specimens was "less than 9 inches in length." All these characters the present writer has been able to confirm. Furthermore, the snout is more convex in front than in the Wels, the chin barbels further from the symphysis than the foremost ones of the Wels, and the opercle is smaller and especially shorter. Such characters evidently indicate specific differences from the central European fish. Had Agassiz only added to his account one word, *four-barbeled*, Felton would have been justified in his exclamation, made after the communication of Agassiz:

> It is a very striking fact, that the fish in question should, so many centuries after the death of Aristotle, have come from the Achelous across the Atlantic to this country, to furnish our associate with a commentary on the great philosopher, and to vindicate his accuracy as an observer against the criticism even of a Cuvier.

The single word "four-barbeled" would not only have demonstrated (accuracy being conceded) that the Glanis was distinct from the Silurus, but would have suggested to the well-informed ichthyologist that its affinities might be with certain eastern species rather than with the northern. The Glanis is, indeed, but distantly related to the Wels of the north and is a near relative of several eastern species. It is, in fact, the offspring of a successful invasion from Persiawards and the Orient. Doubtless the renowned ichthyologist appreciated and intended to have made known these facts, but postponement included non-performance.

The history of the glanis is unique in the annals of ichthyology. A more detailed account of its habits was given than of any other fish by the greatest of ancient scientific authors, but the fish

itself was lost sight of or confounded with another for more than a score of centuries. Then it was reserved for a naturalist of a new world to attempt to revive it, and to a follower of his still living to establish it as a distinct species and to tell us what it really is.

The Glanis is so exceptionally interesting, as well as so little known, that the other sections relating to it, as translated by Agassiz (with a few alterations), are added herewith. It may be seen then how much naturalists, as well as fishermen of classical Greece, knew about at least one of her fishes.[a]

The cordylus (a salamander) swims with its feet and its tail; and it has a tail like the *Glanis*.—*Aristotle, Hist. An., I, 5, 3.*

Of fishes that have gills, some have simple gills and some have double; but the last, nearest the body, is in all cases simple. And some have few gills, others have many, but all have an equal number on both sides. Those that have the fewest have one on each side, but that double, as the capros; others have two on each side, one simple, the other double, as the conger eel and the scarus; others have four simple ones on each side, as the elops, the synagris, the muræna, and the eel; and others still have four, but in two lines, except the last, as the kichle (*crenilabrus?*), the perke (perch), the *Glanis*, kyprinos (carp?).—*Ibid., II, 9, 4.*

Of those belonging to the sea, and having lungs, the dolphin has no gall-bladder; but all birds and fishes have the gall-bladder, the egg-laying, the four-footed, and, to speak generally, sometimes more, sometimes less. But some of the fishes have it on the liver, as the Galeodes (sharks), the *Glanis*, the rhine (angel fish), the leiobatos (a skate), the narke (torpedo); and of the long fishes, the enchelys (eel), the belone (pipefish), and the zygæna (hammerheaded shark).—*Ibid., II, 11, 7.*

The river and lake fishes are exempt from pestilential disease, but some of them have peculiar disorders, as the *Glanis*, which, about the time of the dog-star, by reason of swimming on the surface, becomes sun-struck, and is stupefied by loud thunder; and many glanides in shallow water perish by the bite of snakes.—*Ibid., VIII, 20, 12.*

One passage relative to the Glanis has been overlooked by Agassiz and is here translated from the original Greek:

River and pond fishes are best after spawning and milting, when they have recovered their bodily vigor. Some are good during the spawning season, as the saperdis; others bad, as the *Glanis*. The males of almost all species are better than the females, but the female glanis is better than the male. (Aristotle, Hist., *VIII, 29, 5.*)

Notwithstanding the interest attaching to such a fish, no illustration of the *Glanis* has yet appeared, and undoubtedly the accompanying portrait of one of the original types will be welcome to all. We are indebted to the Museum of Comparative Zoology, and especially Mr. Garman, for the specimen requisite to fill this desideratum (fig 25).

[a] It is of course to be understood that the deficiencies of information manifest in some of the statements by Aristotle are not here made good.

ICTALURINES OR NORTH AMERICAN CATFISHES.

All the North American catfishes are supposed to take care of their eggs and young, but the belief may possibly not be realized, for observation has confirmed the supposition only for two genera and three species. The species observed are the common catfish of the Middle States (*Ameiurus catus* or *albidus*), the common Bullhead or small catfish of the North (*Ameiurus nebulosus*), and the channel or blue catfish (*Ictalurus punctatus*). In view of the difference in breeding habits between such closely related species as the wels of central Europe and the *Glanis* of Greece, it is quite possible that analogous differences may exist among the American catfishes.

The three American species whose habits are known are much alike in such respects. The normal mature fishes, some time after they have awakened from their winter rest and become invigorated, and when their sexual products have become fully developed, seek mates and pair. The time naturally varies with the temperature and con-

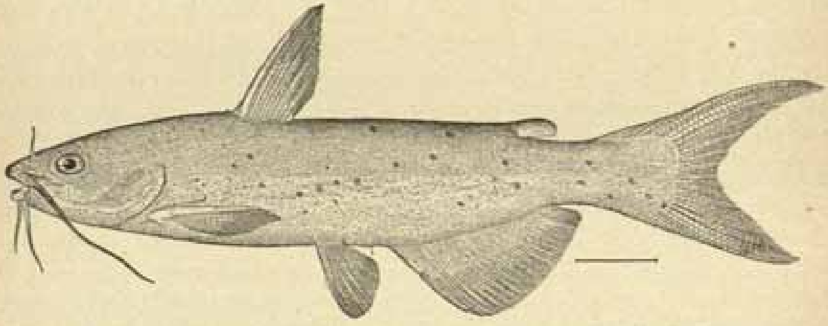

FIG. 28.—Channel cat (*Ictalurus punctatus*), typical of Ictalurines.

sequently the latitude, but in the neighborhood of Washington and New York it may be in April, but apparently is mostly in June and July. A subcircular or irregular area on a sandy or gravelly ground is cleared in shallow water and more or less excavated. The cleared or gravelly bed may serve as the place of deposit of eggs.

The first time the present writer had an opportunity to observe catfishes at close range during their breeding season was in July, 1883, when Mr. (afterwards Prof.) John Ryder informed him that a pair had oviposited and requested him to go to the Fish Commission laboratory and examine them with him. The fishes proved to be of the *Ameiurus catus* (then called *albidus*) kind. On the morning of the 13th of July, a little after 10 o'clock, one of them had laid "a mass of whitish eggs" and both parents were for a time near the eggs. Soon, however, only "one of the individuals remained constantly over the eggs, agitating the water over them with its anal, ventral, and pectoral fins;" the other, "after the eggs were laid, seemed to take no

further interest in them, the whole duty of renewing and forcing the water through the mass of adherent ova devolving upon the " other, " who was most assiduous in this duty until the young had escaped from the egg membranes." During the week this incubation lasted the writer daily visited the aquarium, but did not remain long. By Ryder and the immediate attendant it " was at first supposed " that the watcher was " the female," but the writer contended that it was rather the male. Ryder explained that " on the 30th of June, or when the young were seventeen days old, it was determined to make an examination of the internal organs of both parents, which was done in the presence of Professor Gill, to learn which one of parent fishes it was that had acted as nurse; " it was found that it was the male.

Not only did the male alone act as guardian of the eggs, but on one occasion during the writer's observation, when the female approached nearer than she was wont to do, the male advanced toward her and butted at her with partly open mouth. Occasionally, however, the female may cooperate with her mate, if we may trust to the observation of Hugh. M. Smith and L. G. Harron (1903) which were more extended than Ryder's or mine, and are worthy of reproduction.

> During the entire hatching period both parents were incessant in their efforts to prevent the smothering of the eggs, to keep them clean, and to guard against intruders. The eggs were kept constantly agitated and aerated by a gentle fanning motion of the lower fins, and foreign particles, either on the bottom of the nest or floating near the eggs, were removed in the mouth or by the fins. The most striking act in the care of the eggs was the sucking of the egg masses into the mouth and the blowing of them out, this being repeated several times with each cluster before another lot was treated.
>
> The male was particularly active in watching for intruders, and savagely attacked the hands of the attendant who brought food, and also rushed at sticks or other objects introduced into the aquarium. Practically the entire work of defense was assumed by the male, although the female occasionally participated.
>
> During the time the fry was on the bottom the attentions of the parents were unrelaxed and, in fact, were increased, for the tendency of the different lots to become scattered had to be corrected, and the dense packing of the young in the corners seemed to occasion much concern. The masses of fry were constantly stirred, as the eggs had been, by a flirt of the fins, which often sent dozens of them 3 or 4 inches upward, to fall back on the pile.

When the nest is completed, oviposition may take place at once or be more or less delayed. In the case of Smith and Harron's fishes—

> Two days intervened between the beginning of the nest making and the laying of the eggs. As soon as the nest was made ready the fish became very quiet. During most of the time they rested on the bottom, with practically no body or fin movement, except at intervals. The fish lay close together, often parallel, with their abdomens just clear of the bottom, their weight being borne on the anal and ventral fins. At frequent intervals the female compressed her distended abdomen against the smooth slate bottom with a quivering or convulsive movement, the male often accompanying or following the female in this action, which is obviously for the purpose of loosening the eggs.

On July 5, between 10 and 11 a. m., the eggs were deposited in four separate agglutinated masses on the clean slate bottom. Unfortunately the fish were not under observation at this time, although they were watched for about fifteen minutes after the extrusion of the first two lots of eggs, when it was supposed the spawning had been completed. The masses of eggs were of nearly uniform size, about 4 inches long, 2½ inches wide, and half an inch thick. The newly laid eggs are one-eighth of an inch in diameter, nearly transparent, and of a pale yellow color. The number of eggs deposited was estimated at 2,000. The incubatory period was five days in a mean water temperature of 77° F., the lowest temperature being 75° and the highest 80°. About twelve hours intervened between the hatching of the first and last eggs. Active movement was observed in the embryos forty hours after the eggs were laid. Fully 99 per cent of the eggs hatched into normal fry, a few weak and deformed fry and a few unfertilized or dead eggs being noticed.

Smith and Harron entered into detailed observations respecting the behavior of the male and female catfishes toward each other and their nest making.

The nest-making, as modified by the artificial conditions of the aquarium, consisted in removing all the stones and sand from one end and keeping the slate bottom scrupulously clean from all foreign objects, even the smallest particles of food, sediment, etc. In moving the pebbles, which were mostly from one-half to three-fourths of an inch in diameter, the fish took a vertical or slightly oblique position and sucked a pebble into the mouth, usually beyond the lips and out of sight, then swam toward the other end of the tank and dropped it by an explosive or blowing effort. Sometimes the gravels were carried only a few inches and sometimes the entire length of the aquarium. Usually the fish swam horizontally near the bottom when carrying a stone, but sometimes turned obliquely upward and dropped it from near the surface. Both fish participated in this operation. The removal of finer sediment was effected by a quick lateral movement of the body which caused a whirl that lifted and floated the particles beyond the limits of the nest.

The pair of fish more particularly under consideration, during the first night they were in the aquarium, removed all the gravel from over a space nearly 2 feet long and 1½ feet wide, upward of a gallon of stone being transferred as described. After the second pair of fish had cleared a similar space, a pint or more of gravel was scattered on the nest; the fish immediately began to remove the stones, and in a few minutes had completely freed the nest from gravel. The gravel—regarded by bass and other fishes as desirable material for the bottom of nests—may be removed by the catfish for two reasons: (1) To have a clean place for the eggs and young, so that they may be better guarded, as hereafter described; (2) to provide a smooth place on which to rest and against which to rub the abdomen.

All the observations thus far noticed were made on individuals confined in aquaria and of the species *Ameiurus catus* or *A. nebulosus*.

The best account of the manner and location of nesting under natural, or sometimes rather unnatural, conditions, has been given by Albert C. Eyclesheimer, who had good opportunities to see the common bullhead of the north (*Ameiurus nebulosus*). The observations were made in June, 1896 and 1898, in Wisconsin and Michigan. June 8, 1896, three nests were found in Fowler Lake, Wisconsin.

Two of these were in pieces of stovepipe, the third in an old pail. The nests were in clear water, near a bold, rocky shore, and at a depth of four or five feet; all contained embryos and each was guarded by a parent fish—which one I did not ascertain. On the following day, in searching for other nests, I raised a small piece of tin pipe and was surprised to find a pair within. Though the raising of the pipe they became so wedged that it was impossible for either to get free. They had not yet begun spawning, although the eggs were so ripe that they were easily extruded by slight pressure. [Artificial fertilization was tried but was only partially successful.] A small percentage of the eggs segmented, most of which died before the embryos appeared.

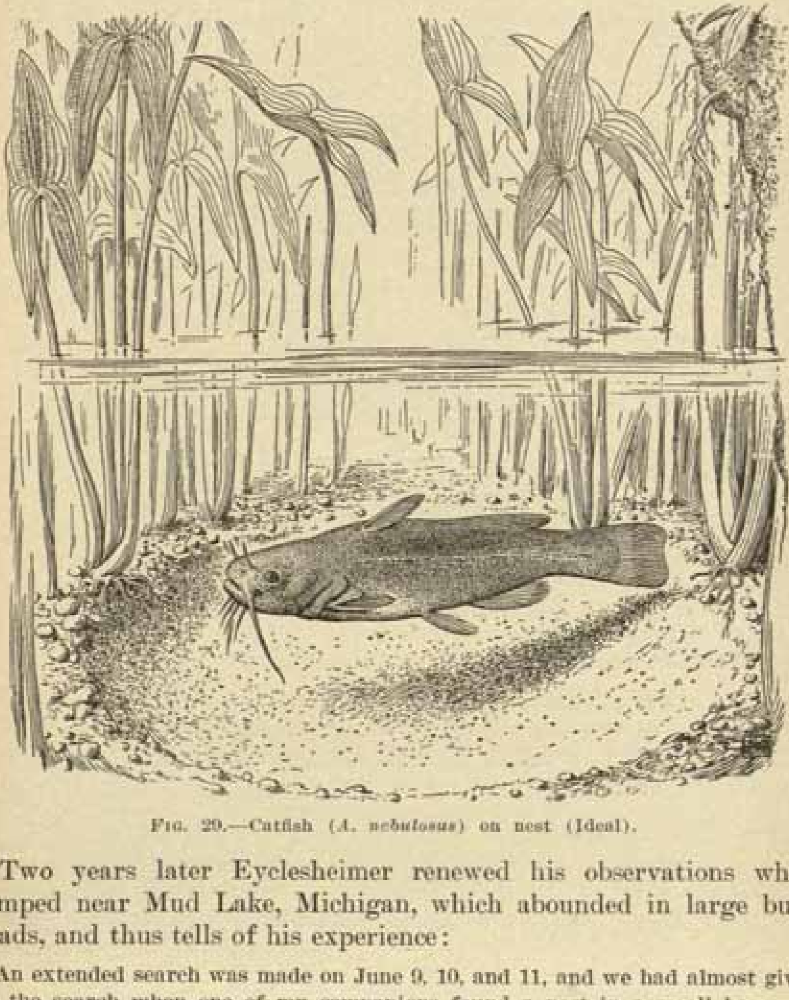

FIG. 29.—Catfish (*A. nebulosus*) on nest (Ideal).

Two years later Eycleshelmer renewed his observations when camped near Mud Lake, Michigan, which abounded in large bull-heads, and thus tells of his experience:

An extended search was made on June 9, 10, and 11, and we had almost given up the search when one of my companions found a nest in a small bay with shallow sandy shoals. Soon a dozen or more were found along this sandy shoal and in a depth of water not exceeding three or four inches. They were usually concealed beneath logs, stumps, or boards, which lay against the bank. One would often observe a slight depression, and upon turning the sheltering object would find the pair engaged in spawning or watching over the freshly laid eggs.

In two nests which were found beneath logs on June 11, the parent fishes were moving about in the small sheltered excavation. The eggs were removed in each case; those of one lot were in early cleavage, while those in the other were in late gastrula. Both nests were visited on the following day, but the fishes were no longer present. Another nest, in which the eggs were in late gastrulation stages, was uncovered and left exposed. When visited on the next morning neither fish nor eggs were found.

While the nest is thus bravely guarded in many if not most cases, it is not in all. In fact much individuality appears manifest in the behavior of the fish toward the precious deposit whose care it assumes. Professor Birge had the opportunity to see many individuals and has given his impressions in excellent form:

There was a surprising difference in the disposition of the fishes on various nests. One of them was extremely tame. If approached cautiously, he would not swim off, and it was quite easy for me to put my hand under him and lift him off the nest. He seemed to enjoy being scratched gently, and when lifted off the eggs would remain where placed or would swim off a short distance, and, in general, was very little disturbed by handling. Others were exceedingly shy, so that as soon as one had approached within a few yards of them they would dart off, throwing the eggs out of the nest as they went, with a jerk of the tail. Of course they always came back and brought the eggs together again. But this violent treatment of the bunch of eggs was apt to break it up, and I observed that a considerable portion of the eggs was lost in such cases. One of the catfish whose eggs were in a stump was particularly ferocious, and this was the only one which I found that had a violent disposition. I found the nest and put my hand down into the stump to take some of the eggs, when the fish seized it and worried it with all his force. After that I found it necessary to remove the eggs from this nest with a pair of long forceps, which the fish would bite in spite of being rapped on the nose with them rather vigorously. It was this difference in disposition that especially attracted my attention in studying the catfish.

If disturbed on the nest, the actions of the parents are characteristic. Eycleshelmer has recorded experiments on a pair:

It was interesting to watch the actions of the fish when the sheltering object was removed. A fence rail covering a nesting pair was carefully turned, when the fishes immediately sought its shelter. As it was turned farther and farther from the nest they followed, keeping as well secluded as possible, the while moving restlessly about in search of the nest. When the rail was finally lifted from the water the male lingered for a few moments, then darted for deeper water. The female approached the shore and began searching here and there for her lost nest. This she passed several times without recognition, although she seemed to know the surrounding landmarks, since she would go but a short distance in either direction, then turning, would pass back to the locality of the nest, which she found in a short time, and despite the fact that it was unsheltered, she remained. On the following morning the nest was visited, but again neither fish nor eggs were to be found.

It is not difficult to allure the fish to an improvised shelter. A number of boards were placed on the shore with one end projecting into the shallow water. The fishes sought these places and made their nests beneath the boards. It is worthy of note that in no case did I observe more than a single nest beneath the same cover, and this quite agrees with the pugnacious character of the fish.

Paternal care is continued for many days after the birth of the young. At first these may be crowded together in a dense mass, but as time passes they disperse more and more and spread round the father. Frequently, especially when the old one is feeding, some—one or more—of the young are taken into the mouth, but they are instinctively separated from the food and spit out. At last the young swarm venture farther from their birthplace, or perhaps are led away by their parent. Such a swarm may be occasionally noticed by the visitor to a likely stream, and one such the present writer saw in his youth as he was wandering along the bank of the Rahway River. Having read the paragraph by Goldsmith, to the effect that no fishes exercise care over their progeny, he was quite unprepared for such a manifestation of parental interest, and, indeed, it was some time before he recognized the nature of the phenomenon. A black cloud was apparent near the opposite bank, which was slowly moving toward the middle of the stream. It was at first conjectured

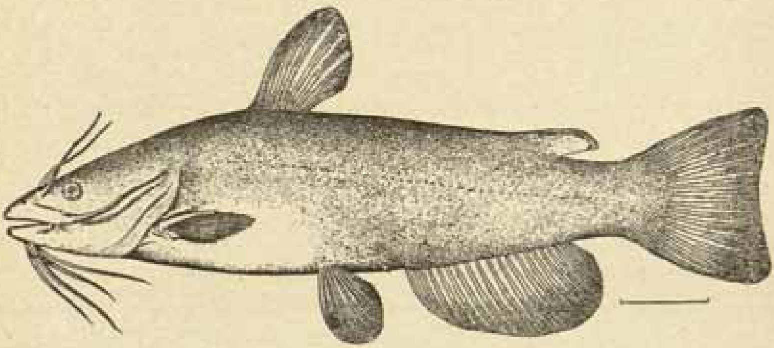

FIG. 30.—*Amieurus nebulosus*. After Bean.

to be a lot of tadpoles, but as it approached a large catfish became distinguishable in the midst of small, black wrigglers, which were at last recognized as young catfishes. The swarm seemed to revolve round the large fish, sometimes almost surrounding him and then massed by the side. For more than an hour the slow movement from the bank to midstream was observed, when other interests led the youth away, and he left the swarm to itself.

The same swarming is practiced by the fish in an aquarium, as the writer has observed. More prolonged observations were made and recorded by Smith and Harron:

> The very young fry were also taken into the mouths of the parents and blown out, especially those which became separated from the main lot and were found in the sand and sediment. The old fish would take in a mouthful of fry and foreign particles, and retain them for a moment, and expel them with some force. After the young began to swim and became separated, the parents continued to suck them in and mouth them, and, as subsequently developed, did not always blow them out.

An interesting habit of the parents, more especially the male, observed during the first few days after hatching was the mixing and stirring of the masses of young by means of the barbels. With their chin on the bottom, the old fish approached the corners where the fry were banked and, with the barbels all directed forward and flexed where they touched the bottom, thoroughly agitated the mass of fry, bringing the deepest individuals to the surface. This act was usually repeated several times in quick succession. The care of the young may be said to have ceased when they began to swim freely, although the parents continued to show solicitude when the attendant approached the aquarium from the rear.

The after fate of the brood is suggestive of some of the conditions and accidents which beset the path of young fishes and indicates why the number of adult fishes does not vary more from year to year in spite of the immense number of eggs and progeny yielded by a mother fish.

When 12 days old about 1,500 of the fry were removed from the aquarium to relieve crowding, and placed in a hatching trough such as is employed for salmon and trout. For some unknown cause, 1,000 of these died during the first three days. The others survived with little or no loss, and are still on hand.

The fry which were left with their parents continued healthy, but their number steadily decreased. There being no way for them to escape, and a closely woven wire screen preventing inroads from the exterior, it was suspected that the old fish were eating their young, though they were liberally fed at suitable intervals. They were kept under close observation during the day, and were seen to be fond of mouthing the fry, more especially the weaker ones—a habit which at this stage seemed unnecessary. They were frequently seen to follow leisurely a fry, suck it in their mouth, retain it for a while, and then expel it, sometimes only to capture it again. There was no active pursuit of the fry, and the tendency seemed to be to spit them out. In one or two instances, however, it appeared that fry taken into the mouth were not liberated, the feeding instinct becoming paramount to the parental instinct. After all the fry which had been left with their parents had disappeared—in about six weeks after hatching—18 from the trough were placed in the aquarium one evening, and only 2 of these had survived on the following morning.

During the entire period covered by these observations liver and beef were fed regularly to the brood fishes, and at no time did their appetites fail. There was apparently no interference with deglutition, or closure of the œsophagus, such as has been observed in some other catfishes, as half-inch cubes of meat were readily ingested during the entire time the fish were under observation.

PIMELODINES, OR SOUTH AND MIDDLE AMERICAN CATFISHES.

Much like the North American catfishes are most of those of South and Middle America, but they have only six barbels instead of eight, the missing ones being the nasal; as in the Ameiurines, however, their nostrils are remote and not close together as in the Tachisurines.

The attitude of the parents to the young among the Pimelodines is unknown in most cases, but it is probably analogous to that prevalent among the North American fishes. There is, however, a remarkable deviation from the latter and doubtless from its relatives of the sub-

family exemplified in one case, the common bagre of Yucatan. Mr. E. W. Nelson obtained specimens of the fish so named in Yucatan, and it was later found by Evermann and Goldsborough that the species was unknown, and they consequently described it as new (in

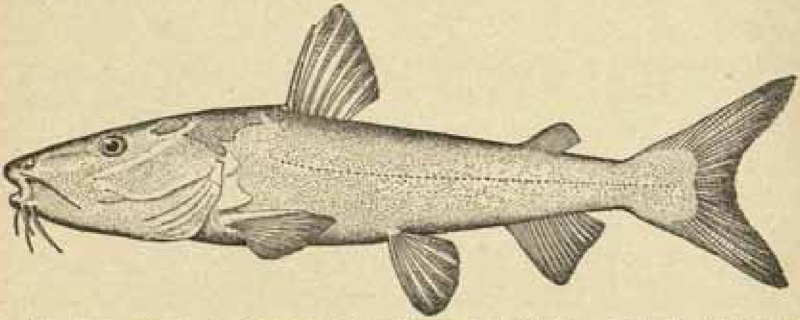

FIG. 31.—The Bagre of Yucatan (*Conorhynchos nelsonii*). After Evermann and Goldsborough.

1902), calling it *Conorhynchos nelsonii*. The accompanying figure will give an idea of what it looks like. It reaches a length of a foot to 18 inches. Two of the males obtained by Nelson had eggs in their mouths, one 16 inches long having no less than 39 well-developed ones, and the other a single one.

SALT-WATER CATFISHES, OR TACHISURINES.

While most of the catfishes are inhabitants of the fresh water, a few have accommodated themselves to life in the sea, and among such are the Tachisurines or Ariines, mostly called sea catfishes. The chief of these are slender, graceful fishes, with comparatively small, bony, granulated head and six barbels; the anterior and posterior nostrils are close together. What is especially remarkable, however, is the fact that of most species the female lays large eggs the size of a small marble which, after fecundation, are taken by a male into his mouth and kept there until they are hatched. While such is the case for most species, however, it is not so for all, for several are said to oviposit on the ground and leave the eggs there to be cared for by the males, while one (*Galeichthys* or *Hexanematichthys felis*) has been declared to be ovoviviparous; this is the most northern of these fishes and occasionally wanders up to Cape Cod.

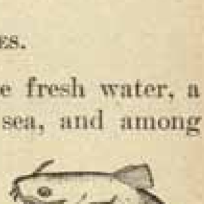

FIG. 32.—The Bagre (*Conorhynchos nelsonii*) hatching egg. After Evermann and Goldsborough.

THE EGG CARRIERS.

When the breeding season has arrived the female gives evidence of it by an increased fullness of the belly, which is the result of the enlargement of maturing or matured eggs. The ovaries are in a

nearly symmetrical pair, and eggs are existent or developed in about three sets. According to Wyman, the eggs "are arranged in three zones corresponding to three successive broods, and probably to be discharged in three successive years. In the female of one species, 18 inches long, the mature eggs measured "three-fourths of an inch in diameter" and those of the second zone "one-fourth," while those of the third were very minute—"about one-sixteenth of an inch." Turner found in an Indian fish that the largest eggs were about as large as "grapes or small cherries," those of the second series "like medium-sized shot," and the smallest "like minute granules." The size of the eggs varies more or less with the species and perhaps with the average size of the species. Those of the common large bagre of the Argentine Republic (*Netuma barbus* or *commersonii*)[a] have a diameter of 17 or 18 millimeters (three-fourths of an inch).

The number of mature eggs differs considerably, but, as would naturally be expected, are never in large number, as fishes' eggs go. Wyman found "between twenty and thirty" in the mouth of each male he observed. Turner found twelve in one of his females, while in the mouth of one male he found ten and from that of another "thirteen were shaken out." In the opinion of Turner, and apparently of Wyman, "a close relation exists between the number of eggs which come to maturity at a given time and the number which the male can carry in his mouth."

According to Day, however, "in the female organs of generation the eggs seem to come to maturity in batches of perhaps fifty at a time," but he "found many males of the genus" *Arius* or *Tachisurus*, "and also of *Osteogeniosus*, with from fifteen to twenty eggs in their mouths." This concatenation certainly requires verification. Doubtless the number of eggs matured varies with size as well as species.

It may be also that the number of eggs in the mouth of a male may be no certain criterion of the number in a given female. Wyman, for instance, "in the mass of eggs with which the mouth" was filled, "occasionally found the eggs, rarely more than one or two, of another species." The only way, he thought, in which the presence of the exceptional eggs could be accounted for "is by the supposition that while feeding the eggs are disgorged, and as these fishes are gregarious in their habits, when the ova are recovered the stray egg of another species may be introduced into the mouth among those which naturally belong there." It is, however, improbable that the male feeds while the eggs are being hatched or that he disgorges them.

In some cases, at least, special provision appears to be made by the female to receive the emitted eggs. Day found, "on examining the

[a] *Arius commersonii* of most authors.

conformation of the ventral fins, those of the females appeared to be larger than those of the males;" further, "these rays were thickened by a deposit of fat, while the innermost one had a large pad attached to its posterior edge." He therefore assumed that "these fins can be expanded into a cuplike surface, the use of which may be to receive the eggs as extruded, which may be vivified there by the male."

As soon as the eggs are extruded by the female and fertilized, they are taken by a male, but whether from the ventral pouch improvised by the female or from the open water is unknown. In the mouth they are probably retained until they are hatched and the fry prepared to take care of themselves. The interior of the mouth is capacious and the oral cavity separated from the stomach by the esophagus, which exercises the function of a sphincter and confines the eggs and fry to the cavity. Wyman, however, found "in one instance, besides some nearly mature fœtuses contained in the mouth, two or three were squeezed apparently from the stomach, but not bearing any marks of violence or of the action of the gastric juice." Wyman naturally assumed that "it is probable that these found their way into that last cavity after death in consequence of the relaxation of the sphincter, which separates the cavities of the mouth and the stomach."

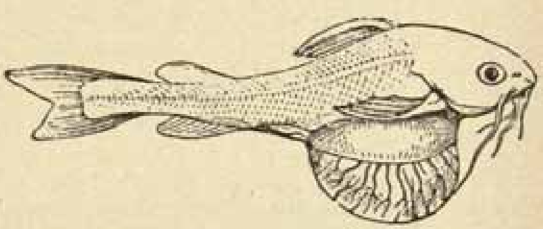

FIG. 33.—A nearly mature foctus of natural size of a sea catfish or Tachisurine. After Wyman.

The number of eggs carried by the males varies between eight or ten and forty or fifty. Wyman found between twenty and thirty. "The mouth and branchial cavity were very much distended, rounding out and distorting the whole hyoid and branchiostegal region. Some of the eggs even partially protruded from the mouth" in one of Wyman's fishes. But, with the exception just noted, "no young or eggs were found in the stomach, although the mouth was crammed to its fullest capacity."

The length of time during which the eggs are retained within the mouth is unknown, but it must be considerable. Before the period of oviposition both males and females in India "are said to be so fat that the curry made with them resembles that made with pork; but after swimming about for a few days with their mouths full of eggs," the males become, according to Boake, "dry and insipid." Eventually they may become quite emaciated. Boake thought that the ovigerous stage lasted for "a period of some weeks." Perhaps

the best evidence as to the ovigerous period has been furnished by the *Netuma barbus* or *commersonii*, a species very abundant in southern Brazil, where it is known as the bagre. H. von Ihering (1889) tells that in the Rio Grande do Sul the spawning season is the late spring and summer—that is, during November, December, and January. The eggs of this species, by the way, have been declared to be the largest of any known Teleost, being about three-fourths of an inch (17 or 18 millimeters) in diameter.

But, although most of the Tachisurines are probably oral egg carriers, all are not so, one making a peculiar kind of nest and another being declared to be viviparous.

A FRESH-WATER TACHISURINE.

The northern Australian fish generally known as *Arius australis*, but which some modern systematists would call *Hexanematichthys australis*, is a nest maker, but makes a nest different from those prepared by the glanis and the American catfishes.

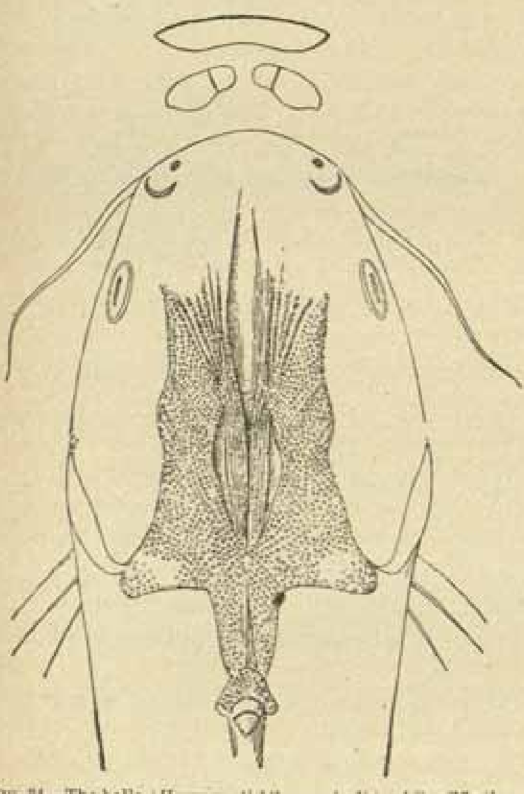

FIG. 34.—The bolla (*Hexanematichthys australis*). After Günther.

The species is an inhabitant of the Hunter River, Richmond River, and the Boyne, and it was in the last that Semon found it in abundance and first noticed its nesting habits. By the English colonists it is called jewfish, and by the native blacks bolla. Inasmuch as jewfish is better known in connection with several other fishes, bolla may be advantageously used. The fish has the general appearance of the familiar sea catfishes and slender fresh-water catfishes of America, but the upper surface of the head or casque from the interorbital region backward is thickly sprinkled with fine bead-like granulations.

The color is uniform blackish above and silvery on the sides. It reaches a size of about 18 inches. Its nesting peculiarities have been described by Richard Semon in his work entitled "In the Australian Bush" (1899, p. 196).

The bolla was found by Semon to resort to "flat, sandy, and stony parts" of the river, "under a rapidly passing current," to spawn. In such places, in August—that is, in early spring in northern Australia—Semon "found numerous light-colored circles of about a yard across." On looking more closely he "often noticed a fish swimming about inside this ring, and, as it seemed, occupied with a work of importance. On examining the ring itself, which has a breadth of about eight inches," he found that its light color was "due to the removal of all stones, large and small, from its surface. They had been carefully carried into the inner circle, so that the surrounding ring shows the gleaming white sand of the river bed, bare of every pebble. The ring shows no other peculiarity. The inner circle," however, excited his interest. At the top he found several layers of big stones, among which nothing was to be discovered. These were succeeded by a mixture of small pebbles and coarse river sand, beneath which followed the common river ground. At first Semon was unable to find eggs in any of these layers, though he closely examined them. Observation through the rapidly flowing water was, however, far from easy, and being sure that this was the depository of the eggs, he further investigated the matter. He took out a part of the gravel, cleaned it from sand by passing it through a strainer, and thus found numerous small eggs—small in comparison with the eggs of the egg carriers, but large in comparison with those of most fishes. They had a diameter of about one-eighth of an inch, and were surrounded by a "closely fitting tegument."

The manner in which the nest thus observed is made has been explained at length by Semon:

> When depositing its eggs and building its nest, the fish goes to work in the following way. It begins by preparing a bedding about half a yard in area, consisting of gravel and small pebbles, among which it deposits the spawn, which is instantly milted by the male. After this it covers up the eggs by several layers of bigger stones, thereby preventing them from being washed away by the stream or being carried off by water-birds fond of this kind of caviare or by marauding little fishes. The material for this defensive structure is derived from the above-mentioned ring, which thereby becomes devoid of all stones and gleams brightly in its smooth garb of white sand. It is wonderful to observe the accuracy of the fish's handiwork and the perfect circle described by the ring. So far as I could see, the fish moved the bigger stones by pushing them along with its tail.
>
> The whole affair shows a very clever arrangement, the eggs thus being well shielded from enemies, well ventilated by the current and even protected against being mud-stifled (save in case of a downright flood).

SUPPOSED VIVIPAROUS CATFISHES.

Besides the two modes of care for the progeny already noticed, it has been claimed that there is a third kind of provision for the young by at least one of the American Tachisurines. Evermann and Barton Bean, during a visit to the so-called Indian River of Florida in 1896, "were convinced" that the sea catfish, known as *Galeichthys felis*, "is ovoviviparous." They urge that, "according to the testimony of competent observers among the Indian River fishermen and dealers, the adult females of this catfish are found filled with well-developed young in March, each rolled up in a ball and the balls connected in a long string." In the opinion of Evermann and Goldsborough (1902), "while the technical description is a trifle faulty, the evidence points very strongly toward the ovoviviparity of the sea catfish."

It is possible, however, that the "Indian river fishermen and deal-

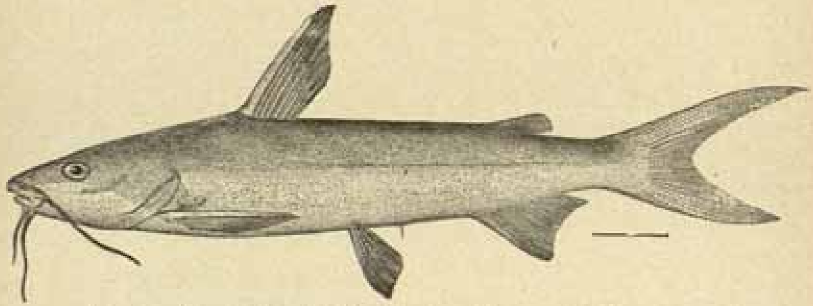

FIG. 35.—Sea catfish of United States (*Hexanematichthys felis*).

ers" confused the contents of the abdomen and the mouth. Certain it is that males of the *Galeichthys* or *Hexanematichthys felis* carry eggs within their mouths.

Another supposed viviparous catfish is an inhabitant of South American rivers. It is the lau-lau, declared by R. H. Schomburgk to be, "next to the pirarucu, the largest fresh-water fish of Guiana." It is, according to that author (Fishes of British Guiana, I, 194), "remarkable that the young of the lau-lau are excluded from the ovarium into the abdomen, in which state they might be likened to the yolk of an egg, in which the two specks of the eyes, the mouth, and fins, are, however, observable. If a lau-lau should be taken when near parturition, in consequence of fear the eggs pass off." A Mr. Hillhouse "assured" Schomburgk that "he had repeatedly put the eggs in a glass of water, where they hatched themselves, and the young appeared with a large yellow protuberance on its belly like the abdomen of a chicken just hatched. When left to nature, the eggs are hatched in the abdomen; and when the young are excluded, they

swim in large shoals over the head of the mother. In case of danger. the mother opens her mouth, and the fry find a safe retreat in the thorax."

If this statement could be relied on, viviparity would be proved, but it is at least possible that the observers, seeing the eggs out, assumed that what had really come from the mouth had issued from the abdomen.[a] Anyway, fry that had found their way from the mouth into "the thorax" would not find it "a safe retreat." The species has not been described or illustrated in such a manner as to be intelligible. Mr. C. Tate Regan, of the British Museum (*in litt.*), thinks that "the lau-lau seems to be an *Arius*;" possibly it is the *Netuma barbus*. Another possibility is that it is related to or the same as the gigantic piraïba of the Amazons (*Piratinga filamentosa*). One objection to the last suggestion is that the flesh of the lau-lau is said to be "delicious, both in the fresh state and when dried;" in fact, the "flesh is so much esteemed, that it is considered to be one of the ties which binds him who has once tasted it forever to the region where it is indigenous." On the other hand, the flesh of the piraïba, is indigestible and even dangerous; in the words of its monographer, E. Göldi (1901, 183), "a carne do Piraibï é tida por pesada, indigesta, perigosa mesmo com a continuação." As British Guiana belongs to a nation endowed with scientific investigators, we may hope soon to know what the lau-lau really is.

The Plotosids, or catfishes, of southern Australia have been also claimed to be viviparous and they at least make provision for the care of their young. In the report of the Royal Commission to examine into the fisheries of New South Wales, it is asserted that in "the fresh-water catfish" (*Copidoglanis tandanus*), "as in most if not all of the *Siluridæ*, the ova are fertilized by the male fish before leaving the body of the female, and both sexes seem to unite in the subsequent attendance on the nest in which the ova are deposited." The intromission of the semen among Silurids will be new to ichthyologists and physiologists.

In fine, while it may be improbable that there is viviparity in Silurids, it is not impossible, and these popular beliefs should lead to a candid investigation of the subject.

SILURINES, ICTALURINES, PIMELODINES, AND TACHISURINES

All the fishes now referred to are related to such a degree as to form a group called the family of Silurids by naturalists. It is the largest and most comprehensive family of the order of Nematognaths,

[a] In another place (I, p. 114) Schomburgk merely alludes to the "young offspring, which swim in shoals about [the parents], and in case of danger enter the large throat of the mother."

about eight hundred species being known. The form is more or less elongated and the trunk naked, at most plates existing only along the lateral line. The head is either naked in some or shielded in others, but with the opercular apparatus well developed. The mouth is normal and has simple lips; maxillary barbels are conspicuous; the dorsal fin, when developed, is near the head and has a spine, but in some is atrophied or entirely suppressed. Coincident with these are certain osteological characters which reenforce the family value of the group.

The European species belong to the subfamily of Silurines, which are distinguished by the great length of the tail and anal fin and the advanced position of the anus as well as the small or atrophied dorsal fin; there is no adipose fin. The species are confined to the Old World and are numerous in Asiatic and African rivers.

The North American species represent another subfamily—Ictalurines—distinguished by the moderate length of the tail and anal fin, the submedian position of the anus, the well-developed dorsal fin and spine, and the presence of an adipose or fatty fin along the back of the tail; the barbels are eight in number, the usual maxillary and chin being supplemented by a pair of small ones close behind the hinder nostrils; further the two pairs of nostrils are quite far apart; the palate is toothless. Catfishes of this kind are nearly confined to North America, few species extending into Central America and northeastern Asia. Between thirty and forty occur in the streams and lakes of America.

The South American and most of the Mexican species are closely related to the North American, and have the same form and fins, but there are only six barbels, the nasal being absent; as in them, however, the anterior and posterior pairs of nostrils are far apart.

The marine catfishes, designated as Tachisurines or Ariines, differ very little from the preceding, having essentially the same from and proportions as well as fins, but the two pairs of nostrils are close together, there are no nasal barbels, and the palate is armed with small and densely crowded teeth. Numerous species inhabit tropical seas near the land, and a few enter fresh-water streams.

All these are closely related and thus may be brought together in this connection. Another subfamily is more distant.

THE DORADINES OF SOUTH AMERICA.

Next may be noticed South American Silurids (Doradines), especially distinguishable superficially by the existence of a single row of plates along the sides, and thus separated from the other groups of the family to which they belong as well as from the Callichthyids, with which they are often confounded by the natives of the countries

both inhabit, the Callichthyids having two rows of plates interlocking along the lateral line. The Doradines have also the branchial apertures separated below by a wide isthmus and the gill apertures correspondingly narrowed. The true dorsal fin is well developed; the anal fin is short; the air bladder is free in the abdominal cavity.

One of the species of this group—the flathead hassar (*Doras hancockii*)—has long been celebrated from the account of John Hancock (1828) as "one of those fishes which possess the singular property of deserting the water, and travelling overland. In those terrestrial excursions large droves of the species are frequently met with during very dry seasons, for it is only at such periods that they are compelled to this dangerous march, which exposes them as a prey to so many and such various enemies. When the water is leaving the

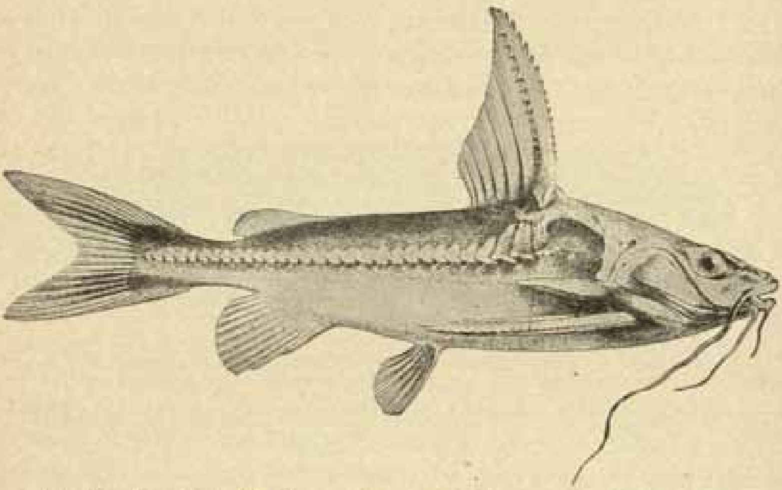

FIG. 36.—A characteristic Doras (*Doras longispinis*). After Steindachner.

pools in which they commonly reside, the yarrow" (a species of *Erythrinus*, probably *E. unitæniatus*) and the roundhead hassar (*Hoplosternum littorale*) "bury themselves in the mud, while all the other fishes perish for want of their natural element or are picked up by rapacious birds, etc. The flathead hassars, on the contrary, simultaneously quit the place and march overland in search of water, travelling for a whole night, as is asserted by the Indians, in search of their object." Hancock, by experiments, ascertained that "they will live many hours out of water, even when exposed to the sun's rays." This endurance is promoted by the narrowed gill apertures and the closeness with which the gill covers can be pressed to the sides. They have also, according to Jobert, a development of sanguiferous papillæ to the intestinal canal serving for aerial respiration analogous to that noticed in Callichthyids, but less complete.

Long ago Hancock described the movement of the flatheaded hassar of Demerara (*Doras hancockii*). A friend informed him that on one occasion he and his family "fell in with a drove of these animals, which were on their march over land to a branch of the Pomeroon. They were so numerous that the negroes filled several baskets with those they picked up." Their movements "over land" have been compared to those of "the two-footed lizard. They project themselves forward on their long arms (the stout pectoral spines) by the elastic spring of the tail exerted sideways. Their progress is nearly as fast as a man will leisurely walk. The strong scuta or bands which envelop their body must greatly facilitate their march," Hancock thought, "in the manner of the plates under the belly of serpents, which are raised and depressed by a voluntary power, in some measure performing the office of feet."

Under ordinary conditions, the flathead, according to Hancock, "frequents only the fresh water of pools, lakes, and rivers, lives by suction, and on aquatic insects, and grows to about a foot in length."

No details of the courtship and parental care of any Doradine have been published. All that is known is what Hancock (1828) has told. "Both" of the species of Nematognaths which he noticed as "species of hassar"—the *Doras* and *Hoplosternum*—"make a regular nest;" the nest of the *Doras* is made "of leaves" while that of the *Hoplosternum* is made "of grass;" the eggs are laid "in a flattened cluster," and covered "over most carefully." Like the roundhead, the flatheads "lay their eggs only in wet weather." Afterwards the parents are said to "remain by the side of the nest till the spawn is hatched." It has been especially asserted that "both the male and female" share in guarding the nest, "steadily hatching the spawn and courageously attacking any assailant."

THE RAAD OR ELECTRIC CATFISH.

Almost all the members of the Nematognath order have stout dorsal and pectoral spines, but the electrical catfish, like other electrical fishes, is entirely deprived of spines or dermal armature of any kind; its electrical battery replaces all such protective devices and is more than a compensatory substitute. The family Malapteruridæ[a] has been proposed for it. The body and head are entirely naked and unarmed, the mouth is terminal, the barbels are like those of the typical catfishes, a true dorsal fin is wanting but there is a large adipose on the back of the tail far behind, the pectorals are lateral and unarmed, and the ventrals submedian.

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[a] The proper name of Malapteruridæ is Torpedinidæ. (See Proc. U. S. Nat. Mus., XXVI, 1903, 697, 698.

The electrical or electric catfish is the only generally recognized species of the family, although several nominal species have been proposed from time to time. Another name by which it is known is raad, raa'ard, or raada. This name, by which it is generally known to the Arab fishermen of Egypt, means thunder, and thus the natives have connected the fish with the phenomenon coincident with the effect which Europeans indicate in the name (electric catfish) which they have given. Raad is an excellent name, and that will be used here.

The raad is indeed especially noteworthy on account of the remarkable development of the electrical apparatus and function. An individual no longer than a hand's length can give quite a disagreeable shock, as the present writer can testify from personal experience. "Both the director and some of the keepers, having received strong electrical shocks from comparatively small" fishes in the aquaria of the Egyptian Zoological Gardens, cared not "to experience how powerful a shock the large fish could give."

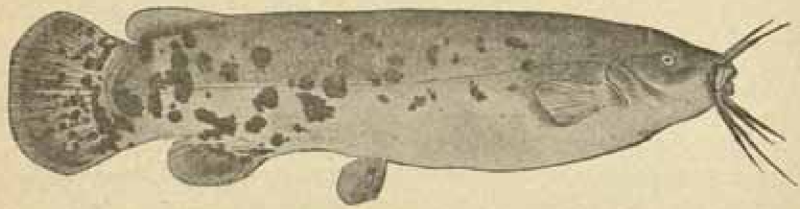


FIG. 37.—Raad or electric catfish (*Malapterurus electricus*). After Boulenger.

In the words of Fritsch (1893), the raad or *Malapterurus* belongs "to quite a different category from other electric fishes." "A transverse section of the whole fish shows the difference at once. The body of the animal is enveloped in a very thick electric skin, constituting one electric organ. Muscular tissue is nowhere deficient, other histological elements must therefore have furnished the material for the electric plates, which are packed very close in the lozenge-shaped compartments of the skin."

In more detail, Francis Gotch (in 1899) explained the structure of the electrical organ:

It is situated in the skin enclosing the whole body of the fish, and has a beautiful and characteristic appearance when seen in microscopic sections. Each organ consists of rows of compartments, and each compartment has slung athwart it a peculiar protoplasmic disc shaped like a peltate leaf, with a projecting stalk on its caudal side. Nerves enter each compartment, and end, according to the recent work of Ballowitz, in the stalk of each disc. By these nerves nervous impulses can reach the organ; the arrival of such impulses at the nerve terminations evokes a state of activity which is associated with the development of electromotive charges of considerable intensity constituting the organ shock. The shock is an intense current traversing the whole organ from head to

tail and returning through the surroundings; it stuns small fish in the neighborhood and can be felt by man, when the hand is placed near the fish, as a smart shock reaching up the arms to the shoulders.

The seeker for further information may find it in the article on "The electric fish of the Nile," by Professor Gotch, in the Proceedings of the Royal Institution of Great Britain for March 17, 1899 (vol. 16, pp. 114–115).

The raad has a wide range through Africa and occurs not only in the Nile, but in the other great rivers, the Kongo and the Niger, besides many smaller intervening streams.

In a state of nature the raad attains a considerable length, exceptionally as much as 3 feet, but is mature and capable of reproduction when less than a foot long. According to Forbes, individuals in confined quarters or captivity scarcely ever grow; "most" of those in the Liverpool Museum—about 6 or 7 inches long—have rarely, though in excellent health, grown much after their arrival." The largest the present writer saw in an aquarium in Liverpool was less than 8 inches long. In the aquaria of the Egyptian Zoological Gardens, however, the director reported (1905, p. 27) that specimens "increased in length and girth during their stay in captivity." One which died in February, 1905, had attained a length of 17¼ inches and a weight of over 3 pounds (3.2 pounds), after having lived nearly two years (since April, 1903) in the aquarium.

A number of good observations were made on individuals living in the Liverpool Museum, by Dr. H. O. Forbes, and published in the Bulletin (I, pp. 25, 26). These we freely draw upon. For the most time and "when in good health the raad lies sluggishly on the bottom, rising to the surface only for the purpose of feeding or when in expectation of being fed." Those in the Egyptian aquarium "appear to spend nearly the whole day lying motionless on the bottom of the tank, from time to time flapping their pectoral fins." In captivity in Liverpool they "thrive well on and take with avidity common earthworms, boiled liver chopped up, and occasionally a young trout from two to three inches in length." Its power of vision is very limited, although it has "small, sparkling, diamond-point-like eyes," but their optic nerves are "extremely attenuated," when compared with those of "other fishes of corresponding size." Its behavior in being fed is characteristic.

If a worm be dropped into the tank to fall wriggling to the bottom, the *Malapterurus* rarely, if ever, sees it. A few moments, however, after the worm has fallen through the water, the fish becomes suddenly agitated, apparently through its olfactory organ, or, perhaps, by its barbels detecting the undulations communicated to the water; and begins turning rapidly about with tensely extended and vibrating barbels, keenly quartering out the tank in quest of the quarry, whose presence it has become sensible of. The sought-for object is, however, as a rule, discovered without its coming into actual contact with the

fish's tactile oral fringe. The worm, once discovered, disappears in a flash down the catfish's throat by suction and is usually not seen again, although sometimes it is brought up to be partially masticated. On the other hand, the presence of a young trout in the tank is not, it would seem, detected in the same way, or so quickly as a worm or a fragment of liver. It more often discovers itself to the *Malapterurus*, by coming in contact with its body, when it is instantly partially disabled by an electric discharge, and pounced upon, when it likewise disappears in the same manner as the worm.

Another of their characteristics adverted to by Forbes is a spirit of pugnacity carried to an extreme which renders their assemblage in an aquarium dangerous to some of the individuals and require them "to be kept isolated in separate tanks." The individuals in the aquaria of the Egyptian Zoological Gardens were comparatively peaceable. According to the director (1905, p. 27), "besides the two Malapteruri" kept in one tank were "several 'bolti,' *Tilapia nilotica*," and "neither species of fish appears to in any way interfere with the other." According to Forbes:

Although supposed to be immune to each other's electrical discharges, the following observation would seem to throw some doubt on whether this be really the case. On one occasion the partition between two halves of a tank, each containing a *Malapterurus*, becoming faulty, two strong and healthy fishes managed to get together, and were found by night watchman on his hourly rounds, fighting with each other. Adjusting the partition, he returned the combatants to their separate cells. On his return, however, an hour later he found the barrier had again slipped, and both fishes were in the same compartment, but one was dead. On examination no external marks of violence were visible, and we can only suppose that the stronger fish had killed its neighbor by a powerful electrical shock.

The raad is apt to kill off other fishes of corresponding size that encroach on its territory, although this is not always the case. It may also make use of them in a way which reminds one of the attacks of jægers on gulls and their consequences. One was confined in an aquarium in Liverpool with a Clariid catfish; it would not eat worms offered to it directly, but after the Clariid had taken them, it would give its companion a shock which had the result of causing him to vomit the worms recently taken, and these the raad would appropriate for his own use with an open countenance.

Sounds, described as being "not unlike the hissing of a cat," were heard to issue from a raad in captivity by a sister of William Sörensen, when staying at Mansourah on the Nile. "This appeared somewhat strange" to Sörensen, but after he had dissected the fish, he "could easily account for it by the long, narrow ducts through which the air has to pass from the anterior to the posterior chamber of the air bladder" (1895).

The manner of reproduction of the raad is still unknown. The eggs are rather large, having a diameter of a couple of millimeters,

but it is not known when or how they are laid. The fishermen of the Nile assert that the fry are carried in the mouth of a parent.

Naturally a fish possessed of such remarkable attributes as the raad attracts general attention, and must be at least tolerably well known to most of the inhabitants of the country in whose waters it dwells. The species was known to the ancient Egyptians, and, according to Gotch, it was delineated on the interior walls of Ti, estimated to have lived five thousand years before the Christian era.

It was doubtless used as a remedial agent from early times. An Arabian physician of the twelfth century described the effects produced by the fish. It was described likewise in a couple of chapters in 1625 in "Purchas, his Pilgrimes" (pp. 1183, 1545), under the name of torpedo. Its electrical power is made use of for sanitary and invigorating purposes by the African natives, who share with many of their European brethren the belief that electricity has peculiar efficacy and restorative virtues. A child may be put into a tub containing a raad and kept for a time in spite of its yells and cries, by the mother, who sacrifices her tenderness of feeling to the desire for the welfare of her offspring.

Not all the natives in the country of the electric catfishes are familiar with or know of their power. Ignorance is sometimes displayed where it would be least expected. One of the party of a Belgian official in the Kongo State on one occasion played a practical joke on his "chef;" a good-sized fish was caught and carried alive to the Kongo chef; he took it and, knife in hand, prepared to skin it, but as soon as his knife touched the skin the man experienced a shock which evoked shrieks of amazement and pain and hurled him to the ground, where he remained prone and bewildered for some time.

THE CALLICHTHYIDS.

Related to the Silurids, but forming a peculiar family, is a group of fishes restricted to tropical America; it is that of the Callichthyids.

The Hassars or Cascaduras, otherwise denominated the Callichthyids, have a superficial resemblance to the catfishes, but are distinguished from them, as well as from all other fishes, by a peculiar coat of mail composed of lateral rows of narrow vertically extended plates, two rows on each side, which interlock along the lateral line and cover completely the sides. The head has a special system of plates, and the operculum is well developed; the mouth is inferior and small and the intermaxillary bones much reduced in size; the lower lip is everted; the maxillary barbels doubled; the dorsal fin is anterior and has a strong spine, and a spine also fronts the adipose fin;

the pectorals are low and horizontal and also spiniferous. From tropical American streams about 30 species have been obtained.

The typical Callichthyids of the genera *Callichthys* and *Hoplosternum* are most at home in streams with a muddy bottom and in the shallow ditches and pools of marshes. In such places they may congregate in considerable numbers, and when the water is low may be readily caught with dippers or pails and even with the hand. When so disturbed they are apt to express their feelings by rumbling or grunting sounds. At all times they may come to the surface of the water from time to time to take in gulps of atmospheric air, and these emergences become more frequent with the lowering of the water. At length, if the water entirely disappears, the resort to atmospheric air supplants aquatic respiration, and a curious complementary mode of respiration is substituted for the normal branchial method. This was discovered by a French physiologist—Professor Jobert—who visited Brazil in 1877 and 1878 and undertook some in-

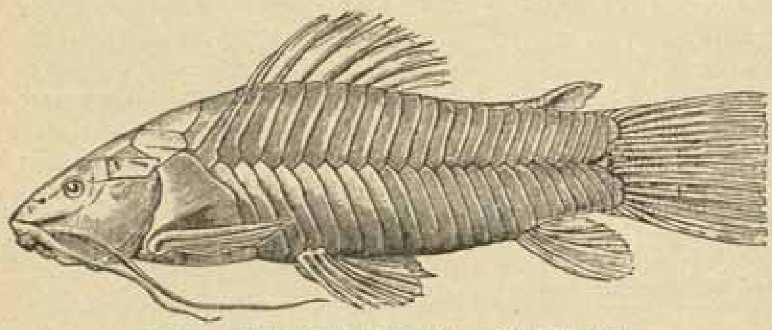


FIG. 38.—*Hoplosternum littorale.* After Boulenger.

vestigations at the instance of the Emperor. These were favorably reported on by a special committee of the French Academy of Sciences of which Milne Edwards was the mouthpiece.

Like the common loach of Europe, according to the reporter, the typical Callichthyid "frequently swallows bubbles of air, partly absorbs the oxygen from them by the walls of its digestive tube, and by the same course excretes carbonic-acid gas, which is afterwards evacuated by the anus mixed with the unabsorbed nitrogen." There is, in fact, "a complementary respiration analogous to the pulmonary respiration of the terrestrial vertebrates, but having its seat in the intestinal canal." Jobert also "ascertained that in the *Callichthys* this tube presents in its anatomical structure peculiarities in connection with this exceptional function." In "the sublaminal portion of the intestine" are developed a "multitude of filiform appendages arranged in tufts on the free surface of the mucous membrane and composed essentially of blood vessels." It is these "sanguiferous appendages of the intestinal coat of *Callichthys*" that "serve to maintain an ac-

cessory aerial respiration in these aquatic animals." The atmospheric air is "introduced by deglutition into their digestive tube, traverses that canal throughout its whole length, and, after escaping by the anus, produces a sort of continual bubbling in the water." The bubbles thus evacuated contain "a large proportion of carbonic acid," and are "naturally less rich in oxygen than atmospheric air." By "studying anatomically the vascular tufts which clothe the walls

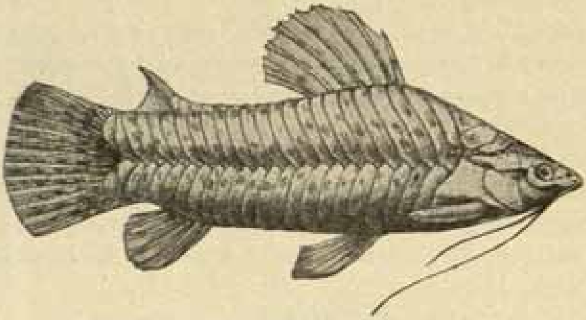


FIG. 39.—*Hoplosternum pectorale*. After Boulenger.

of the intestine in which the air, in passing, loses oxygen and becomes charged with carbonic acid, M. Jobert ascertained that many of these sanguiferous appendages originate from adjacent veins, in the same way as the afferent vessels of a lung."

The habits of two species of very different genera—*Hoplosternum* and *Corydoras*—have been made known. The chief of these, at least so far as size and economical importance are concerned, is *Hoplosternum*. This comprises fishes with a broad head high-arched above and separated from the antedorsal plate by the intervention of two nuchal plates, and the plates behind the head (cœnosteons or proscapulas) are broad and continued downward to the breast, where

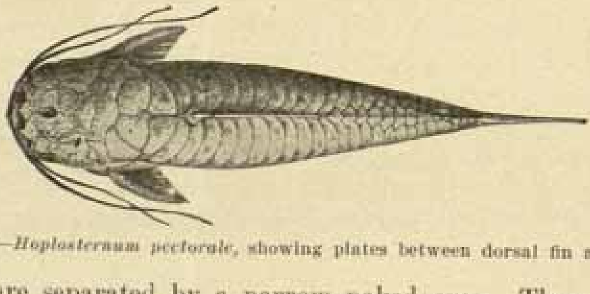


FIG. 40.—*Hoplosternum pectorale*, showing plates between dorsal fin and head.

the pair are separated by a narrow naked area. There are more characters differentiating the genus from others, but those given are sufficient to distinguish it from its nearest relative, *Callichthys*, the name-giving genus of the family. Four species of *Hoplosternum* are known, the most northern being the *H. littorale*, which extends from Trinidad and Guiana to the Rio Plata.

The most generally known English name for any species of *Hoplosternum* is Hassar, which, however, it shares with very different species of the family of Silurids—the Doradines. The etymology and origin of this name is unknown. In the great New English Dictionary (Murray's) it is supposed to be of South American origin ("? native South American name"), but this is doubtless a mere supposition based on the fact that it is current in a South American country (Demerara). According to John Hancock (1828) it is derived from the "Arowaks." Another name having some currency in English is one that may be often heard in the British island of Trinidad. In that island the common species is generally known as the *Cascadura*, which is a survival from the time of the Spanish dominance in that island. This has been translated as "hardhead," but it evidently refers to the segmented or articulated appearance produced by the two rows of high and narrow plates which cover the sides, the Spanish word *Cascadura* meaning "an act of bursting or breaking asunder." The same fish is also called que que by the negroes of Demerara, in imitation of the noise it makes when taken out of the water, which, it is considered, "much resembles the cry of a rat.

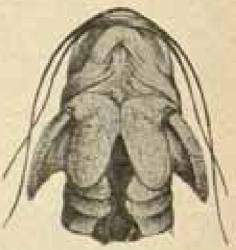


Fig. 41.—*Hoplosternum pectorale*, showing armature of breast. After Boulenger.

The roundhead hassar (*Hoplosternum littorale*) was supposed by Hancock to remain and bury itself in the mud of the pool which was drying up, and he especially stated that it was not "known to attempt such excursions" as the flathead hassar resorted to, "although it is capable of living a long time out of its element." A close relative of the roundhead, however, the cambota of southern Brazil (*Callichthys asper*), was the subject of interesting observations by an American resident in Bahia, Mr. Joseph Mawson. He had six specimens of the fish and kept them mostly "in a narrow-necked tin of water, with some sand and mandioca meal at the bottom, for five days," and they continued "active and vigorous." Mawson's specimens were not full grown, measuring only 2 to 4 inches (5 to 10 centimeters) long. Occasionally he let them out of the receptacle, and once one got out without assistance. Mawson's account was published in Science for December 25, 1880 (I, p. 317), and is worthy of partial republication here, especially as it has entirely escaped the notice of all ichthyologists.

I have had them out in the garden several times. I find that they move best on smooth damp ground, and are embarrassed by sticks or other inequalities. They can jump a little vertically, but their progress on land is effected entirely by a quick wriggling motion of the body, which is nearly flat upon the ground. The paired fins (pectorals and ventrals) are extended laterally and seem to bear

little if any weight, but they move slightly and appear to serve to steady the body.

On one occasion an individual displayed much activity and gave Mawson a good opportunity to observe its peculiar movements.

Last night I heard a peculiar sound, and on looking around I saw one of the fish travelling about the room. He had escaped from the tin which was in my bedroom, had fallen from the table to the floor, and travelled along the corridor, about 12 meters (about 40 feet) to the *sala*. I watched him travelling for two hours, during which time I estimate that he moved at least 90 meters. Toward the end of the two hours he seemed to flag a little, but in the earlier part his method and speed were fairly seen. He seemed to start with a sudden movement of the head or the barbels, then wriggled briskly for 5 or 10 seconds, advancing about a meter. Then he would rest for about 10 seconds, and start as before. This was kept up during the whole two hours, and I left him still moving. This morning, five hours later, I found him dead. While he was moving I spilled some water on the floor, but he crossed it; hence I concluded that it was mud rather than water of which he was in search. The fish are eaten and considered good food.

Many of the hassars bury themselves in the mud as the stream in which they have lived dries up and are able to survive quite a protracted dry period, reviving when the rains again fill the depressions with water.

The roundheaded hassar of Demerara (*Hoplosternum littorale*) is one of the earliest fishes whose nest-building habits have been described. When it was generally asserted by naturalists that "no fishes are known to take any care of their offspring," from far-off Demerara John Hancock, an English surgeon resident in that colony during the second quarter of the last century, in 1829 sent "Notes on some species of fishes and reptiles," and among them were observations on fresh-water fishes which he called hassars—one kind, the flathead, a *Doras*, and another, the roundhead, the *Hoplosternum littorale*. The latter was claimed to assiduously guard its eggs and young. The sexes, it was asserted, cooperate and make a regular nest, formed of grass, in which "they lay their eggs in a flattened cluster, and cover them over most carefully."

According to Hancock, too, "they lay their eggs only in wet weather." He had been "surprised to observe the sudden appearance of numerous nests in a morning after rain" had occurred, "the spot being indicated by a bunch of froth, which appears on the surface of the water, over the nest; below this are the eggs, placed on a bunch of fallen leaves or grass," which the fishes "cut and collect together. By what means this is effected," he continued, "seems rather mysterious, as the species are destitute of cutting teeth. It may possibly be by the use of their serrated arms, which form the first ray of the pectoral fins."

The nest building was later (in 1886) described by Captain Vipan, who observed the same species in Trinidad. He had a pair confined

in an aquarium; and they commenced to make a nest in June. One begun on June 6 and another on June 9 "they soon pulled to pieces. On the night of the 11th they began a new one. It consisted of pieces of *Valisneria*, all the leaves of the *Nymphæa* that were growing in the tank, which they bit off close to the roots of the plants, and a great quantity of river moss (*Fontinalis antipyretica*), each piece being two or three times the size of the fish, so that they must have had hard work to bring them to the surface. They worked these materials together by some mucous substance until the outside was hard, the whole being under a quarter of an inch thick. They next buoyed up the structure with a quantity of mucous foam until it was raised 3½ inches above the water. The whole nest was 9 inches long and 7 inches wide, and somewhat resembled a finger glass turned upside down on the top of the water, with the interior filled with froth."

The process of oviposition is especially interesting and is essentially the same as in a distant relative—the *Corydoras*—which otherwise differs much in habits. According to Vipan, the fish kept swimming close under the nest, "all the time on their backs, and filling it with foam. When finished, on the 12th, the female shed her spawn between her ventral fins, which were clasped tight together, and when full swam to the nest, and, turning on her back, deposited the spawn in it. This occurred several times, the male each time putting the spawn in its proper place and covering it with froth."

The subsequent behavior of the pair must either vary considerably or one of the observers must have assumed more than was justifiable.

After the nest is made the female deposits her eggs in it. Then, according to Hancock, she stays about it and shares with her mate the care of it. The two, says he, "remain by the side of the nest till the spawn is hatched with as much solicitude as a hen guards her eggs, both the male and female hassar—for they are monogamous—steadily watching the spawn and courageously attacking any assailant." This devotion is often taken unfair advantage of by the negroes and the fishes are caught by them "by putting their hands into the water close to the nest, on agitating which the male hassar springs furiously at them and is thus captured."

Captain Vipan's account is more consistent with the facts known respecting the care of the nests by other fishes by the father fish only. According to him, "as soon as the female had dropped all her spawn the male took entire possession of the nest and would not let his mate go anywhere near it, and treated her so badly that" he "had to place her in another tank to save her life. Unfortunately the spawn was not good, only a few eggs hatching and the young fishes dying soon afterwards."

The only other Callichthyid whose breeding habits have been described is a species of the genus *Corydoras*. This has been estab-

lished for species with a compressed head upraised into a narrowed ridge and with the supraoccipital plate continued backward into a narrow process and connected behind with the antedorsal plate.

The amorous dalliances of the sexes of the *Corydoras* were observed by Carbonnier and described by him in 1880 in a very entertaining

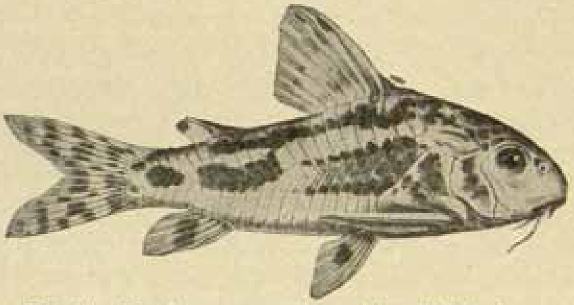
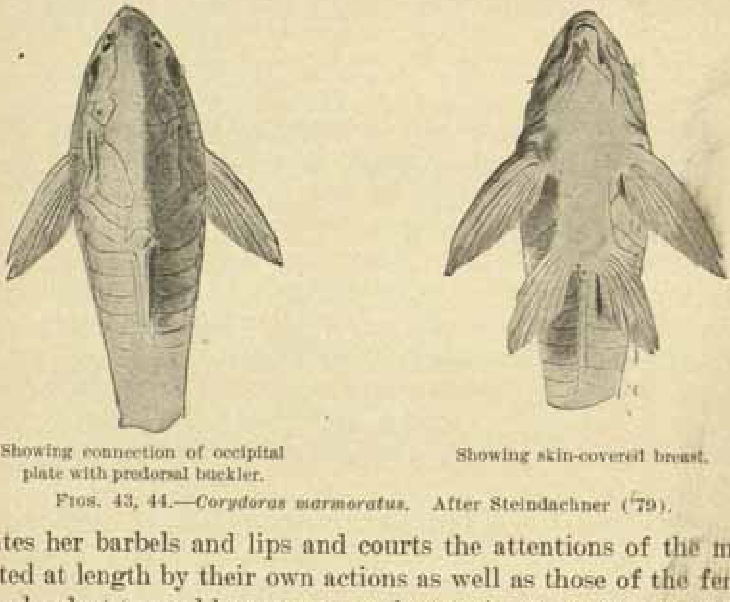


FIG. 42.—*Corydoras marmoratus.* After Steindachner.

style. When the reproductive season arrives males and females give striking evidence of it. The males assemble in groups of three to five and, to use the expression of Carbonnier, disport themselves in quite a feverish manner ("manière toute febrile") and apparently practice a kind of mutual excitation. All this time the female swims slowly and gracefully near the group and in a lively manner



Showing connection of occipital plate with predorsal buckler.

Showing skin-covered breast.

FIGS. 43, 44.—*Corydoras marmoratus.* After Steindachner ('79).

agitates her barbels and lips and courts the attentions of the males. Excited at length by their own actions as well as those of the female, the males dart toward her, some pressing against her sides and wildly disporting themselves there, and others on her back. At length one of the males may stride across the female's head and seize her barbels

by the bony spines with which the pectorals are armed. Then he hugs her vigorously, and without letting go slides around to the lower surface of her head. In this position he forcibly emits his milt along the abdomen of the female. The female is ready. As soon as she had been seized by the male she had brought together her two ventral fins and by their expansion formed behind the ovarian outlet a cavity or sort of bag in which the eggs and sperm are to be received. Very soon afterwards a few eggs are expelled and held in the extemporized receptacle and then fructified by the spermatozoa already lodged there. The set of eggs has about five or six, and these the female holds for some minutes in the pouch just noticed. Then she goes in search of a place to deposit her eggs. Her choice generally is a well cleared area, perhaps a stone projecting out of the water. She clears with her mouth a spot at least four or six inches (ten or fifteen centimeters) below the level of the water; then applying her abdomen to the spot she opens her pouch, parting the ventrals, and fixes her eggs, which become attached by the viscosity which envelops them. All the eggs being thus disposed of, she again approaches the males, and the same procedure is gone through with forty or fifty times in the course of a day. The number of eggs thus provided for is about 250. As polyandry is indulged in by the female, it is not likely that any provision except that just noticed is made for the later care of the eggs by either male or female.

The absence of a special nest is also vouched for by Captain Vipan, who, in 1886, wrote that he had "bred great quantities" of the *Corydoras punctatus* "from the Amazons, but they never made the slightest attempt at making a nest, always depositing their spawn all over the tank and even on the floating thermometer kept in it."

In the island of Trinidad, where species of three genera live, the largest of the Callichthyids, called cascadura (*Hoplosternum littorale*), is so highly esteemed that a proverbial expression has arisen—"He who eats a cascadura will die in the island."[a] The ambiguous phrase is interpreted to mean that if one goes away he will return to satisfy his appetite for the fish. The present writer has not been affected in that manner. He could not appreciate much, if any, superiority over the best of the common American catfishes. In other places than Trinidad, too, the fish appears to be highly regarded. Hancock wrote of the Demerara fish that "the flesh of this hassar is yellow, firm, and very savory, especially esteemed by the creoles in their soups," whose composition is described by him at length.

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[a] An analogous proverb is prevalent in Guiana in connection with a catfish called Paraiba. (See p. 455.)

THE LORICARIIDS.

The sturgeon-like catfishes, or *Loricariids*, are isolated on account of the form and the complete investment with longitudinal rows of angular dense plates. The mouth is inferior, below a projecting

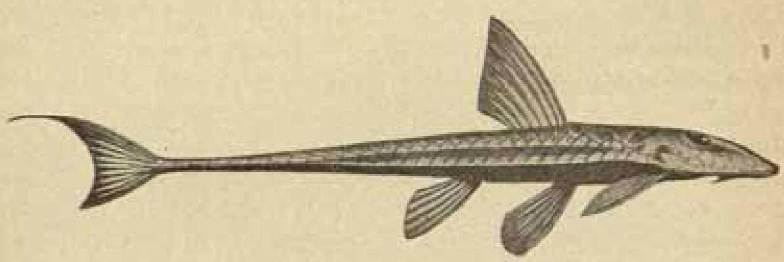


FIG. 45.—*Loricaria spixii.* After Steindachner.

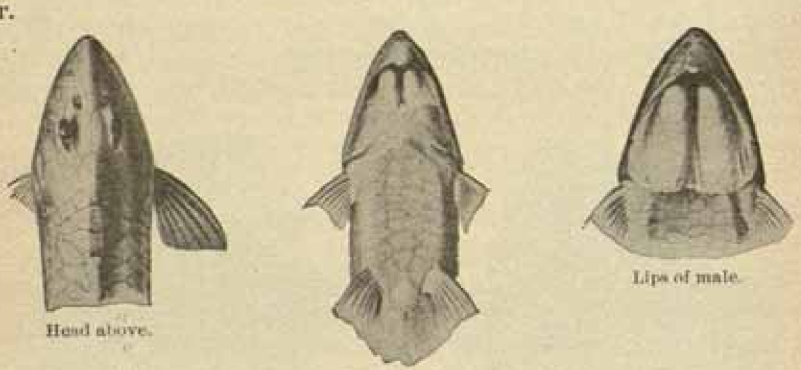
snout, and has large everted lips; the barbels are inconspicuous; the dorsal is anterior; the pectorals are inserted low down and on a level with the inferior surface of the breast, and the dorsal and pectoral fins have marginal spines; the ventrals are more anterior in position than in other Nematognaths. An adipose fin is generally represented by a thin membranous ridge with a spinelet in front, but in many genera is wanting, and, indeed, it has been found in one species to be of so little significance as to be present in some individuals and absent in others. Such are the most noteworthy external characteristics, but those of most fundamental importance are deeper seated and to be found in the skull and the vertebral column. It would, however, entail too much technical knowledge to appreciate them. Anyone who wishes to ascertain what they are may do so by consulting "A monograph of the fishes of the family Loricariidæ," by C. Tate Regan, published in 1904 in the Transactions of the Zoological Society of London. The illustrations, as well as the text, are unusually good.

The Loricariids are peculiar to tropical America, and about two hundred species have been already obtained and described. They are more interesting to the naturalist than the general student and have little or no economical value. Very little is known of their habits. They are bottom fishes, living chiefly, but not only, in streams with a muddy or sandy bed and at moderate depths.

Marked sexual differences are frequent in the species of Loricariids. Regan (1904), indeed, has aptly indicated that "the differences between the sexes in certain genera are very remarkable." The differentiation is generally in the direction of increased spinescence or the development of stronger spines and bristles in the males than in the females. It is also noteworthy that an increase of size appears to be generally correlated with the assumption of the secondary male

characters. This larger size of the male than the female is, in fact, the rule among fishes when the male is distinguished by salient characters, such as increase of armature or brilliancy of coloration. (See p. 409.)

Practically nothing exact is known respecting the breeding habits of any of the species of the family, but doubtless they will be found to be of extreme interest if we may credit the ideas of Prof. Louis Agassiz. That eminent naturalist, during his ichthyological exploration of the Amazon in 1865, made certain observations which should stir up naturalists of tropical America, where species of the genera so abound, to make diligent hunt for them during the breeding season. According to Agassiz, some of the *Loricaria* carry their eggs in folds of their everted lips, while others, of the genera *Plecostomus* or *Hypostomus*, actually sit upon their eggs like birds. These statements were made in a letter to Milne Edwards from Manaos, Brazil, and published in the Annales des Sciences Naturelles (5. ser., Zool., t. 5, p. 228). Agassiz's exact words are: " D'autres espèces portent leurs œufs dans les plis de leurs lèvres, telles sont les Loricaires; d'autres les couvent comme les Oiseaux, tels sont les Hypostomes." It is probable that the Hypostomes or Plecostomes, like the American catfishes, may really rest upon or close to their eggs for a time, but frequently rise above to fan and agitate them to give them the benefit of fresh air.



Head above. Lips of male.

Lips of female.

FIGS. 46, 47, 48.—*Loricaria spixii.* After Steindachner.

No further information was published by Agassiz respecting the oviposition or embryology of any Loricariid. Only an incidental reference to the rearing of the young of Syngnathids is given in his Journey in Brazil (1868, p. 239), and the remark is added that " it is only matched by the equally curious incubation of the eggs in *Loricaria*." F. Steindachner, however, in 1881, in his description of the *Loricaria spixii*, noticed the great development of the hinder or lower lip, especially in the male during the breeding season, and the

adaptation for a brood-pouch of the interspace between it and the underside of the head.[a]

Typical specimens of the *Loricaria spixii* in the Vienna Museum were reexamined by Friedr. Siebenrock in 1903, and he informed Mr. Regan that Steindachner's "statement was based only on the structure of the lip, which seems adapted for such a purpose," but

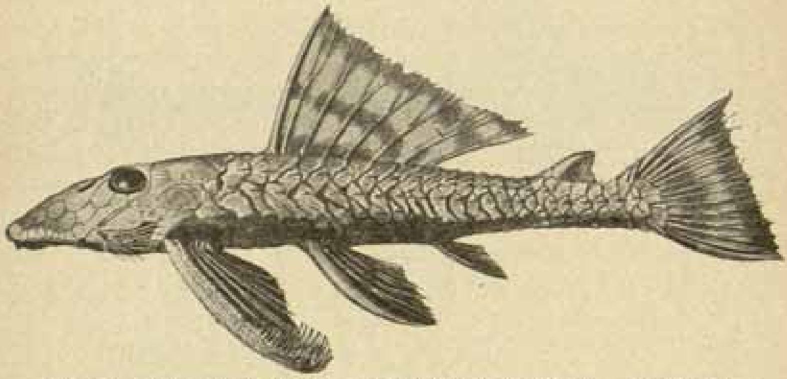
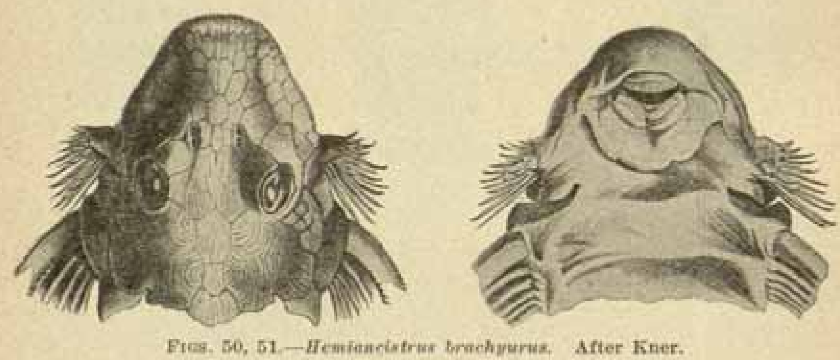


FIG. 49.—An alleged caretaker. *Hemiancistrus brachyurus.* After Kner.

that none of the specimens in the Vienna Museum show eggs in this position. Siebenrock and Regan were apparently not aware of the fact that Agassiz had made the statements already quoted in this article. Even if eggs had been found as indicated, however, they might have become accidentally lodged there. We may repeat, then, that practically nothing exact is known respecting the breeding habits of any species.



FIGS. 50, 51.—*Hemiancistrus brachyurus.* After Kner.

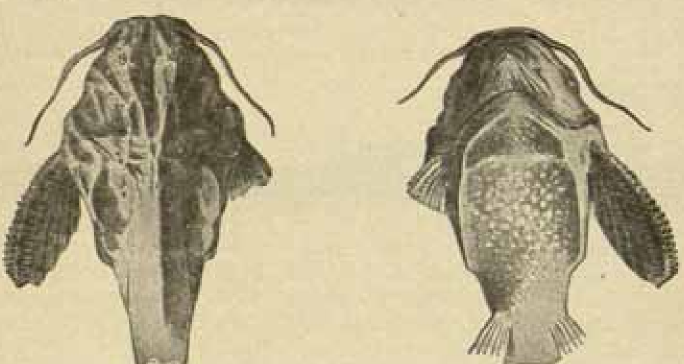
It may be objected to the above statement that a detailed and graphic account of the nidification of a typical species of the family

[a] Das hintere Segel ist stets stark entwickelt, insbesondere aber bei Männchen zur Brutzeit von auffallender Länge, und dient bei letzteren zum Schutze der Eir, die zwischen dem hinteren Mundsegel und der Unterseite des Kopfes zur Entwicklung gelangen.—Steindachner, Ds. K. Akad. Wiss., M.-N. Ch., 44, p. 5.

has been given in the volume on fishes of "Brehm's Tierleben," (1879, p. 206; 1892, p. 243), and that special reference to the same species as a remarkable nest builder has been made by Dr. R. Semon in his "Zoologische Forschungsreisen in Australien und dem Malayischen Archipel" (II, 1895, p. 273), as well as "In the Australian Bush," etc. (p. 196).

The account in the "Tierleben," however, is due to some confusion on the part of the compiler and is in no way descriptive of a Loricariid. The names "*Chætostomus pictus*, Callichthys und Ancistrus pictus" are associated in Brehm's Tierleben with a diagnosis partly referable to the fish named *Chætostomus pictus* by Günther and partly to the one called *Callichthys pictus* by Müller and Troschel. The description of the nest is entirely derived from Schomburgk's notice [a] given in connection with the *Callichthys pictus*, etc. The two fishes have nothing in common but the name *pictus* and belong to entirely different families; the former, now named *Hemiancistrus brachyurus*, is a Loricariid, and the latter (*Hoplosternum littorale*) a Callichthyid, whose habits have been noticed in the present article in the proper place.

When an able naturalist like Semon is misled by a popular work, such as Brehm's, it is time to correct the mistake. It may be added that in the first edition (V, p. 637) the paragraphs copied (with alterations) from Schomburgk's work are rightly associated with *Callichthys* ("*pictus*"), but in the second (VIII, p. 206) as well as third edition (VIII, p. 243) they are given under the head of *Chætostomus pictus*.



Figs. 52, 53.—An Aspredinid, *Bunocephalus bicolor*. After Steindachner.

THE ASPREDINIDS.

The *Aspredinids* are the most specialized of the Nematognaths. The body is more or less elongated, especially the tail, and the head and

[a] Schomburgk, Richard: Reisen in British Guiana in den Jahren 1840–44, II, pp. 411, 412. The nest-building habits are noticed under name *C. coelatus*, but *C. pictus* is said to have similar habits.

forepart of the back are much depressed; the usual opercular bones are present, but rudimentary; the mouth is inferior; the intermaxillary bones are remarkable for being placed in a longitudinal instead of transverse direction; the unarmed dorsal is far forward; the pectorals are horizontal and each armed with a very strong spine. Only a couple of dozen of species are known. A special interest attaches to species of this family on account of the very peculiar care taken of their eggs by some of the species at least.

In all the other Nematognaths, so far as known, the care of eggs and young is devolved chiefly if not entirely on the male parent, but those Aspredinids whose gestation is known (and that of four species is) act quite differently and in a very remarkable manner.

As long ago as the eighteenth century representatives of the family had been described with small globular bodies pendant from the breast and those were supposed to be distinctive of a species named therefore *Aspredo cotylephorus;* their function was unknown and not even guessed at. Not until nearly a century later were they recognized as eggs.

Even the great and learned ichthyologist Valenciennes had no conception of their true nature. As late as 1842, in his chapter on the genus *Aspredo*, he wrote as follows:

A certain number of individuals in each species (of Aspredo) are remarkable for singular appendages on the underside of the thorax and abdomen, and which, after the few observations which I have been able to make, appear to indicate a certain state of the female. I have not seen them in the males and

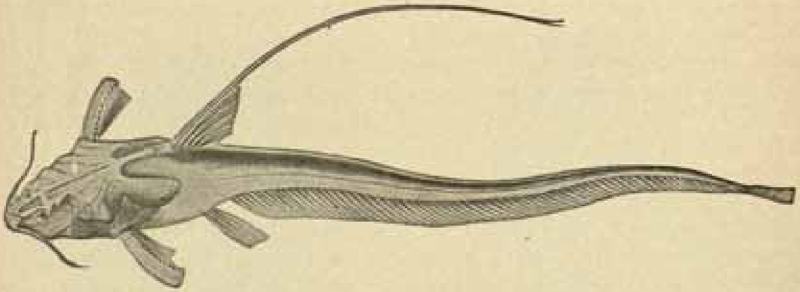


FIG. 54.—*Aspredo filamentosus.* After Valenciennes.

the females do not have them at all times. They first appear as pores on the under and naked surface of the trunk; and these enlarge and swell into tubercles, which subsequently elongate into filaments, and the extremity of each filament is dilated into a small cupule.[a]

It was in this state that Bloch saw them in an individual with six cirrhi, and, taking them for specific characters, named the fish *Platystacus cotylophorus*. But I have seen the same appendages in three species. Artedi, in the text of

[a] Cuvier and Valenciennes, Hist. Nat. des Poissons, T. XV, p. 430.

Seba, had already described two species, to which we now add a third. All three live in the waters of Guiana and this is all we know of their habits.[a]

Not until years later did Prof. Jeffries Wyman, of Harvard College, give a true explanation of the cause of such excrescences. In an able article in the American Journal of Arts and Sciences he reviewed the history of opinion and, after giving the description of Valenciennes, remarked that—

From the preceding paragraphs it does not appear that Valenciennes had supposed that the so-called "cupules" were intended to contain or had contained ova, especially as he had previously expressed the belief that the Aspredos, in consequence of the large size of the eggs, were viviparous. The true use of the appendages in question relates to the development of the eggs, as the following description will show. The habits of the fish are well known to the fishermen, from one of whom Mr. Green obtained information with regard to their peculiar mode of gestation. After many ineffectual efforts we at last succeeded in procuring the specimens on which the following observations were made, and Mr. Green has kindly presented to me some very fine ones from his own collection, without which this notice would have been much less complete.[b]

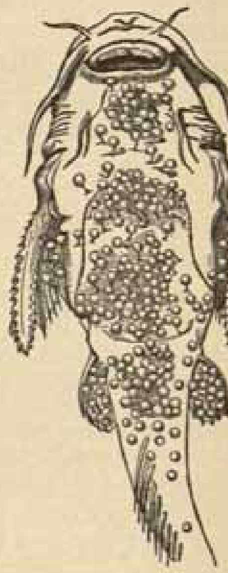


FIG. 55.—*Aspredo lævis*, female with eggs attached to under side.

In the month of June the eggs are found adhering to the underside of the body, to the ventral and pectoral fins, and extend as far forward as the under lip and as far backward as the middle of the tail [fig. 55]. In some, however, the distribution is much more limited. I was unable to learn anything with regard to the transfer of the ova from the genital orifice to the point of their attachment. The only organ which seems in any way adapted to such a purpose is the slender and flexible tail terminated by a delicate caudal fin. It is possible that the eggs may be deposited on the bottom of the river and subsequently attached by pressing the underside of the body upon them.

In those individuals where the ova were still in the ovary, but approaching maturity, the integuments of the underside of the body gave no other indications of the changes about to take place than of being quite vascular. The skin was perfectly smooth, no "pores" were visible, but a large vessel was seen emerging from the region of the liver, and descending along the median line gave off branches quite freely to the integuments. This may have some relation to the future development of the pedicles which support the eggs and perhaps to the nutrition of the embryo as will be adverted to hereafter.

In all the specimens which I have had an opportunity of examining, the eggs were either somewhat advanced or quite mature, so that no observations

[a] Cuvier and Valenciennes, Hist. Nat. des Poissons, T. XV, p. 430.

[b] See an account of the habits of the Aspredo by Mr. Green in the Proceedings of the Boston Society of Natural History for April, 1858. [This was not published.]

could be made on the earlier conditions of the egg and the formation of its pedicle. The pedicle is a flexible outgrowth from the common integuments, is about two lines in length, is attached to the skin by a slightly expanded base, and spreads out at its summit into a shallow cup or "cupule," for the support of the egg. It is composed almost entirely of fibrous tissue, invested with a layer of tesselated epithelium. In some instances when the eggs were but little advanced, numerous fusiform cells were detected among the fibers. It is vascular, two or three vessels reaching to the cup, where they ramify and form a somewhat extended capillary plexus [figs. 56 and 57].

FIG. 56.—Advanced *Aspredo* egg with pedicle of attachment (×4). After Wyman.

The eggs vary according to the degree of development from 0.09 to 0.15 of an inch in diameter, and are covered with an external homogeneous membrane, containing minute punctiform depressions—within this is a second, of a brownish color and composed of epithelium. The embryos which were the most advanced and just ready to hatch, had not as yet completely absorbed the yolk, and were coiled up within the membranes, which in consequence of the irregularities of the mass formed by the embryo had no longer a spherical form.

The eggs are retained in connection with the cup apparently by adhesion alone, for as soon as the foetus escapes, the egg membranes become very easily detached from the pedicle, and this last as shown by some of the specimens undergoes absorption.

The relation of the embryo to the parent in this singular mode of gestation can not be determined very accurately, but the vascular plexus in the cup seems to be more than is necessary for the mere nutrition of the part. The egg increases in size during incubation, those ova in which development had but slightly advanced measuring from 0.09 to 0.11 of an inch in diameter, while those nearly mature measured from 0.14 to 0.15 of an inch. How this increase of size of the embryo over the original size of the egg is actually obtained I have no facts to show, but either of two suppositions is probable; it may be by absorption of materials from the water which surrounds it, or from the capillary plexus of the pedicles, and in this case in a manner analogous to that of Pipa.

FIG. 57.—*Aspredo pedicle*, showing capillary plexus (×8). After Wyman.

Even now nothing is known of the mating or courtship of the fishes. Various attempts have been made to explain, however; the latest and most probable explanation was published by Vaillant in 1898. The eggs, after being laid and fecundated, have a glutinous investment, and when the breast is pressed over them they adhere to it. It is the layer of the eggs—the female that presses the breast over the eggs. Irritation of the skin is set up then, and at the point of adhesion a prominence arises, which becomes a sort of peduncle expanding into a cupule embracing the proximal surface of the egg. It reminds one of a mushroom with its stalk and head. In due time the eggs are hatched and the shells or envelopes of the eggs may be left attached to the mushroom-like expansion, or "oophore," as it has been named. Finally these casts fall off also, the expansions become button or bead

like, and at last all disappear and the skin resumes its normal aspect for the time being. The adhesion of the eggs to the skin is analogous to the mode of oviposition of the celebrated Surinam toad, but in that animal attachment of the eggs is made to the back.

Nothing is known of the subsequent behavior of the mother or children, and of course not of the embryology.

THE SCYPHOPHORES.

In Africa, but in tropical and subtropical Africa alone, are found numerous species which have a peculiar physiognomy by which they can be at once recognized and which have anatomical characters that contrast with those of all other fishes. The most important of their characters are shared in common with the normal Malacopterygians, and therefore they may be placed in the same order; but the distinctive characters are sufficiently important to have led some ichthyologists to differentiate them as a suborder, which has been named Scyphophori, or, in English, Scyphophores.

The Scyphophores are Malacopterygians with a deep cavity on each side of the cranium between the squamosal, epiotic, and exoccipital bones, which is covered in a lidlike way by a thin scalelike supratemporal bone; without an opisthotic and without a symplectic, and with the premaxillaries united. The brain is remarkably developed. Furthermore, the opercular and other bones are concealed by the skin, the branchial apertures are narrow and lateral (being in front of or above the level of the pectoral fins), and the jaws are not protractile. These characteristics impart the physiognomy distinctive of all the group. The species of the group are very unequally divided by structural characters, a single species being contrasted with all the others. The single species is the type of the family of Gymnarchids, while all the rest belong to the family of Mormyrids.

The brain of the Scyphophores is extraordinarily developed and superficially very unlike that of any other fish. Some of the older anatomists thought the cerebrum was like a mammal's. When divested of its most salient peculiarities, however, it has "very nearly the same structure as in ordinary Teleostean fishes." The chief distinction is the development of "an immensely developed tuberosity of a rounded shape immediately above the medulla oblongata and behind the cerebellum," which "appears as a new development superadded to the usual elements of the Teleostean brain," and which was designated in 1882 by Sanders as the "*tuberculum impar*." Another peculiarity is the development of "a fungoid growth taking place from the region in front of the cerebellum; we may then imagine this growth to burst through the *tecta lobi*

optici, forcing them asunder, repressing them to the basal part of the brain, and then to spread out in all directions, covering over and concealing every one of the remaining portions of the brain." So Sanders explains the structures in question. With these exceptions "the other parts of the brain have very nearly the same structure as in the ordinary Teleostean fishes."

The Mormyrids are interesting for another reason: They are of the number of electric fishes. On each side of the tail are peculiar muscle-like structures which were named "pseudo-electric" long ago, and which the researches of modern physiologists, especially Babuchin and Gustav Fritsch, have demonstrated to be real electric organs. These organs are in the form of oblique bands (like the muscular segments from which they are derived), composed of small columns perpendicular to their axis. They have little efficiency compared with the electric apparatus of the electric catfishes, but they are electric all the same, and they are developed to such an

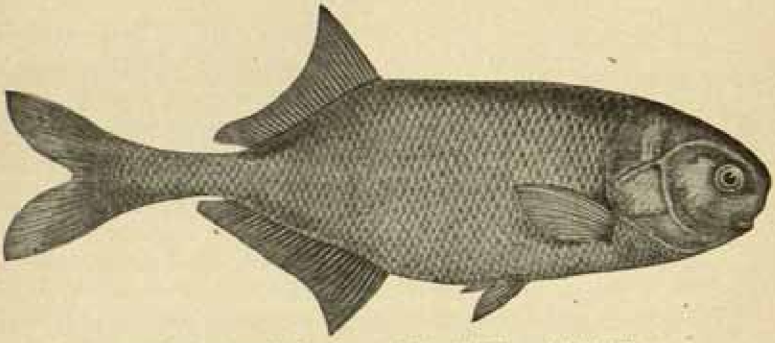


FIG. 58.—*Petrocephalus bane.* After Geoffroy Saint Hillare.

extent as to largely replace muscles. Fritsch, in 1893, demonstrated that "a transverse section of the tail of Mormyrus shows no conspicuous muscles, but in place of them electric tissue filling up the entire space occupied by muscles in ordinary fishes. Of the muscular apparatus there is nothing left except the longitudinal tendons passing outside the electric organs from muscles placed anteriorly. If these tendons were cut across the Mormyrus would be unable to move its tail."

THE MORMYRIDS.

The *Mormyrids* are numerous, about 120 species having already been discovered in the fresh waters of the "dark continent." A caudal fin is always manifest and the vertebræ are in moderate number—37 to 64. An imperfect electrical apparatus is developed from the caudal muscles. The species vary much in the form of the snout

and the extent of the dorsal and anal fins. The osteological and cerebral variation is also great and the differences between the ordinary forms (Mormyrines) and the genus *Petrocephalus* are so many as to have led to the isolation of the last as a distinct subfamily type. Representatives of the Mormyrines occurring in the Nile were reverenced by the ancient Egyptians, and various myths were connected with them.

There is a great range of size in the family, and even rather closely related species may represent extremes. For example, the largest of the family (*Mormyrops deliciosus*) sometimes becomes five feet long, while a congener of the same fauna (*Mormyrops parvus*) may be sexually mature when less than five inches long.

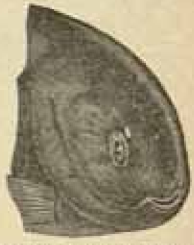


Fig. 59.—*Petrocephalus.*

The food of the Mormyrids naturally is determined by the means for obtaining it. Those with a relatively large mouth are able to secure fishes and moderate-sized crustaceans; those with mouths of reduced size are limited mainly to small crustaceans and worms and the larvæ of insects, supplemented by decaying animal and vegetable matter and some live plants. Boulenger thinks that the species with prolonged snouts make use of them to pry out animalcules which have found refuge between stones or which have buried themselves in the mud, and that the fleshy appendage at the tip of the lower jaw is a tactile organ by means of which they are assisted in finding their food. Some, indeed, seem

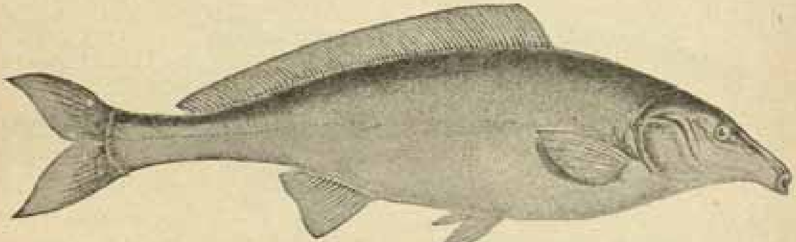


Fig. 60.—*Mormyrus oxyrhynchus.* After Geoffroy Saint Hilaire.

to prefer decomposing matter, and among such is the *Mormyrops deliciosus*, which Delhez declared affected putrifying animals in the midst of the water weeds where they occur in large numbers; especially did they congregate in the neighborhood of encampments, where refuse matter of all kinds was dumped into the water. But that very species exercised a rather wide range of choice, for Peters and Boulenger found in stomachs the remains of fishes and crustaceans.

The longest, if not the best known, of the Mormyrids is the Caschive (*Mormyrus caschive*) of the Nile, which, however, is by no

means confined to that river, but also occurs in the Gaboon and Kongo. Caschive is the familiar name in use among the dwellers along the lower Nile, although it is likewise applied by them to other species of the genus. In ancient times it was known to the Greeks as the *Oxyrhynchus*, and numerous representations of it and related species have come down to us from classical times on the monuments and bronzes which are the handiwork of the ancient Egyptians.

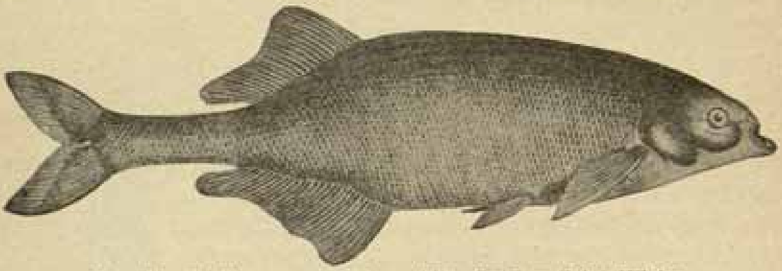


FIG. 61.—*Gnathonemus labiatus.* After Geoffroy Saint Hilaire.

The species of so large and diversiform a family must naturally show considerable differences in habits, and especially in the selection of "stations" or grounds, and little is known about any. Several, however, have been confined in aquaria at the Egyptian Zoological Gardens and some data about them have been published in their reports for 1903–1905. Some (*Mormyrus kannume*) "spend the day lying quietly on the bottom;" others (*Gnathonemus isidori*) "spend most of their time in midwater, with all their fins and tails in perpetual motion, but occasionally, for a short time, they will lie on the

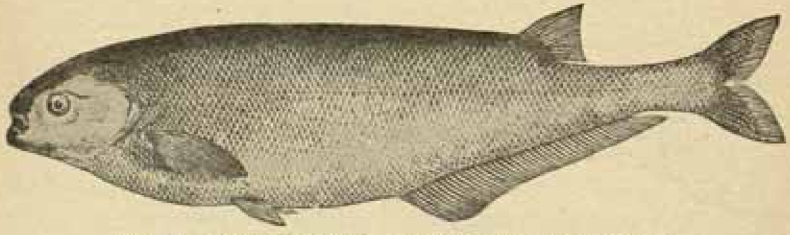


FIG. 62.—*Hyperopisus bebe.* After Geoffroy Saint Hilaire.

bottom of the tank with fins motionless." Still others (*Gnathonemus cyprinoides*) "usually keep moving about the bottom of the tank, the pectoral and tail fins being almost constantly in motion, the other fins being only occasionally used." The kannume, or abu boos, and *Gnathonemus* have "a curious habit of swimming backward, with tail leading," a habit which reminds one of the *Gymnarchus*. "Like the *Gnathonemus*," the kannume prefers "the lower part of their tank; the pectoral and tail fins are moved most, but there seems less of the constant waving of fins about this species than there is with the other two" Mormyrids noticed here.

Some of the Mormyrids, especially the kannume, are quite pugnacious. Those in the Egyptian Zoological Gardens "fight a great deal among themselves, and several individuals which died from time to time during 1903, it is believed, had been killed by their comrades, but latterly these fights have been less frequent." They still continued, however, during 1905, and five were killed in the last year.

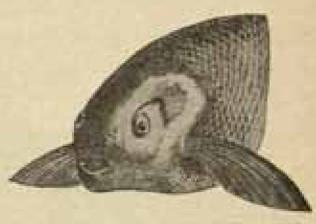


FIG. 63.—*Hyperopisus bebe*. Front view. After Geoffroy Saint Hilaire.

All the Mormyrids in the Giza gardens were fed on "finely chopped-up earth worms," which they soon learned to look for daily. After nightfall the kannume especially becomes "very active, searching energetically for food. When the light from a match or lamp falls on them, their eyes shine very remarkably, sometimes white, sometimes gleaming red."

The Mormyrids appear to be mostly more or less nocturnal in a state of nature, but in captivity most of them soon learn to feed by daylight. The representatives of the *Mormyrops anguilloides*, however, "are of very retiring habits, and spend most of the day hidden under the rock work of the tank, only coming out to feed at dusk." "It is interesting to see" the kannume "searching the bottom of the tank, examining every stone and cavity with their long snouts, for the pieces of chopped-up earthworms which are daily put in for them to feed on."

They are by no means tenacious of life, but die quickly after being taken from the water, and Fritsch had great difficulty in keeping them alive long enough for his experiments with them. In fact, he could not keep them over more than two or three days at most.

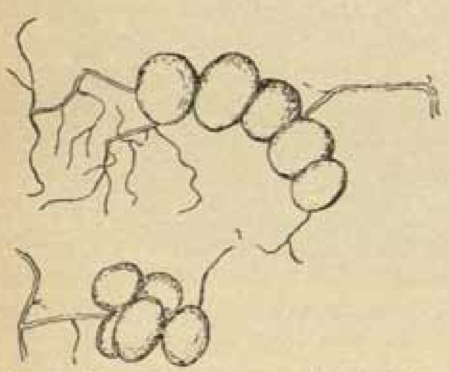


FIG. 64.—Eggs from nest supposed to be that of *Hyperopisus bebe*. After Budgett.

The nesting habits of a fish supposed to be a species of the family (*Hyperopisus bebe*) were observed by J. S. Budgett in 1900. The parent scoops out a depression of the bottom of a swamp, laying bare rootlets of grasses growing in such situations, and to such rootlets the eggs are attached. The eggs are slightly oval and small, being about 1¼ millimeters in diameter and of a yellowish color but semitransparent; they are hatched in about four days. The embryos "are then provided with four large cement glands situated on

the top of the head and two smaller ones on the front of the head." Just as soon as "the larva is hatched it rams the upper part of its head against rootlets and, wriggling away again, draws out from the four cement glands four fine threads of viscid mucus, which are hardened by contact with the water and form a minute rope about the length of the body of the larva. By this the larva hangs suspended for four or five days until the yolk is absorbed. If the larva is detached meanwhile, a fresh rope is formed by a fresh secretion of mucus. While hanging thus, each larva continually oscillates the whole length of its body from side to side. In one nest there are many thousands of these larvæ suspended in this way, presenting the appearance of a shaking mass of jelly, for all the larvæ oscillate themselves in unison."

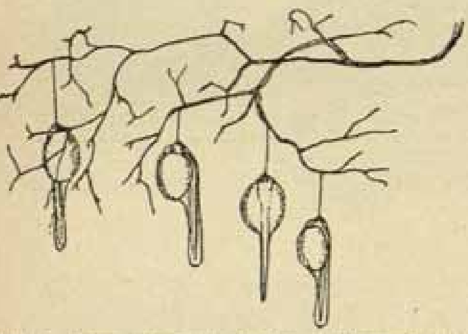


FIG. 65.—Larvæ supposed to be those of *Hyperopisus bebe* suspended from rootlets in the nest. After Budgett.

Many of the Mormyrids are esteemed for their flesh and one, although a foul feeder, was named *Mormyrops deliciosus* on account of the great esteem in which it was held. And, by the way, it is the largest of its family, sometimes reaching a length of even 5 feet. Such a fish, we learn from Boulenger, might command a price of 25 francs ($5) at Boma. It is fished for chiefly at dawn and sunset.

Such are the only facts yet known respecting the breeding habits of any of the Mormyrids.[a] In view of the specialized provision for the care of the eggs in the bebe as well as in its distant relative representing the family of Gymnarchids, it is reasonable to assume that care for the eggs may be exercised by most, if not all, the species of the family.

THE GYMNARCHIDS.

The Gymnarchids are closely related to the Mormyrids, but the tail tapers to the end and has no fin; the anal fin is also wanting (whence the name), and the vertebræ are very numerous (about 120). A single species—*Gymnarchus niloticus*—was long well known as an inhabitant of the White Nile, but in recent times has also been found in the Senegal and Niger, as well as Lake Chad.

[a] I am by no means convinced that Budgett was correct in his identification of the larval fish figured as the "larva of *Hyperopisus bebe*" (in pl. 11, fig. 10) with that fish; it is too unlike that of *Gymnarchus*.

The gymnarchus or suyo of the Gambian natives manifests peculiarities in movement in accordance with its peculiarities of form and structure. "It propels itself through the water, not by the action of its paired fins, not by the motion of the tail or the undulatory motion of the axis of the body, but entirely by the action of its dorsal fin." When the fish starts forward, "the motion is the result of a series of waves passing backward along the dorsal fin. About five such

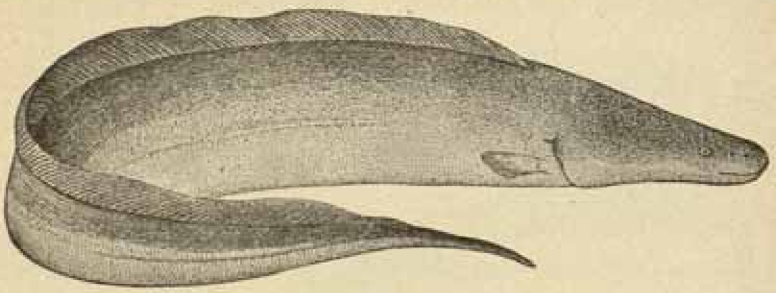


FIG. 66.—*Gymnarchus niloticus.* After Boulenger.

waves are passing at a time. Suddenly the fish will proceed at the same rate in the opposite direction, and now the motion is the result of a series of waves passing forward along the dorsal fin. As the gymnarchus swims rapidly backward in this way it may be seen to guide itself through the grasses by using as a feeler this peculiar tail which it possesses. Thus it appears to be quite immaterial to the

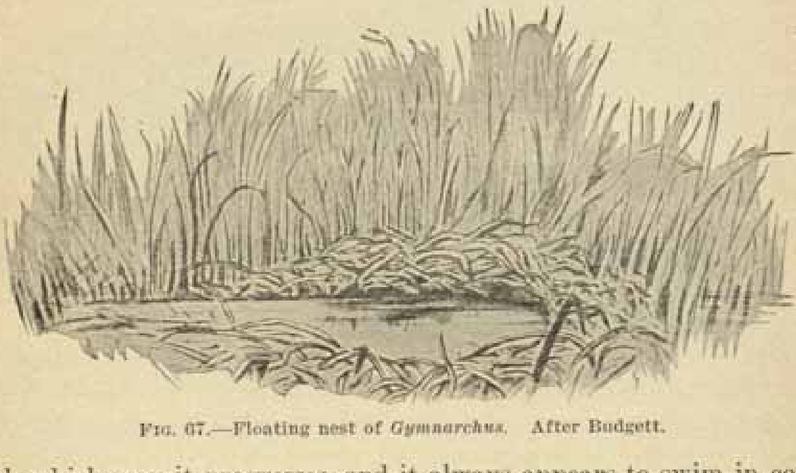


FIG. 67.—Floating nest of *Gymnarchus.* After Budgett.

fish which way it progresses, and it always appears to swim in comparatively straight lines."

The gymnarchus makes a large floating oblong nest, about 2 feet long and 1 foot wide on the outside, in the dense grasses of a swamp and in water 3 to 4 feet deep. In one, especially described by Budgett, "three sides of the nest projected from the water; the

fourth side was several inches lower, being about two inches below the surface. The deepest part of the nest was opposite to that side where the wall was low, the bottom being about six inches below the surface of the water." Such were the typical nests observed by Budgett.

In one nest "were deposited about a thousand spherical amber-like eggs 10 millimeters in diameter. The eggs hatched five days after being laid, and in eighteen days a thousand young fry," about three inches long, left the nest. They were then essentially like the adults. Many of the young were secured by Budgett immediately after they had left their nest, and "lived well on chopped-up worms." He tried to take some to England, but every one died as soon as they "got into colder climes."

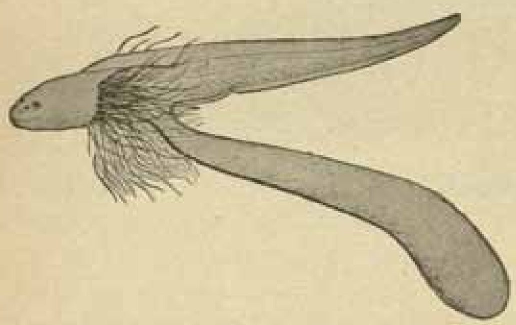


FIG. 68.—*Gymnarchus niloticus*, larva, 6 days after hatching, showing long drawn out yolk-sac and abundant external gill-filaments. After Budgett.

The native Africans "approach these nests with great caution, stating that the parent is at this time extremely fierce and has a very formidable bite."

THE OSTEOGLOSSOIDEANS.

In the fresh waters of various tropical countries are found certain fishes which have a general resemblance to some of the ganoids of old times, and one of them, at least, has a complexity of the lower jaw which is only paralleled by such ganoids as the Amiids and Lepidosteids. The group containing such forms has been designated as a peculiar superfamily—Osteoglossoideans.

The body is elongated and covered with a system of hard scales having a peculiar sculpture, the field being divided into many areas, resembling mosaic work; the head is externally bony and sculptured, and the parietals intervene between the frontals and supraoccipital. By some naturalists three families have been recognized for such fishes, but they are generally united under one—*Osteoglossidæ*. All agree in having the intermaxillaries paired and in the possession of well-developed interopercles and subopercles, and thus differ from their nearest relatives, the dwarfed Pantodontids of Africa. The life histories of these forms are little known, but two of the representatives of the group have been ascertained to be care takers of eggs and young, and very interesting details have been made known of one of them.

THE ARAPAIMA.

The most gigantic fresh-water fish—of America, at least—is that best known as the pirarucu and arapaima. Scientifically it has been most aptly named *Arapaima gigas*, and it is the only species of its genus, as well as family. In addition to the characters already noted, which it shares with other Osteoglossoideans, it has the belly rounded and not keeled, the dorsal longer than the anal, the ventrals

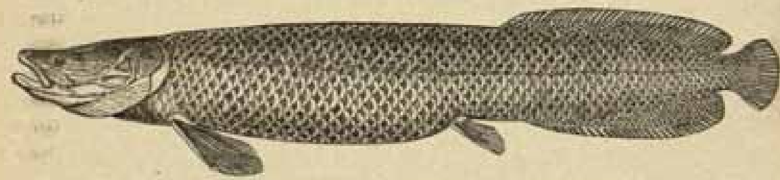


FIG. 69.—The Pirarucu or Arapaima (*Arapaima gigas*).

far behind, postorbitals excessively differentiated and extremely long, and numerous (about sixteen) branchiostegal rays. These characters, of inconsiderable importance by themselves, are the superficial concomitants of important osteological peculiarities which would necessitate too much technical detail for the present article. Those who would seek further information are referred to an article on the "Cranial osteology of the families *Osteoglossidæ*, *Panto-*

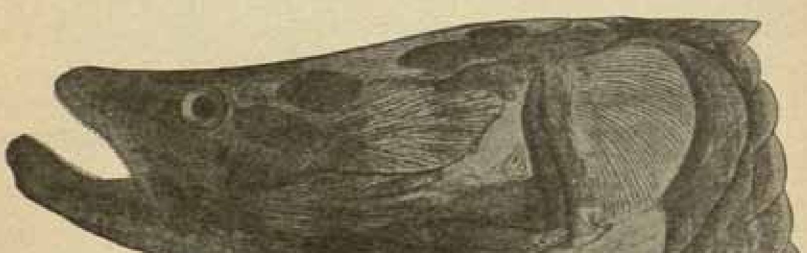


FIG. 70.—The Pirarucu (*Arapaima gigas*). Head enlarged. After Valenciennes.

dontidæ, and *Phractolæmidæ*," by W. G. Ridewood, in the Journal of the Linnean Society for 1895 (vol. 29, pp. 252–282, pl. 30–32).

The pirarucu is known by this name, according to Castelnau, among all the tribes which live along the Amazon. The name is said to be a Guarani word meaning red fish. Arapaima is also a native name.

The pirarucu is unquestionably the largest fresh-water fish of America, if not of the world, as has been claimed. It has, according

to Castelnau, a medium length of about 8 feet (2.50 meters), and one of that size is said to weigh about 330 pounds (150 kilograms). Occasionally, however, a much greater size is attained. Schomburgk "was assured by the inhabitants of the Rio Negro that they have caught some 15 feet long and of 12 to 13 arrobas (410 pounds) weight." These accounts are obviously discrepant. If a fish 8 feet long weighs 330 pounds, one 15 feet long, having the same proportions, would weigh nearly, if not quite, a ton. Undoubtedly Castelnau exaggerated the weight of a fish 8 feet long; Schomburgk more nearly approximated the truth by attributing to a fish "6 to 7 feet" long a weight of "not less than 150 pounds."

The natives claim that the *mother* takes charge of the eggs and watches over them with great care, protecting them especially *against the male*, who seeks to devour them. "The young," it is further as-

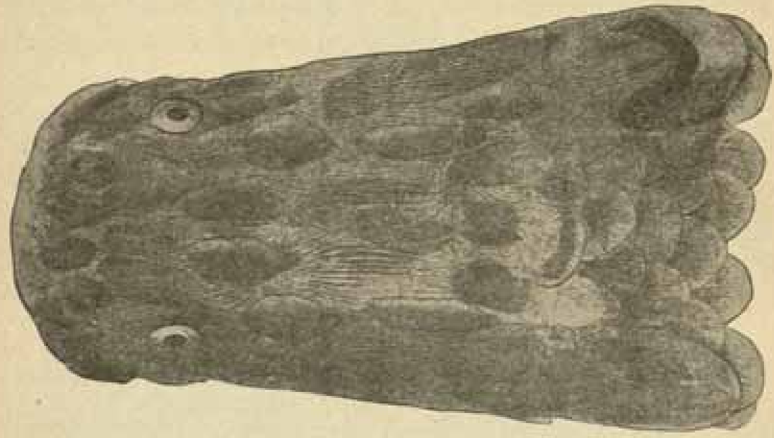


FIG. 71.—The Piraruců (*Arapaima gigas*). Head enlarged. After Valenciennes.

serted, "are protected by the *mother* for some time after they leave the eggs," and they "swim generally over her head."

Both Castelnau and Schomburgk record this belief of the natives, but it is probable they were misled by preconceived notions and knowledge of what birds do. It is likely (but not absolutely certain) that the male takes charge of the eggs, as in the case of most fishes.

The pirarucu was ascertained by Agassiz (1868) to be "found almost everywhere" in the Amazon Valley and to be "the most important fish of the river, that which, as food, corresponds to cattle for the population along the banks." Castelnau records (1855) that its flesh, supplemented by that of the manatee, serves to feed the numerous "nations" of that part of the world. Essentially the same conditions persist to the present time. "When fresh it is excellent, and the belly nearly all fat," and it is the belly that is held in greatest esteem. It is not alone as a fresh fish, however, that it is used.

Great numbers are salted and cured, and it is the object of a considerable commerce.

THE HETEROTIS.

The best account of the nesting habits of any Osteoglossoidean has been given by the late J. S. Budgett, who visited Africa in 1900 for the purpose of studying the life histories of some of that continent's remarkable fishes. Like the arapaima, *Heterotis* is so distinct from all other forms that it has been set aside as the type of an independent family. While it agrees with the arapaima and the Osteoglossids as to the characters already indicated, it has a rounded belly, the dorsal shorter than the anal, the ventrals submedian, the postorbitals continuous in an even curve with the suborbitals, the mouth small, and the branchiostegal rays in reduced number (seven or eight). The principal characters, however, are skeletal modifications, especially of the bones of the back of the skull, and, more than all, of the exoccipital bones, which furnish large accessory condyles for the first vertebra.

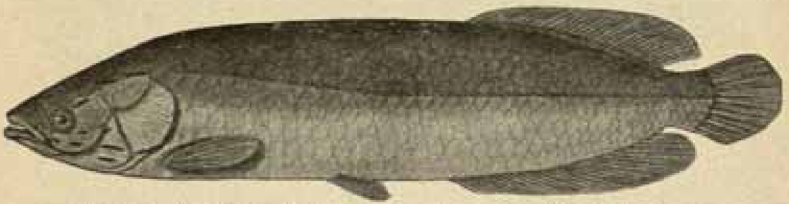


FIG. 72.—The Heterotis (*Heterotis niloticus*). After Valenciennes.

The only known *Heterotis*, *H. niloticus*, is a large fish, occasionally even attaining a length of 3 feet or more. A good idea of it may be obtained from the accompanying figure.

The heterotis makes a very large circular nest, and, indeed, in some of the swamps of west Africa which Budgett visited, one of the most striking features was "the presence of numbers of enormous nests," which looked like "miniature lagoons," and which proved to be those of *Heterotis niloticus*. The "nests measured four feet in diameter and were made in about two feet of water." The walls were "about eight inches thick at the top and compact, being made of the stems of the grasses removed by the fish from the center of the nest." The floor was "the swamp-bottom, and was made perfectly smooth and bare."

Budgett once had the good fortune to see a "fantang" (such is the native name of the heterotis) make a nest, and tells how it was done. "It was circling round and round the wall of its nest, every now and then throwing its tail upwards and outwards, tossing on to the top of the wall the débris from the inside of the nest. Thus it toiled on until the wall reached the surface of the water and was complete. When the nest was finished the water it contained was per-

fectly clean and clear, so that I could see with my water telescope the eggs nearly covering the bottom of the nest. When all the eggs are laid the fish leaves the nest by a hole at one side."

The nest appears to be used "for at most four or five days." The eggs, it was thought, were hatched in about two days. The larvæ had long external blood-red gill filaments.

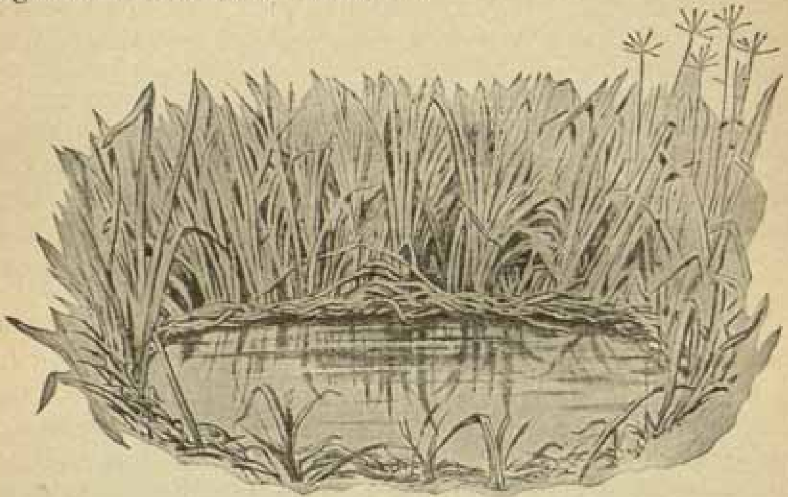


FIG. 73.—Nest of the *Heterotis*. After Budgett.

As soon as they are released they strike out from the bottom, and, the day after hatching, "may be seen continually passing up and down." The next day "they cease to pass up and down, and converging to a swarm about one foot in diameter, form a deep continuous circle remarkable for its regularity and persistence. The swarm occupies the exact center of the little lagoon. The young fry, which by now have lost the long external gill filaments, are seen to be steadily

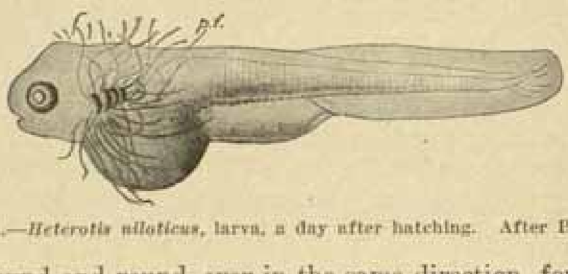


FIG. 74.—*Heterotis niloticus*, larva, a day after hatching. After Budget.

careering round and round, ever in the same direction, for at least a day. About the fourth day the swarm becomes less persistent and regular, the larvæ swimming first to one side of the nest and then to the other, until about the fifth day they leave the nest by the exit for a few trial trips, attended by the parent, and finally leave it altogether, swimming hither and thither in a dense swarm, from which the par-

ent is never far distant." Budgett kept many of the fry for several weeks, but "could not get them to feed and eventually they all died."

THE UMBRIDS, OR MUDFISHES.

The pairing and oviposition of Mudfishes or Umbrids has not been observed in America, though I had some for months under observation, but P. Carbonnier appears to have succeeded in mating them and observing the behavior of a parent fish to the eggs and young. The fact, however, has been universally overlooked owing to his misnaming of specimens. He called them "la Fondule (*Fundula cyprinodonta*, Cuv.)," but no such name appears in any of Cuvier's works and the fish in question was evidently not a *Fundulus*, and there is little, if any, doubt that it was the common Mudfish (*Umbra pygmæa*) occurring around New York. The reasons for this identification are given in Science for December 21, 1906. The article by Carbonnier is in the Buletin Mensuel de la Société d'Acclimatation for November, 1874 (pp. 665–674). It seems that the female fish there described watches over her eggs "with a tender solicitude" during the fortnight of "incubation." "Elle écarte et emporte avec soin tous les sédiments terreux qui pourraient être une cause d'alteration," etc. For full details the original article should be consulted. The identification here made should be confirmed by observations on living fishes. The habits of the species are of unexpected interest.

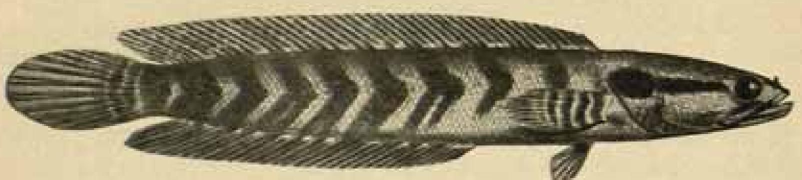


Fig. 75.—An Ophiocephalid, *Ophiocephalus africanus*. After Steindachner.

THE OPHIOCEPHALIDS, OR SNAKEHEADS.

The old Romans had a way of expressing incredulity by reference to nature, but they were not always happy in so doing. Horace took as the acme of improbability the existence of a black swan—*rara avis in terris;* yet all the swans of Australia are black. Seneca would "go a-fishing in the sea," and contrasted with such a natural course another: "There are many things in this place will come into thy minde, which a man may term after a merry sort, both incredulous and fabulous, that a man should go and fish with his pickaxe and not with nets and hookes."

But with pickax and spade may the Ophiocephaloid fishes be sought in India. The bed of a pond or even a river that appears to

be barren on the surface may harbor a few inches below quite a harvest in the shape of fishes which have found their way there for refuge from the drought. It is this group of Ophiocephalids, too, which furnishes some interesting examples of paternal care.

The Ophiocephalids are elongated fishes with a flattish, declivous head, scales of moderate size on the body and larger ones on the head in oblique rows, a long dorsal and a long but shorter anal (both spineless), and ventral fins behind or under the bases of the pectoral with six soft rays, the outermost being undivided, but articulated distally. These characters are supplemented by a peculiar modification of the branchial apparatus adaptive to aerial respiration, as well as by many other anatomical characters. The labyrinthiform apparatus is also useful under certain other disturbing conditions, according to Day. "When pollution or poisonous substances find access to rivers or mud is carried down in such quantities as to choke the gills of most forms, these Ophiocephalidæ are almost unaffected, for breathing atmospheric air direct, the presence or absence of fluviatile contamination is not of such material consequence to their existence. They are able to live until the poison has passed downstream and the waters are again purified." The differences from all other fishes, indeed, are so great that there is not universal agreement as to the affinities of the family.

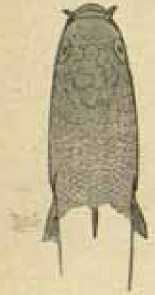


FIG. 76.—*Ophiocephalus.*

The Ophiocephalids are about 30 in number and found in almost all the tropical and even subtropical regions of the Old World, 3 occurring in Africa, but all the others in Southern and eastern Asia and the islands to the southward. In the Philippine Islands are found at least 5 species.

There is no general English name that can take the place of Ophiocephalids. Snakeheads is a book name that interprets the Latin title, but is rarely used. The word in most popular use is murrul, variously spelled, which is the common vernacular Indian term for species of the family.

When a prolonged drought dries up the ponds or bodies of water in which they have flourished the snakeheads do not necessarily succumb to the consequences, but are provided with means to contend against the adverse conditions. Some burrow into the drying bottom, sometimes to the depth of 3 or 4 feet even, into a moister horizon, and in such places may survive till later rains release them from their entombment and restore the waters to their former beds. The fishes retain moisture enough to keep their gills from dessication and are able to breathe the little air needed direct or even to suspend respiration. Others wander from the receding pond to seek more favorable quarters. Such emigrations are mostly engaged in during night time

and when the ground and air are moist they can travel considerable distances. This capacity is frequently exercised "in the beginning of the rainy season," when they may be "often seen travelling among wet grass;" it is also made use of in the opposite season of incipient drought. It is claimed by some that such emigrations are not entirely pointless, and that instinct guides them to water, but such claims have not been confirmed—at least not fully confirmed.

Peripatetic showmen and jugglers avail themselves of this, for a fish, remarkable aptitude for terrestrial progression, both in India and China. They carry the fishes about, and when a fitting audience can be obtained take the fishes from their receptacle and place them on the ground, when they proceed to "walk" or "crawl about," greatly to the wonder and amusement of the children. "Owing to the breadth of their bodies they are able to progress in a serpentine manner, chiefly by means of their pectoral and caudal fins, first one of the former being advanced and then its fellow." The progression is really of the nature of crawling.

The Ophiocephalids are especially piscivorous, but their voracity

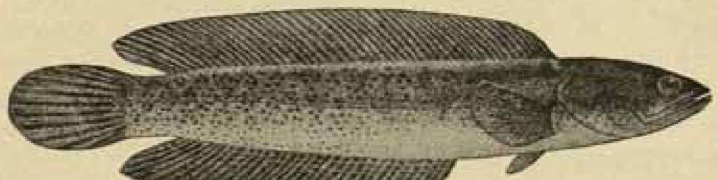


FIG. 77.—*Ophiocephalus barca.* After Day.

is by no means limited to fishes; indeed they "appear to consider a frog, mouse, or rat as luscious a morsel as a fellow fish. A frog, in fact, proves to be as captivating a bait for some of them at least as it is to a pike. "Near Ganjam," India, a native official told Day "how he had ventured out one night to see how murrul"—the walking fishes or ophiocephals—"were captured. The fisherman was provided with a long flexible bamboo as a rod, and as a bait used a live frog. Hardly had the frog splashed into the water when a moderately sized murrul seized and swallowed it. Desirous of observing what would occur next, the fish was left on the hook as a bait for something else. Before long a large water snake was seen swimming toward it, and soon had the fish inclosed in its capacious jaws, and in this fashion all three were pulled together out of the water." It would from this seem that they are active and feed by night as they also do by day.

Naturally when the species are so numerous, there is considerable diversity in habitat and habits. "Some of them reside in ponds,

others prefer rivers, where they take up their residence in deserted holes which they find in the banks. The pond species delight in lying at the grassy margins, where the water is not deep enough to cover them; and here they are able to respire atmospheric air direct." So teaches Day (1883). "Some of the ophiocephali prefer dirty to clean water, perhaps for purposes of concealment. When they have stirred up all the sediment and exuded a quantity of mucus they appear to be delighted, their colors become more vivid, and they ascend to their favorite resort, lying amongst the vegetation just beneath the surface of the water. As soon as clean water is given them they become excited, as if they imagined the time had arrived when they should change their abode."

But such places and postures are at times exchanged for others. They may be "frequently seen floating on the surface of the water as if asleep." Such individuals "may be approached very closely." In some places guns are used and the fish are shot, but "the game usually sinks when killed and has to be dived for or otherwise obtained."

The differences either in size or coloration between the sexes are inconsiderable. Monogamy and parental solicitude are accredited to them. They mostly, it is said, breed twice a year. The eggs are quite large and vary in number in accordance with the size of the female; in one Day estimated there were about 4,700 eggs. Oviposition is provided for in a rude receptacle which is prepared by the male. "The *O. striatus* of Mysore is said to construct a nest with its tail among the vegetation near the edges of the tanks, whilst it bites off the ends of the weeds which grow in the water." Over this the parent keeps guard, and his care is exercised not only for the eggs, but for the young until they are developed and strong enough to care for themselves. "Then they are driven away to seek their own subsistence," and those who are "too obstinate to leave," it is believed, are "eaten by their progenitors."

The Ophiocephalids are highly esteemed for table use, "those which inhabit rivers being better flavored than the others which live in sluggish or stagnant water." They form in many places a very important part of the fish supply of the community. They are in prime condition, or at least chiefly demanded, in a perfectly fresh state. To supply such a demand, "in China they are often carried alive in tubs or pails of water, and slices are cut for sale as wanted, the fish selling dear whilst it retains life, while what remains after death is considered as of little value." The entrails are removed before taking the fish around but the muscles remain long responsive to irritation, and "when the irritability of the flesh is so much exhausted that it no longer quivers under the knife, its value is greatly depreciated." This practice, Richardson thinks, "however much it

may shock the feelings when described, is not worse than the crimping of cod on the London fish stalls." It is almost superfluous to add, after this account, that "they are very tenacious of life."

By the natives the adult fishes, as well as their eggs, are "greatly sought after as food."

To insure a continuous supply they are kept to a considerable extent in ponds or tanks and even in aquaria, but their wandering proclivity and climbing capability entail precautions against their emergence. "They are exceedingly difficult to retain in aquaria unless the tops are covered over, as otherwise they manage to escape and proceed on their travels."

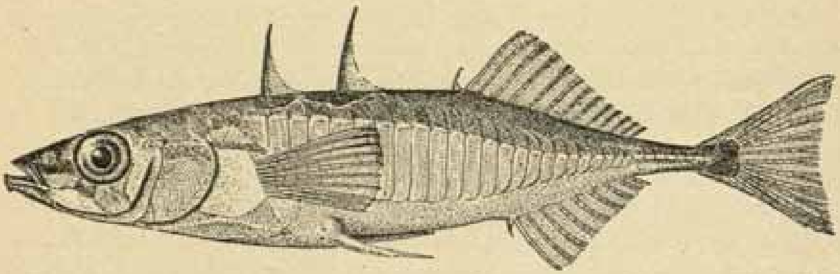


FIG. 78.—Common Three-spined Stickleback (*Gasterosteus aculeatus*). Enlarged.

STICKLEBACKS.

The *Gasterosteids*, or sticklebacks, are more or less compressed fusiform or moderately elongated fishes with a partly or wholly naked skin, but generally with a row of high plates along part of the tail at

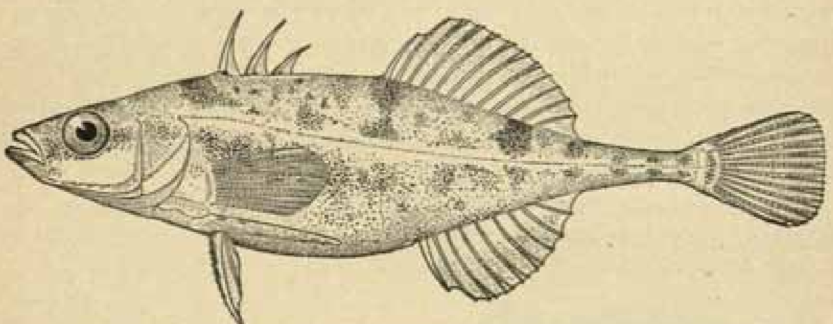


FIG. 79.—Four-spined Stickleback (*Apeltes quadracus*). Enlarged.

least; the head is conic and pointed in front or prolonged into a short tube, and the jaws armed with narrow bands of teeth; the ventrals are a short or moderate distance behind the bases of the pectorals, and each has a stout spine and one or two reduced rays; the dorsal furniture consists of two to fifteen free dorsal spines and behind them a dorsal fin with branched rays, and the anal is like the second dorsal.

There is, in other respects than those mentioned, much more diversity than in most other families, although the species are not very numerous; their exact number, however, is uncertain. The species appear to be subject to unusual variation, and characters which would be of specific importance in most groups in this appear to be merely individual deviations. A result of this was that before the extent of this variability was appreciated many specific names were based on what later proved to be unstable characters. For instance, an able French naturalist, Prof. Émile Blanchard, thought that in France alone there were seven species with three dorsal spines and four species with many. He was even strongly inclined to think that other species (plusieurs espèces) remained to be discovered.

Naturalists of the present day reduce the seven to one (*Gasterosteus aculeatus*) and the four to another (*Pygosteus* or *Pungitius pungitius*). It is not impossible, however (but not probable) that it may be found that from the extreme of undue multiplication or "splitting" of species there has been a revulsion to an opposite extreme of excessive "lumping." Much more certain are the genera: these are readily separated and stand out boldly in nature. Three of these occur in the Old World—*Gasterosteus*, *Pungitius* (*Pygosteus*), and *Spinachia*. *Gasterosteus* and *Pungitius* are equally well represented in North America, and the absence of *Spinachia* is more than balanced by the existence here of two unknown to Europe—*Eucalia* and *Apeltes*. Of all these the nesting habits are more or less known.

All the sticklebacks take care of their eggs and the newly born young, but it is the male, and not the female, that exercises parental care; he it is that builds a nest that would do credit to a bird and drives or entices the full female to enter into it and deposit her ripe burden. When a sufficient supply of eggs has been secured, the male closes the nest and remains in charge till the young have reached a size which he considers to be sufficient to enable them to wander away and seek their own living.

The sticklebacks have been divided among three groups or subfamilies.

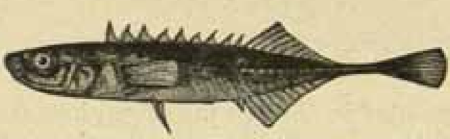


FIG. 80.—Ten-spined Stickleback (*Pungitius pungitius*). After Storer.

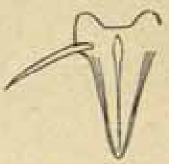


FIG. 81.—*Gasterosteus*. Pelvis below.

The best-known forms, or *Gasterosteines*, have the pelvic bones forming an arrow-like or V-shaped plate below, the point extending backward.

The three-spined sticklebacks (*Gasterosteus*), ten or many spined sticklebacks (*Pygosteus*), and those with four or five dorsal spines reclinable directly backward (*Eucalia*) belong to it.

One peculiar American type, the *Apeltines*, have the pelvic bones

FIG. 82.—Four-spined Stickleback (*Apeltes quadracus*). After Storer.

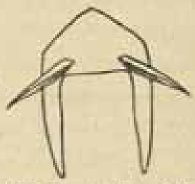


FIG. 83.—*Apeltes*. Pelvis below.

obtuse behind, lateral bars, and between them an unarmed belly.

A third type, the *Spinachiines*, have the pelvic bones loosely connected in front only and the ventral fins inserted farther back than in the others; the body is also more elongated, the snout extends forward in a somewhat tubiform manner, and the dorsal spines are more numerous.

The most generally distributed and characteristic of the genera and that to which the largest species except *Spinachia* belong is *Gasterosteus*, or the three-spined sticklebacks. The body is comparatively high and has a fusiform contour, there are two large free spines on the back and a smaller one in front of the fin, and the ventral spines are considerably behind the roots of the pectorals and under the interspace between the first and second dorsal spines. The most common species—common to Europe and America—is the *Gasterosteus aculeatus*.

Almost any permanent body of water, however small, may harbor some. In the words of Smitt, "It is often met with in collections of water so small and so isolated that it appears difficult, if not impossible, to explain the manner in which it has been conveyed thither, or the sources from which it derives its support. It is fondest of calm water, and in summer frequents shallow spots close inshore, especially where the sunshine has full play. Here it leads a merry life, and one may often see it leap several centimeters out of the water, while at other times it keeps still at the same spot, as though there were nothing in the world to disturb it. But in a moment it is all life and spirit and darts off with the speed of an arrow. In stormy weather it is tossed on the waves and has thus been cast even into a boat. Toward autumn it retires to deeper spots on the shores of channels, estuaries, or larger inlets. In late autumn and at the beginning of winter, however, it roams about in large companies." It then prepares for winter quarters; "when the cold is most severe, it probably lies packed in large shoals at the bottom."

It is an eminently gregarious fish and its schools are sometimes very large, but they are not equally large every year. Some years they may be comparatively few and in others exceptionally abundant. In many of the northern streams, W. C. Kendall (1902) testifies, they occur "in such vast numbers as to be used for fertilizer" and "as food for cows and dogs, and even for men. They were taken in large numbers in the brush weirs used for catching small herring on the coast of Maine, and in the same locality often become a nuisance by clogging the nets of the swelt seiners."

One instance illustrative of their occasional extraordinary numbers has been often quoted, but is as apt now as ever. In 1776 Pennant claimed that "once in seven or eight years amazing shoals appear in the Welland" Canal "and come up the river in the form of a vast column. They are supposed to be the multitudes which have been washed out of the fens by the floods of several years and collected in some deep hole till, overcharged with numbers, they are periodically obliged to attempt a change of place. The quantity is so great that they are used to manure the land, and trials have been made to get oil from them. A notion may be had of this vast shoal by saying that a man employed by the farmer to take them has got for a considerable time 4 shillings a day by selling them at a half penny a bushel."

This account has been quoted as unparalleled, but several notices in American publications come nearly, if not fully, up to it. In the Canadian Annual Report on Fisheries for 1863 (p. 61) it is reported that the three-spined stickleback or picassou was "caught in great quantities in the small rivers, brooks, and *barachois* of Magdalen Islands, where it is used as food for cattle and as manure," and that "400 barrels were caught" in 1862 "in the *barachois* of Basque Harbor" alone. Four hundred barrels were also caught in 1866 and sold as manure at 25 cents per barrel, but in 1867 the catch was smaller (150 barrels) and prices advanced to "1s. 3d. per barrel."[a]

Sticklebacks are very voracious and almost omnivorous, their rapacity being only limited by their size. The eggs and fry of other fishes suffer severely from their attacks, but with apparently equal relish they take worms, the minute entomostracan crustaceans, the larvæ and imagines of insects, and small mollusks. But they do not refrain from attacking fishes much larger than themselves. "Mr. Mable, at the Weston-super-Mare Museum, had some three-spined sticklebacks in an aquarium, and some roach, *Leuciscus rutilus*, were added. With this invasion the prior inhabitants were dissatisfied, but not frightened, as they forthwith attacked the newcomers, biting at them anywhere until they became thoroughly cowed. These little tyrants were observed to place themselves in front of the roach,

[a] Fisheries Appendices for 1866 (p. 42) and 1867 (p. 34).

steady themselves by their tails, and then suddenly dart straight at the lips of their intended prey, from which they bit pieces out. These attacks were continued until all the roach had been killed, when they were eaten by their conquerors."

Another instance of insatiable voracity has been recorded by Baker. One devoured in five hours 74 young dace, which were a quarter of an inch long and of the thickness of horsehair. Two days afterwards it swallowed 62, and would probably have eaten as many every day could they have been procured for it.

Such are the main facts respecting the general habits of the sticklebacks, but their chief interest to us are the extraordinary nests which they make and the still more extraordinary provision with which nature has endowed the males to make those nests.

When spring and warm weather are well advanced males and females become impressed with the instinct to reproduce their kind, and the whole organization is modified accordingly. The female's abdomen becomes distended with eggs, and the male, who had been silvery white during winter, assumes a brilliant livery, develops from the urinary bladder and kidneys the material for a peculiar thread-like substance, and prepares to make a nest for the reception of eggs of such females as he may be able to influence.

The peculiar secretion from the kidneys deserves some notice here, for it is unique and only known in the sticklebacks. It was first fully described by Karl Mobius (1885) and soon afterwards by John Ryder (1882) and E. E. Prince (1885). The last has not only given an excellent account of the peculiar structure, but some apt illustrations, and these are reproduced herewith. (Plate I.)

EXPLANATION OF PLATE I.

After E. E. Prince.

Fig. 1. Transverse section (male *Gasterosteus sp.*) of renal mass, urinary bladder, etc., *in situ*, × 150 diameter. A, kidneys (coalesced portion): *a*, *a*, right and left ureters passing longitudinally along outer ventral borders of kidneys; *b*, urinary tubules, nuclei of epithelial cells indicated. B, urinary bladder, behind the cervix: *a*, epithelial; *b*, fibrous layer; *c*, *c*, right and left ureters (on opposite sides of bladder); *d*, contained thread-like secretion from kidneys; C, intestine; D, D', testes.

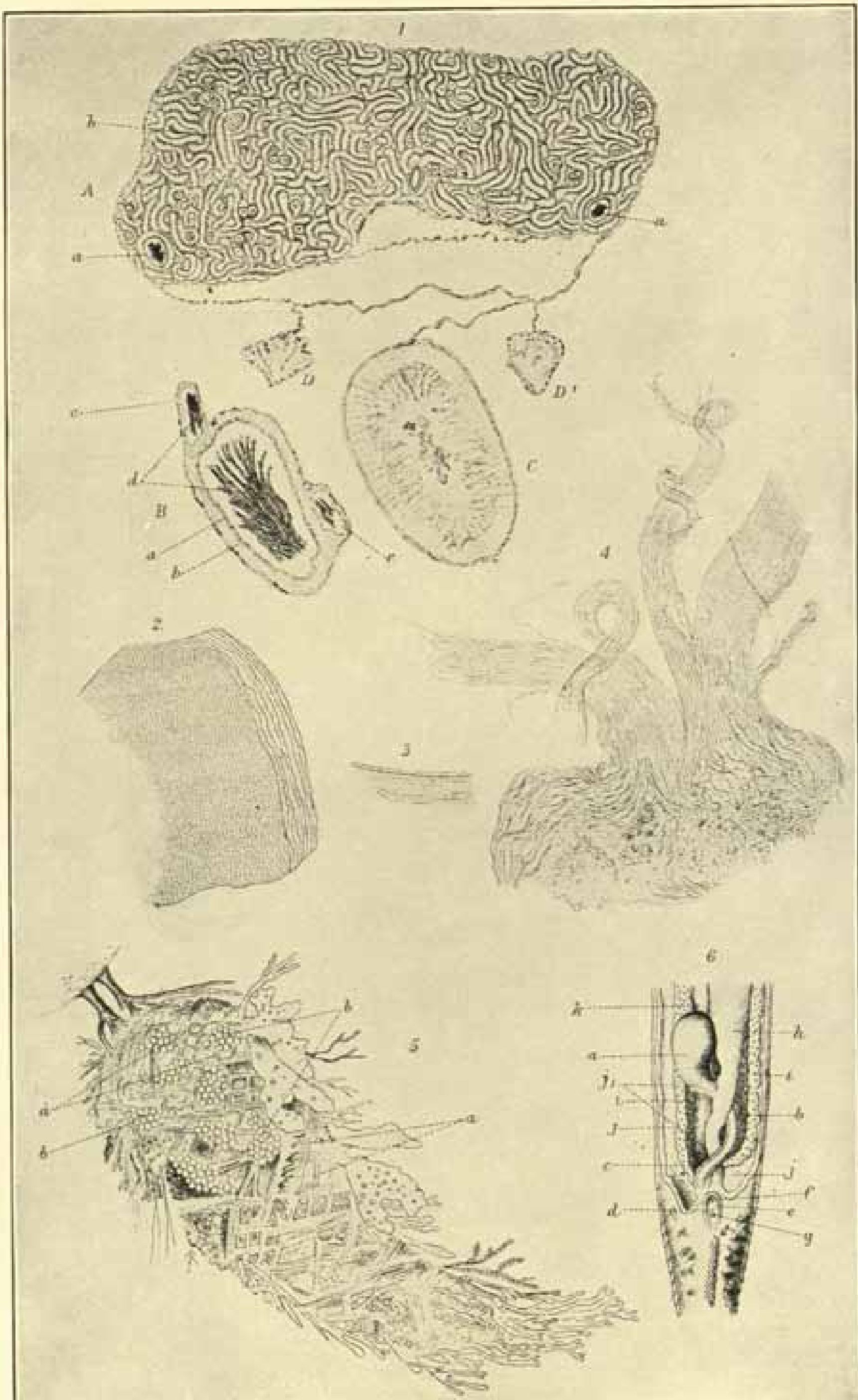
Fig. 2. Fragment of hyaline capsule of ovum, showing the rows of pits and lamellæ, × 300.

Fig. 3. Fragment of hyaline capsule of ovum, in transverse section, showing numerous lamellæ, × 350.

Fig. 4. Portion of mucous secretion, showing funicular structure, × 350.

Fig. 5. Sketch of nest (diagrammatic), one-third natural size, the pockets containing ova exposed. *a*, *a*, transeversely arranged intersecting threads; *b*, *b*, masses of ova contained in the interspaces of nest.

Fig. 6. Dissection of male, showing viscera of posterior portion of abdominal cavity, about natural size. *a*, enlarged urinary bladder; *b*, left flexure of urinary bladder (cervix); *c*, right flexure of urinary bladder (near posterior termination); *d*, genital pore; *e*, cloacal depression; *f*, anus; *g*, urinary aperture; *h*, alimentary canal; *i*, *i*, right and left testes; *j*, *j*, kidneys; *j'*, ureters; *k*, swim bladder.



SECRETION FROM KIDNEYS IN GASTEROSTEUS.

On examining the male at the breeding season, the kidneys are seen to be considerably swollen, the enlargement being especially noticeable posteriorly (fig. 1 A). Sections of the kidneys reveal an altered condition of the sinuous tubules (fig. 1 A, *b*), the conical epithelial cells of which are swollen at their free ends and indefinite in outline. The nucleus of each cell is slightly displaced and occupies a more terminal position than in the normal condition. These epithelial cells are active in secreting the material used in constructing the nest. They perform the function, indeed, of cell glands, and their secretion is carried by the uriniferous tubes to the outer ventral border of each kidney, where a large duct passes longitudinally. In cross section the ureters (pl. I, fig. 1 A, *a*, *a*) are oval, and their capacity is very great at this time, the walls being of dense fibrous tissue lined with pavement epithelium. Both ureters emerge from the renal mass near the posterior end, and descending in a forward direction become applied to the wall of the so-called urinary bladder, which at this point is somewhat attenuated, and passing anteriorly they open obliquely from without inward into the bladder. This structure, it is unnecessary to say, is not morphologically connected with the urinary receptacle of higher vertebrates, the lengthened course of the ureters, of which it is simply a dilated common portion, being due to its extraordinary development in the male stickleback. In a fish 5¼ inches in length it is about an inch long, and at its widest part one-fifth inch in diameter. Situated on the right side of the abdominal cavity, immediately below the swim bladder in the posthepatic region, it has the form of a capacious pyriform sac, ending blindly anteriorly, and diminishing in circumference as it passes backward (pl. I, fig. F, *a*). Before terminating posteriorly it describes a double curve, crossing over the intestine from the right to the left side (pl. I, fig. 6, *b*), and after a short parallel course passing on the ventral side of the intestine to the right side again (pl. I, fig. 6, *c*), debouching behind the genital pore (pl. I, fig. 6, *d*) into a urinogenital sinus, forming the posterior portion of a cloacal depression (pl. I, fig. 6, *e*), into which also the anus opens (pl. I, fig. 6, *f*). The wall of the bladder consists of two layers, an internal epithelium (pl. I, fig. 1 B, *a*), which is readily detached, and a dense external connective layer (pl. I, fig. 1 B, *b*), which thins out as the blader enlarges anteriorly. Traces of an intermediate muscular layer appear posteriorly where the walls are extraordinarily thickened. The descending ureters (pl. I, fig. 1 B, *c c*) approach opposite sides of the bladder, that on the left proceeding obliquely below the common duct of the *vasa deferentia*, and passing forward and merging in the walls of the bladder on the left side.

This union is shown in the same transverse section which shows the union of the *vas deferens* of the left testis with that of the right. The course of the right ureter is shorter and more direct, as the bladder lies on that side of the abdominal cavity at this point. It coalesces with the right wall of the bladder precisely opposite the left ureter. As the bladder descends to cross the intestine inferiorly it twists, so that the left ureter is brought to the central side of the cervix of the bladder. Both return to the lateral position as the bladder crosses the intestine. The intestine now curves to the right, and the relations of the ureters become reversed, the right being below and the left rising to the dorsal side of the bladder. They increase rapidly in capacity, showing in cross section an extremely elliptical cavity, and as the bladder enlarges they pass obliquely into its chamber, their walls being continuous with the external layer of the bladder. Along this tortuous course the viscid secretion of the renal tubules reaches the bladder, where it is stored up. When first formed the secretion is simply a plastic jelly; but a fibrillar structure appears to rapidly develop in it.

Indeed this appearance is assumed while the secretion is contained in the ureters. The epithelial cells of the urinary canals exert so actively the secreting function that the bladder becomes much distended by the accumulating mucus, and at length it flows slowly to the urinary aperture, where it emerges as a tenacious elastic thread which readily adheres to any external object on contact. It can hardly be doubted that this secretion can be extruded at pleasure, the walls of the bladder, assisted by the abdominal parietes, being sufficient to effect this; but it is produced so abundantly that it also often appears to ooze out involuntarily. Male fishes may often be seen with a glistening, pendulous, conoid mass hanging from the urinary aperture, and increasing in size until it becomes detached. Such flask-shaped masses of mucus occur frequently in tanks where these fishes are confined and no opportunity is afforded for nest building. When, however, an appropriate mass of seaweeds has been selected by the male, the fish has merely to approach closely, so that the protruding mucus may adhere to a projecting frond, and by passing and repassing round the mass the weaving operation is accomplished. Occasionally a rapid ejaculatory movement is observed, and it is interesting to note that the threads are not carelessly superposed, except when necessary for increasing the density of the nest, but are crossed at an angle by the varying movements of the fish, so that rhomboidal spaces are inclosed and a regular reticulum is thus produced (pl. I, fig. 5).

Often the tightly drawn thread snaps asunder, though its tenacity is extreme. The fibers then curl up and form a terminal pellet, many of which occur on the surface of the nest. As before remarked, the mucus is not merely a semisolid plasm, but assumes a funicular character while in the ureters. If one of the chords binding a nest together be examined, it will be found to consist of several strands, the cord itself measuring from 0.0046 to 0.0051 inch in diameter, and the constituent threads from 0.0008 to 0.00092 inch. These smaller threads again consist of fine homogeneous filaments, which adhere in parallel order. The parallel arrangement of the ultimate fibrils is very striking and quite characteristic (pl. I, fig. 4).

The stickleback is by no means a monogamist, as was once believed, but endeavors to induce a number of females to deposit eggs in the nest he has built. His bellicose tendency, always considerable, is now greatly intensified, for he is exceedingly jealous and takes offense at every appearance of intrusion or even approach to the domain which he has appropriated for his own. The males, too, are fewer than the females, and a consequence is that there are many furious battles. Smitt tells what may happen:

Two rivals rush with the speed of arrows against each other, deal a powerful side-stroke with their sharp ventral spines, and hasten with undiminished speed each back to his own domain. After a few onsets the superiority of the stronger combatant is demonstrated, his territory is extended, and he signalizes his triumph by a splendor of colours, while the vanquished lays aside his brilliant dress as though overcome by shame. While the males disport themselves in these chivalrous tournaments, or rather, fight for their nests, the females swim about in long troops of greater or less strength outside the battle ground, and now and then a male selects his temporary mate from the company. The female that heads the troop swims forward with rapid darts, followed by the others, suddenly stops and assumes a vertical position, with head turned toward the bottom. The others assemble round her and range themselves in

the same manner, as densely packed as possible. When she has thus collected the troop round her, she suddenly deals a blow that scatters the whole crowd in an instant. This sport is often repeated, but the rapidity with which they disperse renders it impossible to observe whether it is always the same female that takes the lead or whether they change places. These operations are continued as long as the sun is high in the heavens, for four to six days, according to the weather. It seems more than probable that during these evolutions the females lose some roe, which adheres to water plants, and that this is fertilized by the males that, perhaps only for the time being, have not built any nest for the eggs. Benecke has also ascertained that under certain circumstances—as, for example, when he finds a suitable crevice or secluded nook among the water plants—the male does not build any nest, properly so called. Thus we have to deal with two methods of spawning in which the eggs are developed where they fall, among the water plants, and the more connubial method in which the eggs are developed in a nest made by the male. But in any case the nest building is one of the most interesting parts of the life of the three-spined stickleback, and one which many have been in a position to observe.

FIG. 84.—Three-spined Stickleback male laying the foundation of his nest. After Coste.

One of the fullest and best considered, as well as earliest of the accounts of the habits of the stickleback was published in 1854 by Albany Hancock, in "Observations on the nidification of *Gasterosteus aculeatus* and *Gasterosteus spinachia*," in the Transactions of the Tyneside Naturalists' Field Club for 1851–1854 (Vol. II, pp. 312–317). He provided an aquarium in May and—

Into this new home were put four or five sticklebacks, [and] they at once made themselves perfectly at ease. One, without the least hesitation, took possession of a certain spot, which it guarded with the greatest pertinacity, attacking vigorously any of its companions that might happen to approach the chosen locality. The beetle, too, which sometimes came slowly paddling by, was pounced upon and unceremoniously tumbled over; but secure within his scaly armor, as the knights of old, he little heeded the onslaught of his naked assailant, so overpowering all opposition he scrambled onward in his undeviating path.

This fish was rather small, had the throat of a bright red colour and the eyes of a brilliant bluish-green. At first, all the others were pale; but in the course of a few days one of them gradually assumed the rich hues of that just described, and soon afterwards it also became attached to a spot, taking up its abode in one of the corners of the trough. On examining attentively the two

selected localities, a nest was found in each, composed of a collection of delicate vegetable fibers, resting on the bottom of the trough and matted into an irregularly circular mass, somewhat depressed, and upward of an inch in diameter, the top being covered over with the same materials and having in the center a large hole. The fishes scarcely ever strayed from their nests, but were constantly on guard, defending or repairing them. They were perpetually prying into the hole at the top and thrusting their heads right into it. On one occasion, one of them entered by this hole, and slowly forced itself through the side of the nest. As it gradually moved onwards its body had a peculiar, lateral vibratile motion. They would frequently seize hold of the nest and give it a violent tug, shaking and tearing loose the vegetable matter of which it was composed; at other times they would carry to it in their mouths fine conferva-stems and press them with considerable force into the wall of the nest or thrust them into the hole, which by this means was partially concealed. Occasionally each was observed hovering over its nest with the head close to the orifice, the body being inclined upwards at an angle of about 45°, fanning it with the pectoral fins, aided by a lateral motion of the tail. This curious manœuvre was apparently for the purpose, so to speak, of ventilating the spawn, which could be distinctly seen through the orifice at the top; at least, by this means, a current of water was made to set in towards the nest, as was rendered perfectly evident by the agitation of particles of matter attached to it. This fanning or ventilating process was repeated at short intervals during the day and every day until the spawn was hatched, to accomplish which took between two and three weeks.

FIG. 85.—Three-spined Stickleback male assisting female in spawning. After Coste.

Only one nest contained spawn; the other was torn in pieces and the materials scattered about, in the hope that we might have the pleasure of seeing it reconstructed. In this we were not disappointed; the fish immediately began to form a new nest in exactly the same spot, and by the following day it was more than half completed. It took a mouthful at a time and was at some pains in adjusting each load, spreading the materials out and pressing them down with its mouth; it then drew its body slowly over the whole, vibrating

all the time in the same peculiar manner as when it forced its way through the nest, as before stated.

On the 13th of June, the hole at the top of the fruitful nest was found to be much enlarged, so that the entire mass of spawn was exposed to view, and on looking attentively a few of the newly hatched fry were seen flitting around the wall of the nest. The assiduity of the parent was now greatly increased; it never left the spot; by night it rested either on the nest or by its side, and during the day nothing was allowed to approach. It fiercely seized a quill that was passed down toward the object of its solicitude with such vigour that the shock of attack was distinctly felt by the hand. Combats with its companions became more frequent, but its ire was chiefly directed toward its neighbour, which, like itself, was engaged in parental duties. This having also a nest to defend, never shrank from the conflict, and the encounters were therefore fierce and prolonged, but nevertheless conducted with all due caution and apparently with much science, as the gentlemen of the ring would express it. The sparring was very wary, and generally lasted a few seconds before the combatants closed. The attack was usually commenced by one quietly creeping up, watching its opportunity; on this, the other, acting on the defensive, would turn its broad side to the enemy, and raising the ventral spine wait to receive the onslaught; the assailant, intimidated by this formidable demonstration, would then slowly retreat, and in its turn had in the same manner to defend itself. After thus advancing and retreating for a few times, one, taking advantage of an unguarded moment, would rush in upon its opponent and butt at it with its head, apparently endeavoring to bite; the other, rallying, returned the compliment, and after dashing at each other in this way two or three times with extraordinary rapidity the round would terminate and each fish retreat to its nest, to recommence its more immediate nidimental duties.

The fry were at first so minute and transparent that they could scarcely be discerned as they lay partially concealed amid the meshes of the nest; every now and then a slight fluttering motion betrayed their position, otherwise it was almost impossible to distinguish them. As I closely watched their motions at this time, one of the newly hatched fishlings, with intrepidity beyond its experience, ventured to pass the limits of its cradle; in an instant the watchful parent was there, and with gaping mouth seized the little wanderer, which immediately disappeared, the jaws having closed upon it. Seeing this I at once gave up the fry as lost, deeming that here was an instance of instinct at fault and that all the affectionate solicitude of the parent was to end in devouring its offspring. In this I was mistaken; the old fish, quietly returning, dropped the straggler into its nest lively and uninjured. During the whole of this day none of the fry were permitted to ramble beyond the precincts of their fold; when any attempted to do so—and many did attempt—they were invariably brought back in the mouth of the parent; none escaped its vigilant eye, and it was amusing to see with what a hurried, fluttering motion the little things dropped almost perpendicularly down into the nest, so soon as they were released from the jaws of the parent.

It was three days before all the eggs were hatched, and the attention of the parent during all this time was unremitting. On the second day I marked its manœuvres for five minutes and found that in this short period it ventilated the nest eight times, warded off an attack of the neighbouring fish, and brought back to the nest a straggler or two. During this day the spawn was frequently examined by the parent, who would occasionally seize hold of it and give it a good shake, apparently for the purpose of throwing off adherent matter, that the water might freely circulate about the eggs. The parent would then dive head

foremost into the nest and bring out a mouthful of mud, which it would carry to some distance and discharge with a puff.

The third day was passed in much the same manner, only as the eggs were now all hatched the nest was less frequently fanned or ventilated, and the fry, about 40 in number, were allowed greater liberty, the strongest being permitted to recreate themselves among the confervæ that grew on a stone about 2 inches from the nest. On the fourth day the fanning had ceased altogether, and the rambles of the young were less restricted. They were not yet, however, permitted to pass beyond certain limits. When any transgressed these bounds they were immediately seized as heretofore and carried back to the nest, into which they were always very glad to escape from the clutches of their ardent parent. Notwithstanding all her vigilance one contrived, on the fifth day, to escape her eye, and in passing the fateful boundary was immediately devoured by the other fish, which now seemed always on the watch, neglecting its own barren nest, being intent only on appropriating to itself the nestlings of its fruitful neighbour. In this act of cannibalism we see the reason for the parent's anxious care and its jealousness of its kind; and it is evident from Mr. Crookenden's account, previously quoted, that they greedily devour each others spawn. The young fry, however, have other enemies as well as their own species. One day a favorite *Hydra* (*H. fusca*) was observed to be distended in a most extraordinary manner. On examination it was found to have swallowed the head and shoulders of one of the young fish many times larger than itself, and the caudal extremity, which was too much for it and which was projecting out of its mouth, had been seized upon by another *Hydra*. Thus it would appear that these low organized but powerful and voracious animals occasionally regale themselves on the flesh of the *Vertebrata*. This happened when the fry were three or four weeks old.

All the old fish, with the exception of that with the young, were, in consequence of their cannibal propensities, turned out of the trough; and danger being thus removed, the fry were no longer restricted in their rambles, but enjoyed the whole range of their crystal abode. Henceforth the parent's assiduity gradually relaxed, though for days afterwards it was its custom to take the young occasionally into its mouth, and after carrying them a little distance to let them drop out again. I took one of the fry out one day for examination with the microscope. On returning it to the trough it was in so sickly a state as to be scarcely able to leave the vessel, which was held in the hand. The old fish, perceiving the helpless condition of its offspring, came up to the surface of the water, and seizing hold of the exhausted young one carried it off almost from amid my fingers, and taking it to some distance puffed it out of its mouth into a tuft of confervæ. This courageous act of our little fish would seem, in some measure, to give credence to the assertion, so frequently made, that some of the sharks protect their young by receiving them into the mouth on the approach of danger.

The stickleback's life is probably a short one. For a long time it was supposed to be biennial, but one individual at least was kept for "nearly double that time."

Such are the habits of the three-spined stickleback. Those of the other species of the family are similar in most respects, but each group of species seems to have its own special way of making its nest, as Coste long ago (1848) showed. According to the French naturalist, while the three-spined sticklebacks (Épinoches) invariably (invari-

ablement) construct their nests on the ground and open to view; the many-spined sticklebacks (Épinochettes) on the contrary always attach theirs to vegetation, such as the leaves of aquatic plants. Coste considered this difference to be of importance enough to indicate generic distinction for the fishes making the nests, and consequently

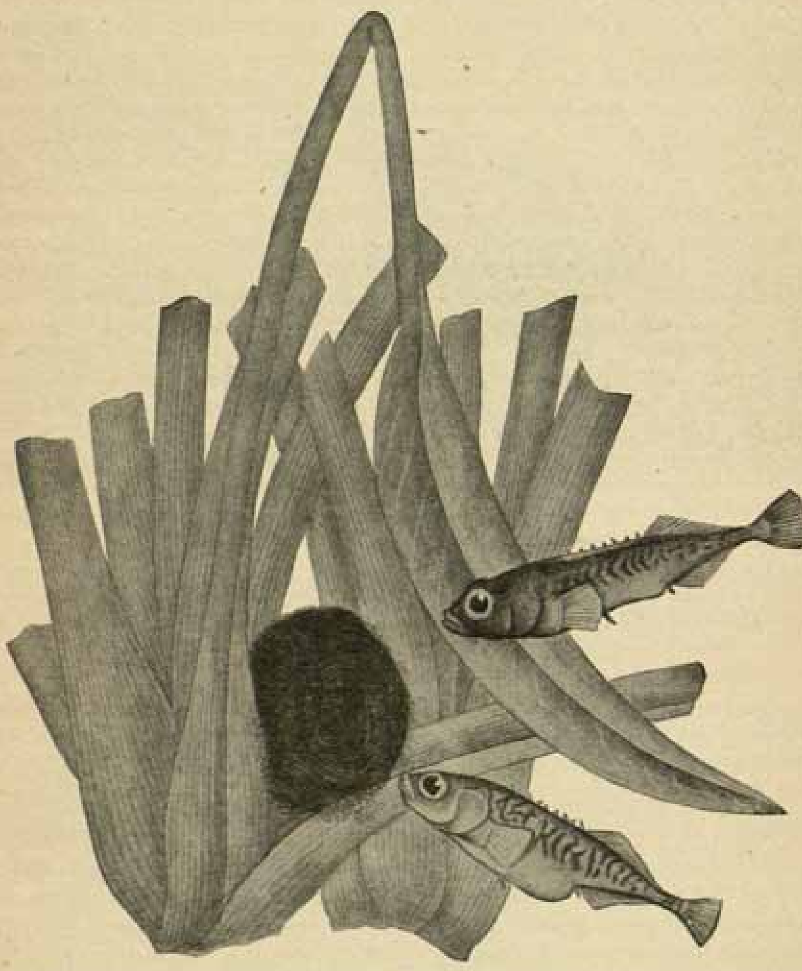


FIG. 86.—Nest of Ten-spined Stickleback. Female preparing to enter a nest to lay her eggs. After Coste.

he restricted the name *Gasterosteus* to the three-spined sticklebacks, and proposed *Pungitius* for the many-spined species.[a]

[a] As the nomenclatural proposition has been universally overlooked, and the work in which it is published is inaccessible to most, Coste's own words, concluding the generalization, may be given: "* * * différence caracteristique qui parit justifier la séparation qu'on a faite de ces poissons en deux genres (*Gasterosteus* et *Pungitius*)." *Pungitius* thus anticipates *Pygosteus*.

Spinachia has also a characteristic habit of making a nest, using as a basis a frond of seaweed or some sea plant. The nests "occur most frequently among seaweeds fringing the tidal pools, and of such marginal reeds they are constructed," as has been indicated by Prince.

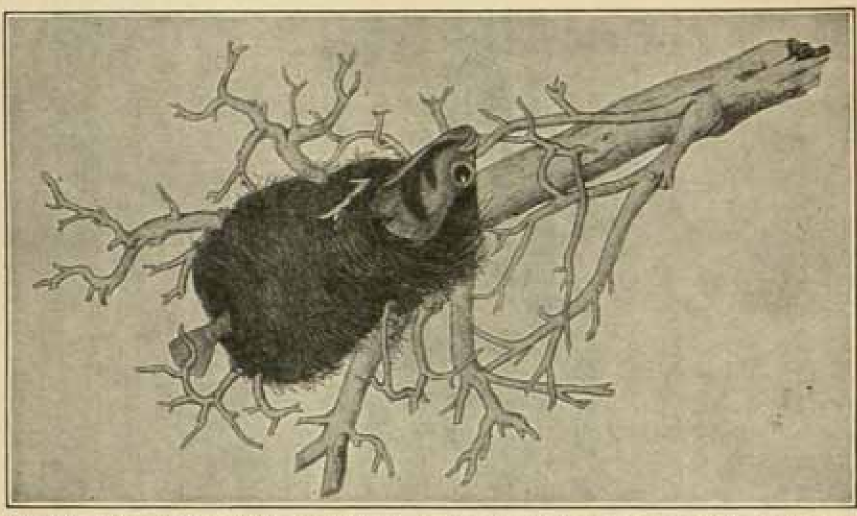


FIG. 87.—Nest of Ten-spined Stickleback. Male rotating in his nest to make it tubular. After Coste.

It has been generally forgotten that the nest of a *Spinachia* was first illustrated in 1843 by Robert Hamilton in his British Fishes (pl. 6).

THE SUNFISHES AND THEIR KIN.

Perhaps the fishes best and most generally known to the boys, and consequently the elder natives of eastern and middle America, are those most frequently called sunfishes or sunnies, but which also are misnamed in various localities bream, roach, and perch. Bream and its corrupt form, brim, are, indeed, in most common use in many places, especially in the Western States. These are the most gayly colored of a family designated by ichthyologists as Centrarchids, and with popular intent sometimes dubbed the Sunfish family. All have a compressed body, which is mostly expanded vertically and almost equally below and above the longitudinal axis of the body. The scales are mostly rather large or of moderate size, but in some (the black basses) rather small, and the lateral line is continuous. The head is scaly and in most the suboperculum is expanded backward in an ear-like flap. The nostrils are double. The roof of the mouth is dentigerous, the teeth being in some confined to the vomer, but in most extending on to the palatines and in some also to the pterygoids and the tongue. There are mostly six branchiostegal rays, very rarely

seven. The lower pharyngeal bones are always distinct. The dorsal and anal fins are diversiform, but in most of the species the soft portions of the dorsal and anal fins are almost exactly opposite and balance each other. These characters are supplemented by still more important osteological ones, which confirm the natural association of the genera.[a]

Besides the sunfishes, others of greater economical importance belong to the family, as the black basses, the crappies, and the rock basses. Thirty and more species in all represent the family and all are confined to North America and mostly to the United States, but half a dozen extend into northern Mexico and two are peculiar to her northern States.

So far as known all the Centrarchids take more or less care of their eggs and young, and doubtless it is always the male parent that undertakes this charge. There are, however, various degrees to which care is exercised, and it is possible (not probable) that some may fail to take any care of either eggs or young. There should certainly be some young naturalist who will undertake to watch and study the aberrant members of the family.

The species whose life histories are best known are the black basses (*Micropterus dolomieu* and *M. salmoides*). On these innumerable articles and pamphlets have been published, and 3 volumes or treatises of superior value.[b] One of these is James A. Henshall's "Book of the Black Bass" (1881, 1889; 463 pp.; 2d ed., 1904), another, Henshall's "More about the Black Bass" (1898), and the latest and most authoritative of all is a monograph by Jacob Reighard, "The Breeding Habits, Development, and Propagation of the Black Bass," published as Bulletin of the Michigan Fish Commission No. 7. Henshall expresses the opinion of many in his declaration (More, 47) that "the Black Bass is excelled by no other fish that swims for gameness and among fresh water species by but one, the White-fish [*Coregonus*], for the table."

The family is quite diversiform and three major groups or subfamilies are recognizable, the Micropterines, the Lepomines, and the Centrarchines.

The *Micropterines*, or black basses, are the least specialized and most like serranoid or perciform fishes. They are of rather elongate oblong form, with weak dorsal spines reduced backward and an anal shorter than the soft dorsal and also with weak spines. The colors

[a] The characters here given compare and contrast with those of the Cichlids, to which most of the Centrarchids bear so much resemblance.

[b] A recent volume by W. C. Harris and T. H. Bean, "The Basses, fresh water and marine" (1905), also relates chiefly to the black basses.

contrast with those of other members of the family by their dark and somber hues. Only two species are recognized.

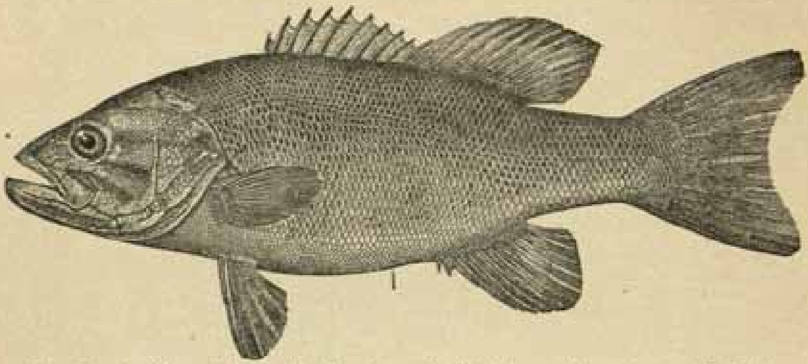


FIG. 88.—A Micropterine. The Small-mouth Black-bass (*Micropterus dolomieu*).

The *Lepomines*, or sunfishes, have the body comparatively short, the dorsal spines robust and not decreasing in size backward, and the anal fin has a soft portion opposite and equal to that of the dorsal and with its front part formed of three or more stout spines. Most of the species of the family belong to this group, and almost all are brilliantly colored and especially conspicuous by the large black and sometimes variegated earlike extensions of the opercular membranes. The colors rival those of such tropical fishes as the angel fishes or Chætodontids and the lady fishes, or Labrids.

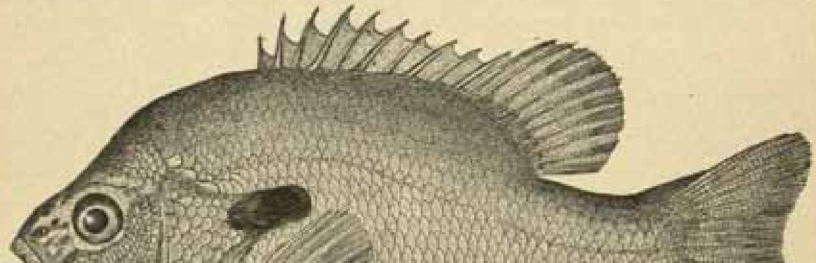


FIG. 89.—A Lepomine. The Long-eared Sunfish (*Lepomus auritus*).

The *Centrarchines*, or crappies, have deep fusiform bodies and quite characteristic, vertical fins; the dorsal and anal are about equally large and obliquely opposite each other; that is, the commencement

and end of the anal are farther back than the corresponding parts of the dorsal; each has nearly the same number of spines, which regularly increase in length backward.

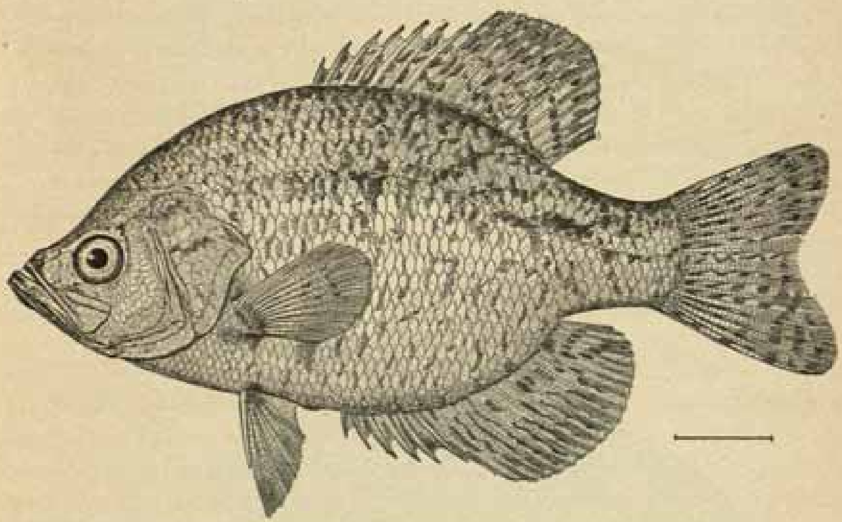


FIG. 90.—A Centrarchine. The Calico Bass (*Pomoxis sparoides*).

The common sunfish (*Eupomotis gibbosus*) may be taken as the best known of the typical species of the family, although of course the black basses are the most famous and have been most written about. The habits of the sunfishes and black basses are not very different from each other.

THE SUNFISHES AND ESPECIALLY THE COMMON SUNFISH (*Eupomotis gibbosus*).

If we are able to approach near enough, under ordinary conditions we may watch the sunfishes in all their movements. One will be found suspended in the water some distance above the bottom, with the dorsal and anal spines depressed backward and the soft portions erect and perhaps every once in a while gently undulated; the pectorals are extended outward, but also slightly undulated, while the ventrals are mostly closed and kept tightly appressed to the belly; the mouth is slightly open, and the branchiostegal membrane barely moves. Another may be seen with all its fins as erect as those represented in the illustration. Some may rest horizontally in the water, others tilted forward and downward, and still others with the snout directed upward.[a] A flirt of the caudal fin and bend of the tail impel

[a] The "mud sunfish" (*Acantharchus pomotis*), which is not properly a sunfish, according to Abbott (1884, p. 369), in an aquarium "much of the time assumed a perpendicular position, head down and tail up, in a bunch of river weeds," and "in every instance" when seen in a creek were in the same "remarkable position; not, indeed, in every case perpendicular, but always closely approaching it, and with the head downward" (p. 370).

the fish in a different direction. They are sociable fishes and apt to be found in small schools. There is a deliberate slowness in their movements, when undisturbed, which gives one the idea of dignity of manner. A splash in the water, nevertheless, at once disperses them, and away they scurry with rapid fin, to reassemble after a short time. The sociability is most pronounced in the first year of the fish's life, but afterwards, as the fishes advance in age, they are more disposed to keep to themselves. The time of activity is mostly during daylight, and at night they rest.[a] They are entirely voiceless.[b]

The common sunfish, on the whole, prefers clear and temperate water and the neighborhood of aquatic plants; ponds and lakes are the favorite bodies, and a couple of the names that the species bears—pond fish and pond perch—are popular tokens of recognition of that

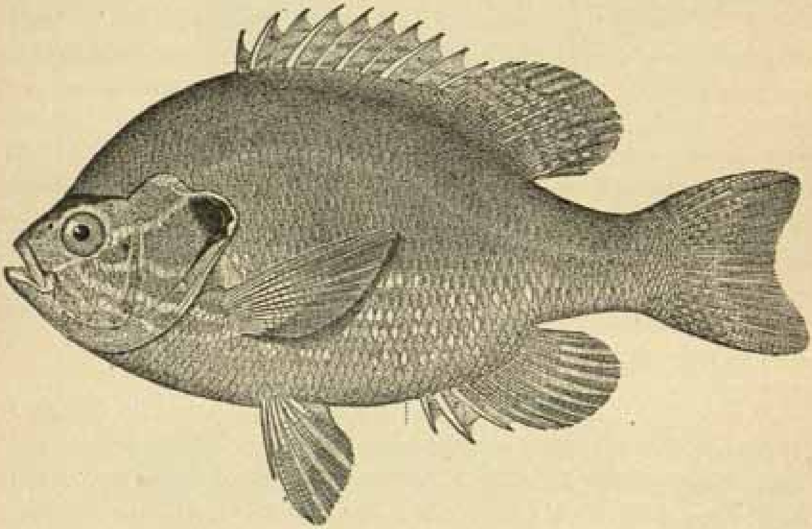


FIG. 91.—Common Sunfish (*Eupomotis gibbosus*).

preference; some are, however, found almost anywhere, carried by currents or wandering of their own will, and thus may be sometimes found with the long-eared sunfish, which is more of a running-water species.

The food of the sunfish has been examined by S. A. Forbes, and the results published in the Bulletins of the Illinois State Laboratory of Natural History (1878–1883). It is not ichthyophagous—that is, a fish eater—as seems to be generally supposed, but depends mostly on small shellfish and insects. A considerable percentage of vegetation is also taken in, perhaps incidentally with the shellfish and insects found in connection with it. "Not a trace of fishes was found in the

[a] The mud sunfish "is really nocturnal in its habits." Abbott, pp. 371, 440.

[b] The mud sunfish "has a well-developed voice" and "will utter at times a deep grunting sound that can not be mistaken." Abbott, pp. 371, 440.)

stomachs of 25 individuals critically examined. Over half of the food was ascertained to be of small mollusks (46 per cent of univalves and 6 per cent of bivalves); insects contributed 20 per cent, and crustaceans 22 per cent; the remaining percentage (12 per cent) was furnished by plants—characeæ, myriophyllum, and algæ." Of course the percentage would vary greatly with conditions. Although no worms appear to have been found, anglers need not be told that an earthworm is an excellent bait. Doubtless little fishes, too, may be occasionally taken in if they come in the way. Another source of food not referred to by Forbes is yielded by true fishes. The sunfishes are, to a considerable extent, spawn eaters, but at least they are not notorious for attacks on the spawn of useful fishes, and, so far, they are best known for the service they perform as spawn eaters and not for injuries committed, for it was through forays on the eggs of the useless and harmful bowfin or dogfish of the lakes (*Amia*) that its spawn-eating proclivities became most evident. Reighard, in his long-continued observations of the nests of the bowfin, found that whenever one was deserted by its maker it was liable to be raided by sunfishes.

When the returning heat of spring has put new life in the fishes, as well as the rest of nature, the sunfish feels its influence, and it is made manifest in an added brilliancy of coloration to the males and the turgid abdomens of the females. They are ready to proceed to their procreative duties about May. The fullest observations of the nuptial condition have been made by Jacob Reighard.[a] "In the male of *Eupomotis gibbosus* the colors are much brighter than in the female. The vermicular markings on the cheeks of the male are more brilliant than those of the female; the opercular ear flap is larger and bordered with scarlet and blue; the ventrals of the male are black, while those of the female are yellow; the dorsal and caudal of the male are much more brilliantly blue than those of the female. In approaching the female, in order to induce her to enter his nest to spawn, the male elevates or puffs out the gill covers so as to display their brilliant markings. At the same time the opercular ear flaps are erected and the black ventral fins spread out. When in this attitude the male faces the female, and it is when seen from the front that his display of color is most brilliant. He assumes a similar attitude when threatening other males. He was never seen to assume this attitude except under the circumstances described, so that the display of color resulting from the attitude must be regarded as a means of expressing the emotions."

But, like the cock, which it emulates in action as well as decoration, the sunfish is apt to excite and incur the hostility of rival males.

[a] J. Reighard, Science, April 11, 1902, p. 575.

According to Abbott, the "courtship of this gaudy fish has been no easy matter. Hundreds of his kind, as bright as he, have, like him, striven by the hour to clear the field of every rival, and the clear waters are often turbid with sand and grass torn from the bed of the stream as the older males chase each other from point to point, endeavoring by a successful snap to mutilate each other's fins. No courtship battles among birds are more earnestly fought, and as the bird with bedraggled feathers is wise enough to withdraw from the contest and quietly seek a mate when his soiled plumage is in part restored, so the sunfish with torn fins retires from the contested nesting ground. But not a sound has been made by these excited fishes

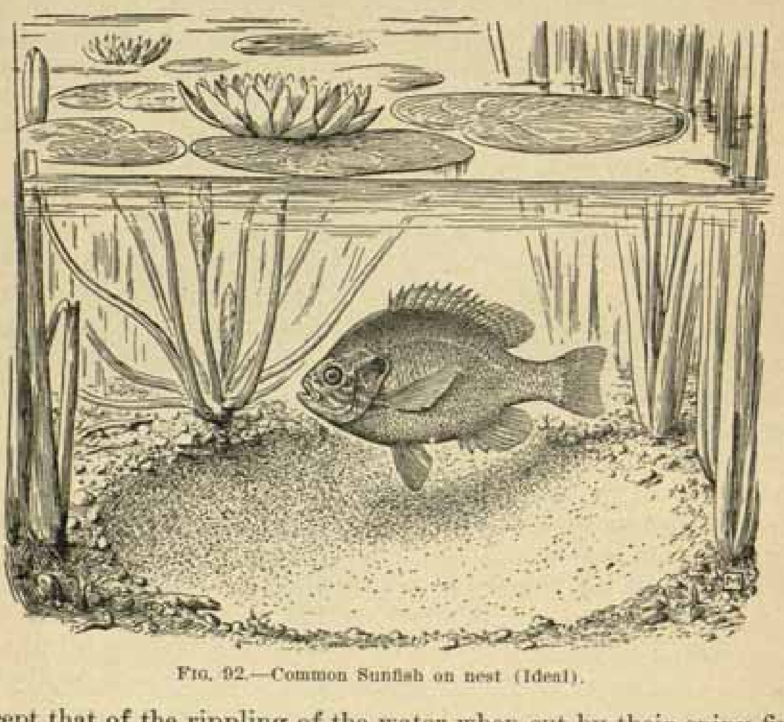


FIG. 92.—Common Sunfish on nest (Ideal).

except that of the rippling of the water when cut by their spiny fins as they chanced to reach above the surface."

Meanwhile the male has selected a spot in very shallow water near the shore, and generally in the midst of aquatic vegetation not too large or close together to entirely exclude the light and heat of the sun, and mostly under an overhanging plant. His choice is apt to be in the same general stretch of shallow water as is favored by many others, so that a number of similar nests may be found close together, although never encroaching on each other, close by the shore. Each fish slightly excavates and makes a saucer-like basin in the chosen area, which is carefully cleared of all pebbles. Such are removed

by violent jerks of the caudal fin, or are taken up by the mouth and carried to the circular boundary of the nest. An area of fine, clean sand or gravel is generally the result, but not infrequently, according to Dr. Reighard (*in litt.*), "the nest bottom is composed of the rootlets of water plants." The nest has a diameter of about twice the length of the fish.

Very often, if not generally, the row of nests is in water that rapidly becomes deeper offshore, so that if the sunfish is alarmed it may quickly scurry off into deep water, where it remains till the alarm is over. According to Abbott, "the return to the nest is as rapid and direct as the exit. Each fish, wherever it may go, has some point which is recognized as the terminus of the lane leading to the nest, and having found this it speeds up the narrow pathway with incredible velocity, and stops as suddenly just at or in the nest." [a]

To the nest thus formed a female is enticed, who is prepared to make a deposit of her eggs After a longer or shorter courtship, as the case demands, the two come together bringing their bellies close to each other, the male a little behind his mate, and eggs and milt follow each other in rapid succession. The conjunction lasts for about a minute, more or less, and, as a rule, is not repeated very soon after. The viscid eggs as soon as laid fall to the bottom and become attached to the gravel that forms the bottom of the nest. According to Dr. Reighard (*in litt.*) "a female if undisturbed takes about an hour to lay her eggs, though she may frequently during this time leave the nest and return to it again." When the female has completed oviposition, she departs and the male assumes sole charge. The sunfish, however, is not strictly a monogamist,[b] and is not always satisfied with the eggs of one female.

Reighard (1903) has noticed "a case in which an individual male

[a] The actions noted by Abbott must be manifested only under certain conditions. I have not noticed analogous instances.

[b] Doctor Abbott was doubtless mistaken in supposing (1884) that "they are not merely paired for the season, but remain a faithful and loving couple all the year and for several years," and that "in these nests both fishes will often be." In nests familiar to me many years ago I do not recall one with more than a single fish in peaceful possession, and that a male. Until 1889, however, the nest and parental care was entirely credited to the female, or to both. In accounts by Godman (1833), Kirtland (1856), Agassiz (1857), Abbott (1884), and Stone (1889) this idea is assumed as a matter of course. In 1889, however, I urged in Nature (40, 1889, 319) and Forest and Stream (Aug. 8, 1889) that I believed "that the chief or the sole guardian of the eggs after their deposition is the male," as is the case of the Gasterosteids and Silurids (catfishes). That such is the case has been later abundantly proved. Reighard recently (1903) has also stated that "his own unpublished observations on *Eupomotis gibbosus* have convinced" him "that, as surmised by Gill (1889), the female takes no part in building the nest or guarding it."

of *Eupomotis gibbosus* reared in one nest two broods laid at quite different times by two females." The relation between the sexes of the sunfish, indeed, is analogous to that of *Amia* which, Reighard thinks, "may be described as a promiscuous polygamy." The female enters or is led by her own impulse to the nest after more or less preliminary play or courtship, deposits her eggs, and then departs or is driven away. The male having fertilized the eggs redoubles his care. For many minutes—it may even be for hours at a time—he may remain poised near the middle of the nest, close above the eggs, watchful for them and against intruders. If a rival approaches too near, he sallies forth against him and drives him away. One may occasionally fall a victim to his zeal if a larger fish, snake, or turtle assail him; prudence nevertheless prevails and impossibilities are not attempted; at a man's approach he flees into deep water, and as long as the man manifests activity remains away, although reconnoitering; if the man remains inactive and perfectly still, the fish may return and settle over the nest again. Among the most dangerous enemies, however, are not the large but the small. The darters especially may deserve their name by darting upon the eggs and bearing off those dainties for a meal. By Dr. Reighard (*in litt.*) the blackheaded dace (*Pimephales notatus*) was found to be the most destructive to sunfish eggs in Walnut Lake last summer (1905).

John Godman, who was the earliest to publish observations on the nests of sunfishes, and did so as early as 1829 or 1830, frequently in an unsportsmanlike manner caught fishes from their nests by means of a net. He could "always select the finest and largest of these fish," and "such was their abundance that the next day would find all the nests reoccupied." Whether the newcomers actually assumed the rôle of nest guardians or nest assailants was not demonstrated.

For about a week, more or less—it depends on the temperature—the male's attention is absorbed in the care of the eggs, which are at last hatched. When the larval fry have appeared the parent considers his work at an end and leaves the young to take care of themselves as they best may. According to Reighard, care of the eggs is only "continued until they are hatched," while in the case of the black basses it "may follow the young fish until they are well grown."

The prominence of the nests of sunfishes in the landscape of a place is amusingly exemplified by their utilization for forecasting the weather by country wiseacres, according to Doctor Abbott, of Trenton, N. J., who writes as follows:

The old men of the neighborhood frequently speak of them in this connection and undertake to forecast whether the coming summer will be wet or dry, from the fact that their nests are sometimes in water a foot in depth, while at others less than one-half this depth covers them. These wise old men of the village sagely shake their heads when the facts are stated, and remark, if the nests

are comparatively deep, "It will be a dry summer," and vice versa. This is based on the supposition that in dry summers the evaporation will exceed the rainfall, and that the fish place their nests in deep water to prevent them from being left high and dry.

Doctor Abbott justly adds that "the absurdity of this is apparent. The nests are occupied but for a portion of one month, and what the summer may be can in no wise affect them; but of this the village sages never think. The truth is the same spots are used year after year, whether the water be high or low."

The sunfish is to a considerable extent used as a pan fish and is at least as good as a perch, but on account of its small size (it averages less than 6 inches) it can not be ranked as an important market fish. It has been, nevertheless, the object of considerable demand in different parts of the United States, and the United States Fish Commission raised and distributed a large number, especially in the early nineties. The demand, however, was doubtless to a large extent from dealers in fancy fishes and for artificial ponds and household ornamentation.

THE CICHLIDS.

The next family that may be considered is that of the Cichlids. Its chief representatives are much like most of the Centrachids, but there is considerable diversity in some respects. The form varies from a high and much compressed body to an elongated one like that of a pike; the scales are generally of moderate size, in some cycloid, in others ctenoid; the lateral line in most is interrupted and double for a short distance on the tail, but in a few merely deflected; the head is scaly; the nostrils are always single; the palate is never dentigerous; there are mostly five branchiostegal rays, and never more than six; the lower pharyngeal bones are united, at maturity at least, into a single bone. Further, systematists lay much stress on the fact that they have two rows of filaments to the last branchial arch as well as others usual in fishes, but not in the Pomacentrids, to which they are most nearly related, and that there is no subocular shelf.

The family is almost entirely confined to fresh waters and further to those of tropical Africa and America. A very few have extended beyond these bounds; from Africa several into neighboring Asia including Palestine; from tropical America one species into subtropical Texas.

Until near the close of the nineteenth century it was supposed that America was far richer both in genera and species than Africa, but long after the discovery of Lake Tanganyika explorers of the animal riches of that great lake were rewarded with an unexpectedly rich harvest of new types of fishes as well as mollusks. No less than 73 species, representing 24 genera of Cichlids, had been discovered therein up to the middle of the year 1906.

The latest monographer of the family, J. Pellegrin, in 1904 recognized 294 species of the family, and of these 161 were inhabitants of Africa (including Syria) and 133 of America. The 294 were ranged by him under 55 genera. The chief authority for African fishes (Boulenger) in 1905 admitted 179 species for that continent, and more recently Regan has enumerated 133 American species. Including subsequently introduced or fortified species, there are now known nearly, if not quite, 350 species.

It is especially noteworthy that each genus is strictly limited to one continent or at least continental area, not a single African having American representatives, nor any American an African one. There is not, however, a natural aggregate of American types to be contrasted with another of African. Nevertheless most of the American types are closely related to each other, and there is not the diversity that is manifested by the African. In one respect, nevertheless, the variation is much greater. All the African species have three anal spines, and three only, while in the American they range from three to as many as fourteen.

Most of the American species at least are very much like the familiar sunfishes of the North American streams and lakes, and when the writer first saw a small school of coscorobs (*Cichlasoma*) in a river of Trinidad he thought it was one of the familiar sunfishes. Not until he had carefully examined some that were caught was he undeceived. A couple of writers of an illustrated book on the Fishes of Guiana (1841) were not only impressed with the likeness, but perpetuated their impressions in the nomenclature, actually referring species of the family to the genera "*Pomotis*" and "*Centrarchus*;" and so also had two very great ichthyologists (Cuvier and Valenciennes) been misled by a colored figure of a Cuban fresh-water fish, which they referred to the genus *Centrarchus*, but which proved to be a member of the characteristic middle American Cichloid genus *Heros* or *Cichlasoma*. Nevertheless the likeness of Cichlids to Centrarchids is entirely superficial, for they differ in the single nostrils, toothless palate, the lateral line, the number and arrangement of branchiostegal rays, the single lower pharyngeal bone, and various other anatomical characters. Still they may have originated from not very remote common progenitors, which were, however, neither specialized Centrarchids nor Cichlids.

The Cichlids exhibit remarkable diversity of oviposition and care of the eggs and embryonic young. Some "lay their eggs in the sand," or, like the northern sunfishes, "build a kind of nest in the sand or mud in which they deposit their eggs, hovering over them until the young are hatched." Among such are the *Hygrogonus* (*Astronotus*) and *Chætobranchus*, according to Agassiz. One

(*Geophagus lapidifera*) was observed by Castelnau in the Araguay River to carry many pebbles, one by one in its mouth, to a spot where it deposited them to form a nest. These pebbles were the size of the end of a finger. In this nest the eggs, resembling mustard seed, were laid.

Like the Centrarchids, the Cichlids, probably generally, exercise a parental care, but according to some great authorities (Boulenger and Pellegrin) in most cases the females assume guardianship. Pellegrin found that all the individuals (four) of a common *Tilapia* of Palestine (*T. simonis*) examined by him which had eggs in the mouth were females. Boulenger confirmed the ovigerous agency of the females for many other species. At present, in fact, it appears that in most (probably all) of the African Cichlids, at least, the females are the egg carriers rather than the males.

The earliest information respecting the oral gestation of the Brazilian species was given by Agassiz (220) from observations on "a species of *Geophagus*" (the sex not stated). "The eggs pass," he knew not how, "into the mouth, the bottom of which is lined by them, between the inner appendages of the branchial arches, and especially into a pouch formed by the upper pharyngeals, which they completely fill. There they are hatched, and the little ones, freed from the egg case, are developed until they are in a condition to provide for their own existence." He did "not know how long this continues," but had "met with specimens whose young had no longer any vitelline sac, but were still harbored by the progenitor." Occasionally, instead of eggs, Agassiz "found the cavity of the gills, as also the space inclosed by the branchiostegal membrane, filled with a brood of young already hatched. The eggs before hatching are always found in the same part of the mouth, namely, in the upper part of the branchial arches, protected or held together by a special lobe or valve formed of the upper pharyngeals." The cavity thus occupied by the eggs was thought by Agassiz to correspond "exactly to the labyrinth" of the fishes with labyrinthiform pharyngeals.

AN OLD EGYPTIAN AND PALESTINIAN OVIGEROUS CICHLID.

The principal and longest known of the Cichloid genera is *Tilapia*, for a long time generally called *Chromis*. One species, indeed, was familiar to a numerous and highly civilized population thousands of years before there was an English language. It was the object of the angler's as well as professional fisherman's pursuit along the banks of the Nile under the Pharaohs, and was sculptured on various monuments. The same species and closely related ones are inhabitants of Palestine and undoubtedly were the chief products

of the fisher disciples of Jesus Christ, but they are not specifically mentioned in the Bible.

Abundant as these fishes are in the lake so celebrated in biblical story, no specific mention of any of them, or of any other fishes, occurs in the Bible. All that came into the nets of the old fishermen of biblical times were simply "fish." But even in that prescientific age, it was recognized that one of the same kind that abounded in the lake was also found in the Nile. Josephus, in his eulogy of the beauties of the Plain of Gennesareth, tells that it is "watered from a most fertile fountain. * * * Some have thought it a vein of the Nile, because it produces the coracin fish as well as that lake which is near Alexandria." The coracin or crowlike fish, so called on ac-

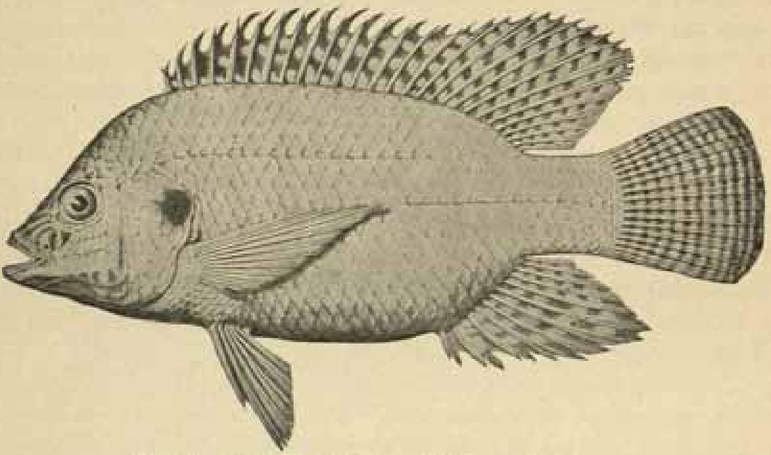


FIG. 93.—The Bolti (*Tilapia nilotica*). After Lortet.

count of the dark or "crowlike" color of the fish, was undoubtedly a Cichlid of the genus *Tilapia*, closely related, at least, to the bolti of Egypt.[a]

What is known of the preliminary advances of the male to the female or courtship has been derived from observations of the *Tilapia simonis* of the "Sea of Galilee" or Lake Tiberias made by L. Lortet.[b]

The eggs, which are about as large as shot No. 4 (French measure),

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[a] Lortet identified the Coracinus with the Clarioid catfish *Clarias*, but without sufficient reason.

[b] The translation or paraphrase of Lortet's notice is left as written and without comment save that it appears to have been proved that the egg carrier is always the female. It may be added, however, that Lortet was, doubtless, perfectly convinced that he had really observed the transfer of duties from the female to the male. Anyone who has attempted to follow a pair of active fishes and to discriminate between them will appreciate how confused he may become. Placing too implicit faith in the universality of the rule that the male fish takes care of eggs and young, the fish which Lortet found with eggs in

are of a deep blue color. These are deposited by the female in a slight excavation which she makes among reeds and bulrushes. About 200 is the ordinary complement of a good-sized fish. After she has laid her eggs the female appears exhausted, and remains almost motionless at a short distance from the deposit. The male, on the contrary, appears to be much agitated, hovers around the eggs, swims without cessation above them, and probably fecundates them at this time. Some minutes later he takes the eggs, one after another, into his mouth and keeps them inside his cheeks, which become notably swollen and distorted outside. Some of the eggs, however, pass backward between the branchial arches and find a resting place there. These eggs, though not restrained by any membrane nor by any glairy or sticky matter whatever, remain in place within the mouth. The parent never loses them when in the water, and it is only when he is caught and thrown on the sand that the eggs fall out in consequence of his spasmodic efforts to breathe. Some, however, still remain in the mouth.

A SOUTH AFRICAN MALE OVIGEROUS CICHLID.

The most complete observations of the actions of the male guardian of the eggs and the care of the eggs as well as young were made by another naturalist, N. Abraham, in 1901. The species whose actions Abraham describes was one abundant in Natal, where he lived, and has been named *Tilapia philander*.

In the month of November of 1900 I visited a pond in the neighbourhood of Durban and received several chromides (*Tilapia*). I introduced them into a tank prepared for them and kept careful watch. I at once noticed that one of

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mouth was from that fact assumed to be a male; evidently dissection was not resorted to.

The article by Mr. Abraham was sent to Doctor Günther and by him contributed to the Annals and Magazine of Natural History (VIII, 321–325). Doctor Günther, in his introductory remarks, stated that "one of the specimens sent [to him] is the individual which Mr. Abraham had under observation for some weeks, and is a male." Doctor Boulenger, however, after examination of the same individual, and of "a further series of *Tilapia philander*, together with some *T. natalensis*, which he had received from the Rev. N. Abraham, several of which have eggs in the mouth, as well as in the genital glands, found *all* the egg carriers to be *females*. Doctor Günther must, therefore, have assumed the egg carrier determined by him to have been a male from general principles, and not after dissection. (See Boulenger, T. Z. S., XVII, pp. 538, 539, Oct., 1906.) In accordance with Boulenger's determination, wherever the words "he" and "his" occur in the annals "she" and "her" are substituted in the present article. Boulenger aptly remarks that it "remains unproved whether in any of the African or Syrian cichlids the 'buccal incubation,' as it has been called by Doctor Pellegrin, devolves on the male; the instances previously adduced being either controverted or unsupported by the only reliable evidence, an examination of the genital glands."

these fish showed indications of carrying ova in its mouth. The gill covers did not fit closely over the cavity containing the gills, but were distended, making the fish look as though it had a swollen head. This fish I removed into another "tank," of which it became the sole occupant. This little fish measured two inches and three-quarters in length including the tail. The tank in which I kept it for observation was a small aquarium measuring eight inches by five, with a depth of water of two and a half inches. A few roots of *Vallisneria spiralis* provided the necessary oxidation of the water. A few days after the fish was introduced into this "tank" the swelling out of the gill-covers became more marked, until they stood out or remained opened quite a distance from the cavity of the gills. Beyond this feature nothing particular was to be noticed for some days. But after these days a very interesting stage in the development took place. I was enabled to see that the ova had evidently matured, for I could see a number of tiny living forms moving about in the mouth of the parent fish. A slight development also took place beneath the lower jaw of the fish in the shape of an expansion of the membrane, which made more room in the mouth and reminded one somewhat of the dilatable pouch affixed to the lower mandible of a pelican. This pouch being partly transparent, as well as a portion of the head near to it, I was enabled to see fairly well right into the mouth cavity.

For some minutes nothing could be observed in watching the head of the fish but the rhythmic movement of the lower jaw and gills; but after an interval I could clearly see all the young fish in a great state of commotion, filling the whole front of the mouth with a living pack of minute dark creatures whose movements reminded one of the ways of tadpoles when huddled together in dense masses, only with this difference, these tiny fish moved with great rapidity. After these creatures had made one of their periodic excursions to the front of their parent's mouth they always retreated out of sight to the back, and nothing more would be seen of them for a few minutes, and then there would be another turmoil and mad rush to the front; but none of them ever escaped out of the mouth. I think that these movements might be accounted for on the supposition that as these embryonic fish began to grow they gave the parent fish some inconvenience, and that owing to this the fish was obliged to constantly force his growing family from the pharynx to the front of the mouth, giving [her] an opportunity of relieving [herself] from the choking feeling [she] must have been constantly subjected to. These little fish did not swim to the front of the mouth, but were evidently rushed there, as they looked like a ball composed of a great number of minute wriggling creatures whose real shape could not be seen because of the rapidity of their motion, which was more a revolving motion than any other. I could not see well enough to observe whether they were really fish-like in form or embryonic, and I did not like to disturb the fish enough to find out. I simply kept close watch day after day. These movements continued for some days, during which time I allowed several of my friends to come to my study and witness the strange sight, which was regularly repeated every few minutes.

After two weeks had passed these movements almost ceased for a time, and I had fears that all was not going well; but after careful watch for a few more days I entered my study early one morning, and to my great delight saw a large number of little fish, very perfect and beautiful, slowly and gracefully swimming about near to their parent's head, their movements now being very different from the wriggling, hurry skurry which marked their movements prior to their leaving for the first time their parent's mouth. I tried to count the number of young in this shoal so strangely brought into the world. I counted sixty for certain, but there were probably two or three more. And now, being

anxious to prove the assertion that the parent fish among the chromides take their young into their mouths, I called into my study some of my family and asked them to watch what happened when I revolved the table top upon which the aquarium was standing. Half a return of the revolving top was sufficient—the whole shoal quickly gathered about the parent's head; [she] opened [her] mouth, and into it swam the sixty little fish, leaving us to wonder what had become of them. It was a wonderful sight and made a vivid impression upon my mind. It is difficult to describe such a sight; one must see it to appreciate it. Swiftly, but in perfect order and with great grace, all the young swam into the open mouth of the parent and disappeared. I ascertained that they measured a little more than one-third of an inch in length. The parent fish, as I have said, only measured two and three-quarters inches, yet [she] found room to pack away in [her] throat over 60 young, each measuring a third of an inch in length. Once safely within [her] mouth, [she] did not let them out again for several hours, and then I was fortunate enough to see [her] expel them. Two or three were first thrown out of the mouth (shot out, as a smoker puffs out smoke from his mouth). Then a few more were thrust out, until nearly thirty were swimming about; then with a circular motion [she] scattered all the rest almost simultaneously into the larger world of water contained in the tank.

Now that the young fish were out the parent fish watched over them. I had introduced two fresh-water shrimps into the tank a few days before. The fish had taken no notice of them, but now the jealous parent chased these poor shrimps up and down the tank in such a savage way that I had to take them out. I may add that whenever I wanted to see the young fish swim into their parent's mouth it was only necessary to make some slight disturbance on the table, and at once the beautiful and strange scene was enacted. After two or three days the little fish began to venture to the extreme limits of the aquarium hunting for food, and now, when danger was near, the parent fish did not wait for the fry to come to [her]—in fact, they did not seem quite so eager to be swallowed as at first—but [*she*] *went after them*, gathering them up one by one from all parts of the tank until every one was safe within [her] mouth. Each evening also, at about sundown, all the young fish were gathered up and kept in the mouth all night. I did not watch all night, but when I looked during the night I could never see any of the fish about, so I concluded [she] never let them out after collecting them at sundown until the next morning.

The young fish began to grow not only in size, but in independence, and after five days from their first exit the parent fish treated them as though the time had come for them to look after themselves, and soon after [she] took no further trouble with them, except in the way of fighting any supposed enemy that was introduced into the tank.

I may add that I have since observed other fish, with the same result—I mean, of course, other chromides (*Tilapia*).

A SOUTH AMERICAN NEST-MAKING CICHLID.

In 1901 a number of living individuals of two Brazilian species of Cichlids, identified as *Geophagus brasiliensis* and *G. gymnogenys*, were received in Germany, and two aquariists recorded

[a] The cichlid figured on page 525 of this article "may be *Geophagus brachyurus* Cope," according to Mr. C. Tate Regan (*in litt.*) who has recently reviewed all the American cichlids.

observations on their habits in the periodical entitled Natur und Haus (X, pp. 244–246, 324–328). Those by W. Schroot (pp. 324–328) are in part translated here. Schroot obtained four fishes from

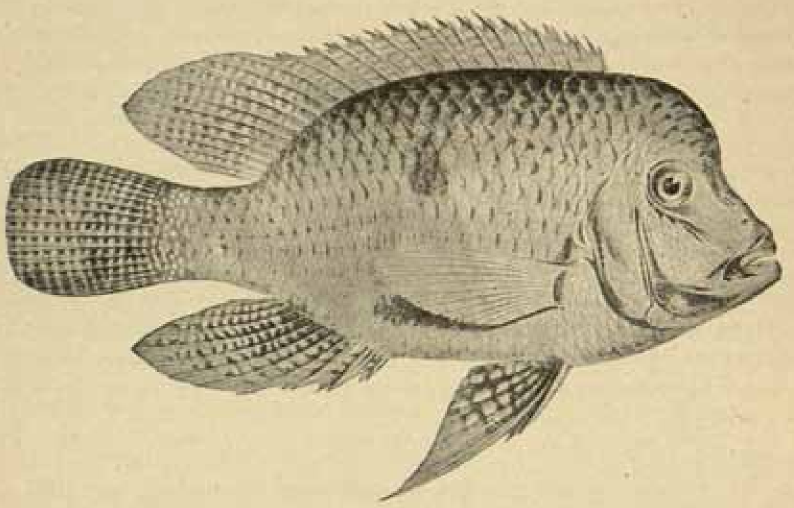

FIG. 94.—*Geophagus brasiliensis*, male. After Steindachner.

Paul Nitsche, who procured a number of them from a naturalist resident in Brazil (Hensel), and thus gives his experience:

Mr. Nitsche placed the fishes for breeding purposes in the then

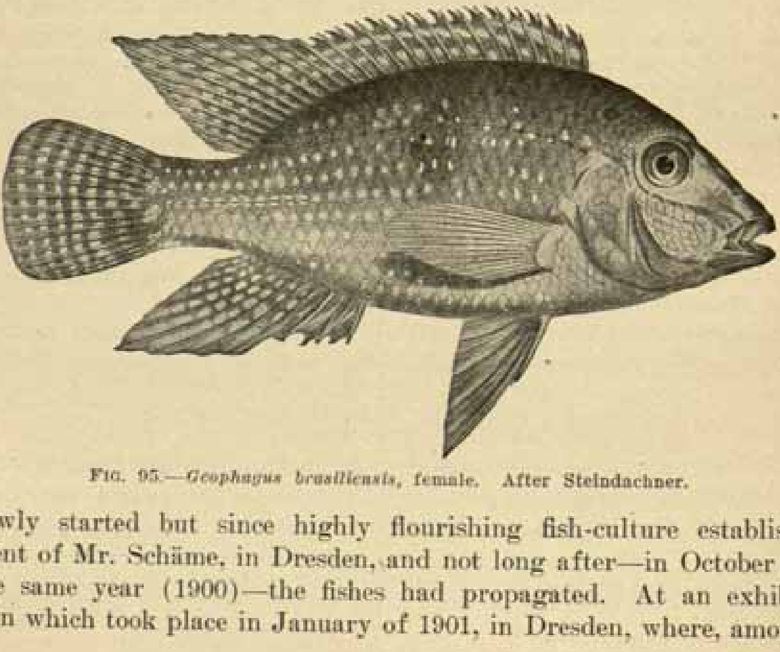

FIG. 95.—*Geophagus brasiliensis*, female. After Steindachner.

newly started but since highly flourishing fish-culture establishment of Mr. Schäme, in Dresden, and not long after—in October of the same year (1900)—the fishes had propagated. At an exhibition which took place in January of 1901, in Dresden, where, among

others, a few of these fishes were exhibited by Mr. Schäme, they justly created quite a sensation. In the spring of 1901 the young were already on the market, and I, as one of the first, obtained four individuals. They were fishes measuring about 5 to 6 centimeters in length, which I placed in an aquarium of a capacity of about 45 liters of water. The fishes felt apparently quite comfortable in the well-planted basin, ate with relish all that I offered them—earth worms, raw meat, and daphnia—were seldom seen, and thrived perceptibly. But after awhile they became more lively in the aquarium, and fights and persecutions took place constantly. It was then seen on closer examination that the four fishes presented a very slight gradation with regard to size. And now the largest was continually pursuing the three others, the second largest did not leave the two smaller in peace, and number three made the smallest the target of his persecutions. The end of the matter was that I withdrew the two smaller, which had already their fins very much torn, and placed each one by itself, while I left the two larger in the aquarium. Meanwhile July had come, and the larger of the two fishes seemed to take a special pleasure in digging up the whole aquarium, without, however, stopping the persecution of the smaller fish. Everywhere he had dug deep holes into the sand, thereby, of course, uprooting many plants. When about the middle of July, I examined the smaller fish more closely, it appeared to me as though its body had swollen perceptibly. I did not, however, pay any further attention to this increase in size, for it did not occur to me that the fishes, only about nine to ten months old, were already about to propagate, but, on the contrary, I took this increase to be a sign of their good condition. But from that time on the behavior of the larger fish toward the smaller changed. The persecution stopped, and the larger fish devoted itself exclusively to examining the bottom of the aquarium, which seemed to consist of little hills and valleys. As the sand covering the dirt layer was only about 3 to 4 centimeters deep, it happened in some places that the fish also stirred up the dirt with it, which could not but influence the clearness of the water. At last it appeared to have found a place suitable for its purpose; I came to this conclusion because it busied itself for a greater length of time about this place; it had generally taken only a short time in making the other holes.

After some time I saw how the fish dug up some vallisnerias in this place, then pulled at them, and finally put the plants away with evident exertion. After that it deepened the resulting hole very carefully, fanned away all dirt with its caudal and pectoral fins, and went in search of the other previously so badly persecuted female. In the meantime the size of the little fish had further increased a

little, and now there was no doubt left in my mind that I had before me a highly pregnant female and a male preparing a "cradle"—consequently a pair. It may be imagined with what expectancy I looked forward to what was going to happen. In the last days of July the ovipositor of the female developed, and on the morning of August 1 I found eggs deposited on the side of the aquarium next to the window, which I estimated to number from two to three hundred. Because of the troubling of the water through the digging of the male I could only indistinctly discern the parents, which constantly swam up and down in front of the eggs. After five or six days I discovered that the eggs had disappeared from the glass, and on turning aside the plants covering the place where the male had dug the hole I could discern the constantly moving young. One of the parents was continually hovering over the hole and appeared to keep watch while the other was feeding. After eight more days I noticed one morning that the hole was empty, and on looking about I saw the whole swarm of young ones accompanied by the parents in a corner of the aquarium searching the bottom and the plants. And from that time on the young were daily swimming about accompanied by the parents, and generally so that the female was in the midst of the young, while the male would always swim around the swarm, on the lookout that none of the little ones should get lost. Sometimes it happened that one of the young stayed behind a little, then the closely watching parent took the little one into its mouth and spit it out again in the midst of the swarm, whereupon the young one turned a few somersaults and then swam merrily away. To be sure, I also saw at different times that the male did not handle the young very gently; indeed, at times it would seize them so roughly and spit them out again with such violence, that they could not stop their somersaults and slowly sank to the bottom, where they lay twisting and quite slowly recovered. In three or four cases the young perished through the rough treatment of the father. Every evening the young were taken to the hole where they remained during the night.

This pretty exhibition of family life lasted about four weeks and the young had already grown somewhat. Then came, in September, some very cool days and yet cooler nights, and the number of the young decreased every day, while the behavior of the parent fishes to one another became as before, so that I was finally obliged to protect the female from the bites and hits of the male by removing it from the basin. The weather became yet colder and with it the number of the young steadily decreased. I had not at my disposal an aquarium capable of being heated and so had to see how the young, one after another, disappeared. The male seemed hardly to care

about them any longer, and at last I counted only seven of them. Those I took out of the basin and placed in a little breeding tank. They held their own in it for a few days more, but finally one morning the last one was dead.

Later I had prepared a small aquarium capable of being heated and in which I intended to have the parent fishes winter, but only a few days later I was obliged to isolate the female, as the male had been too hard on her. This time the female did not recover from the bites and wounds received, and after two days I found it floating dead on the surface of the water. The male, however, was very well during the entire winter. I had provided the aquarium which it occupied with only a sand bottom, into which I had put a few plants

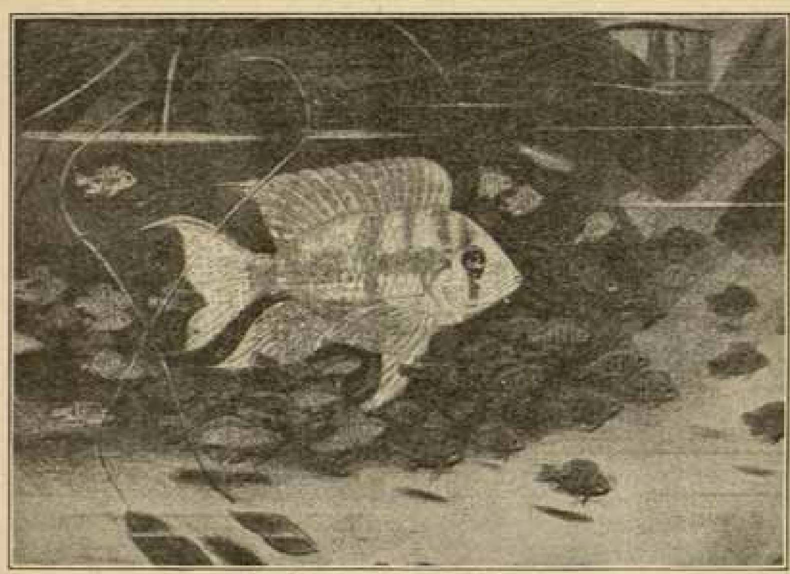

FIG. 96.—*Geophagus brachyurus.*

(*Elodea densa*). In this sand the fish dug one hole after another during the whole winter, whereby the plants were of course continually pulled out. In the beginning I always put the plants back into the ground when I saw that they had been dug up. But I became at last tired of continually replacing the plants and left them as the fish wanted to have them. Gradually it got them all dug up, excepting one behind which it had its place of hiding and of rest. When it saw anything moving in or near the aquarium, it took refuge behind this plant. In February I was obliged to give away this fine fellow for want of room. It stayed with its new possessor a few days in a tank without any bottom soil whatsoever, and whether it there missed the digging as a condition of living or whether it became diseased I can not tell. The short and the long of it is that it soon

followed its children and its mate into eternity. Thus the pretty fish disappeared from my aquariums, for I had given away the two smaller ones in October.

THE ANABANTOIDEANS.

In tropical Asia and Africa, countries where a long "dry season" alternates with a "wet" one when showers are frequent, live a number of fishes with singular appendages to the branchial skeleton. They have in common a vascular suprabranchial respiratory organ, which is developed around the topmost joints, or epibranchials, of the first of the branchial arches. By means of this they are able to breathe air direct, and are consequently admirably adapted for life in countries where the streams and ponds dry up or shrink so that ordinary fishes would be deprived of a sufficient amount of oxygen in the water. Not only are they not dependent on the supply of oxygen in the water, but they demand more and have developed to such an extent as to require air direct, and if prevented from obtaining such die of asphyxia.

There are at least two families which are so distinct as to have been far removed from each other by some modern ichthyologists, although by the older ones all the species were associated in the same family. Most of them have the normal union of the pelvic bones with the shoulder girdle by a direct connection of the respective bones. These belong to the Gourami family (*Osphromenids*). Others have the pelvic bones rather loosely connected by ligament with the shoulder girdle and have consequently been removed from the Acanthopterygians and associated with the mullets and related fishes in the suborder Percesoces. They form the family of Anabantids and are best known through the *Anabas scandens*, in popular parlance designated the climbing fish, and in the Malabar or Tamil language the paumi-eyri or sennal, one signifying "tree climber." Sometimes united with the Osphromenids and sometimes distinguished as distinct families are two monotypic groups designated Helostomids and Luciocephalids.

A little detail explanatory of the structure referred to is here necessary.

The uppermost element but one of one pair (the first) of the gill-bearing arches is peculiarly modified; that is, the element (called branchihyal) of each side, instead of being straight and solid as in most fishes is excessively developed and provided with thin plates or folds erect from the surface of the bone and from the roof of the mouth to which the arch is attached. These plates, by their intersection, form chambers, and are lined with a vascular membrane which is supplied with large blood vessels. There are corresponding

cavities to receive these appendages. It was formerly postulated that this apparatus had the office of receiving and retaining supplies of water which should trickle down and keep the gills moist; such was supposed to be the adaptation for the sustentation of life out of the water. The experiments of Surgeon Day and others, however, threw doubt upon this alleged function and tend to show (1) that these fishes die "when deprived of access to atmospheric air, not from any deleterious properties either in the water or in the apparatus used, but from being unable to subsist on air obtained solely from the water, aerial respiration being indispensable;" (2) "that they can live in moisture out of water for lengthened periods, and for a short and variable time in water only;" (3) "that the cavity or receptacle does not contain water, but has a moist secreting surface in which air is retained for the purpose of respiration, and it seems probable that this air, after having been supplied for this purpose, is ejected by the mouth and not swallowed to be discharged per anum."

In fine, the two respiratory factors of the branchial apparatus have independent functions: (1) the labyrinthiform or pharyngeal portion being a special modification for the use of atmospheric air; (2) the gill filaments discharging their normal function.

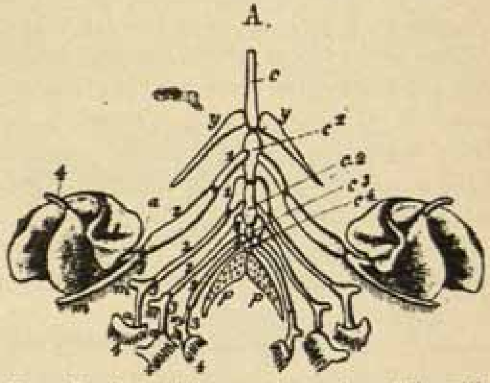

FIG. 97.—Branchial apparatus of a fish with labyrinthiform pharyngeals, the Gourami, *Osphromenus gurami*: a, articular process of epibranchial; c, copula or basibranchials; l, labyrinth-plates of epibranchial of first branchial arch; m, muscular process of epibranchial; p, pharyngeals; y, basihyal; 1, Hypobranchial; 2, Ceratobranchial; 3, Epibranchial; 4, Epipharyngeals or Upper pharyngeals.

If, however, the fish is kept in the water and prevented from coming to the surface to swallow the atmospheric air, the labyrinthiform apparatus becomes filled with water, which can not be discharged owing to its almost noncontractile power. There is thus no means of emptying it, and the water probably becomes carbonized and unfit for oxygenizing the blood, so that the whole of the respiration is thus thrown on the branchiæ. This will account for the fact that when the fish is in a state of quiescence it lives much longer than when excited, whilst the sluggishness sometimes evinced may be due to poisoned or carbonized blood.

Later investigations, especially those of N. J. Zograf on *Polyacanthus* in 1888, have confirmed these results.

The suprabranchial or epibranchial organ varies in complexity

with age. At first there are, as the basis, exceedingly thin bony laminæ, which increase in number and plication with time, till finally they well merit the designation of labyrinthiform, if not "labyrinthiform branchiæ," which was conferred on them by Cuvier. The osseous laminæ are covered with a special mucous and aeriferous tissue and functions as a lung. It is by means of this organ that the fish is enabled to avail itself of a supply of air which it seeks or is forced to avail itself by stress of circumstances.

Although occurring in "tropical Asia and Africa," the Anabantoideans are by no means found everywhere in those countries, and their distribution indeed is remarkable. The Anabantids are more widely distributed in Africa than in Asia, but while the Osphromenids have a wide range in southern Asia and the archipelagoes, they are limited (so far as known) to a single genus and species (*Micracanthus marchii*), restricted to tributaries of a single river of western Africa—the Ogowe. Consequently, a vast area exists between the present headquarters of the family and the area where a single relict survives to bear testimony to the former extension of the family. Why fishes apparently so well fitted for the struggle of life should have succumbed is one of the many mysteries which constantly confront the naturalist.

Only one of the Anabantoidean families—the Osphromenids—requires notice here. Its members construct remarkable nests.

THE OSPHROMENIDS.

The Gourami family have an oblong and rather irregular body, covered with scales which extend over the head; the head and mouth small, the palate toothless, and the fins very diverse. Almost every genus is distinguished by special fin modifications, but the anal always extends farther backward than the dorsal. The ventrals are more or less behind the roots of the pectorals and have a spine (in one genus atrophied) and an outermost more or less elongated ray developed at some expense to the others—that is, the others are reduced in length or more or less suppressed.

There is an extraordinary range of variation in the dorsal and anal as well as ventral fins. At one extreme are the Gourami and its near relatives, whose fins are very long and have numerous spines, and at the other the pla-kat or fighting fish (*Betta pugnax*), deprived of both dorsal and anal spines. Again, at one extreme are the *Polyacanthi*, with the completely developed ventrals (having a spine and five rays) of an ordinary acanthopterygian fish, and at the other the *Trichogasters*, with those fins each represented by a single filamentous ray. Between such extremes are a number of intermediate forms, which certify to the fact that such differences do not have the value

they do in the case of other fishes and that the family in which they are combined is a natural one. So far as the ventrals are involved, the gourami is one of the intermediate types, having all the rays but the outer filamentary one much abbreviated.

Each of the genera whose ovipositing habits are known has its own special method for the elaboration of the nest. The simplest of these nests is that formed by the *Trichogaster fasciatus;* next to it is that of the fish of paradise (*Macropodus viridi-auratus*). That of the gourami is the most complex. A notice of the first can alone be given here.

THE RAINBOW FISH.

The *Trichogaster fasciatus* (generally named *Colisa vulgaris* in the popular accounts of it) has a wide range in the waters of India. The ground color is greenish above, light below, and fourteen or more oblique orange bands traverse the sides, but besides these are brilliant colors which have gained for the fish the English name rainbow fish and the French equivalent poisson arc-en-ciel. It sometimes grows to a length of about 5 inches, but those of an inch and a half are the most common. The first and best account of its nesting was given by Paul Carbonnier in 1875. Here is a translation which was originally published in the Annals and Magazine of Natural History for February, 1876. The next year (1876) the author's son, Pierre Carbonnier, gave later observations in the Bulletin de la Société d'Acclimatation (p. 11–21).

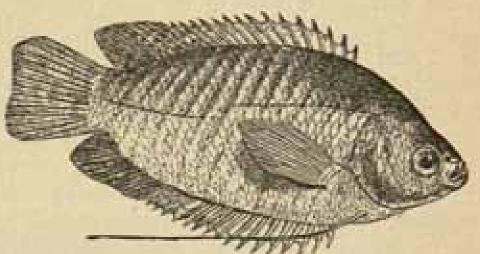

FIG. 98.—The Rainbow fish (*Trichogaster fasciatus*). After Day.

The rainbow fish is met with in the tanks and ditches of the country watered by the Ganges. Its length never exceeds 4 centimeters. It is one of the prettiest of known fishes. One is agreeably surprised with the exuberance of colour that nature has bestowed upon this little animal; but its most important peculiarity, from a scientific point of view, is its mode of nidification.

As the spawning time approaches, the male, spreading his brilliant fins, plays round the female, showing her his bright colours; with his long ventral filaments he pats and touches her in all directions, until, overexcited by his caresses, she takes to flight. I believe that all these graceful movements of the male fish, all these amorous proceedings, influence the physical condition of the female and aid the maturation of the ova.

The male fish then commences the preparations for oviposition. Seizing a little conferva in his mouth, he carries it to the surface of the water. The plant, from its greater density, would fall back very rapidly to the bottom; but our little workman sucks in a few bubbles of air, which he divides and places immediately beneath the plants so as to prevent them from descending. He repeats this process several times, and thus, in the first day forms a floating

island 8 centimeters in diameter. The bubbles of air are not coated with a greasy liquid as in the case of the fish of paradise, *Macropodus viridi-auratus*; all those which approach sufficiently to touch, unite together and fuse into one.

The next day the male continues his provision of air, which he now accumulates towards the central point. These bubbles exert a pressure from below upwards, the consequence of which is the elevation of the vegetable disk, which, issuing from the water, becomes converted into a sort of a dome floating on the surface.

The nest being completed outwardly, the fish busies himself with giving it a firmness which may protect it from shipwreck. With this view, he creeps upon it in all directions and glides over its walls to smooth the surfaces; he forcibly presses this felt with his muzzle and his chest. If one of the twigs is too prominent, he seizes it and removes it or, by means of successive pushes with his head, forces it into the interior. It is by turning and pressing the wall from all sides that he succeeds in rounding it nicely.

The protective roof being finished, the male plays about the female, shows her the brilliancy of his dress, touches her with his appendages, and seems to invite her to follow him. The female then soon enters the nest. While she is feeling its walls and examining its arrangements, the male, bent horizontally under the entrance, turns spirally upon himself, throwing towards the summit of the edifice the lustre of his many-coloured tints.

Speedily the female approaches the male with confidence; she applies her head near the extremity of his anal fin, and thus traverses it as far as the origin of the filaments; then she bends into a semicircle. The male fish, by a like inflexion of his body, embraces her, turns her over, and presses her side, an operation the result of which is a first emission of ova. These, from their lightness, tend of themselves to rise; but with a foresight which can not be too much admired, the male, in pressing the female, forms, by means of his dorsal fin, a concave fold, a receptacle in which the ova undergo the contact of the fecundating principles. Soon after there is a new visit of the female and a fresh approximation of the male until the ovaries are completely evacuated.

The spawning over, the female quits the conjugal roof, leaving to the male the care of rearing the family, a task of which he acquits himself with a truly paternal zeal. Collecting with his mouth the ova scattered through the plant, he raises them into the nest and arranges them in orderly fashion; if they are too much agglomerated, he separates them by a movement of the head and compels them to remain in the same plane; then he issues from the nest, and sets himself with great activity to contract the entrance. When this operation is completed, he goes away and swims round his edifice to examine the whole, and not without anxiety, for he often goes to fetch fresh bubbles of air, which he places intentionally under doubtful points or under menaced parts.

After seventy hours of incubation, the male, foreseeing that the ova require fresh care and quite a different medium, ascends in the nest and pierces its summit; the air bubbles escape and the dome immediately flattens upon the water, imprisoning all the embryos, the existence of which begins to be manifest.

Fearing lest the young should escape his care, he sets to work to make a new barrier for them. For this purpose he follows and traverses the outer margin of the floating carpet, and pulling at it with force, separates it from the felt, thus obtaining a sort of pendent fringe where the stray young ones will not be able to pass; then, having got rid of all anxiety from this side, he takes his young in his mouth and removes them to short distances, always conveying those of the circumference toward the center.

If some of the young fish venture to descend vertically, he goes in search of

them, and carries them back to the protective dwelling. This surveillance lasts until the embryos, having undergone their complete evolution, have acquired strength and agility. Their numerous and frequent flights announce to the male the end of his troubles, which comes about eight or ten days after the sinking of the nest.

The same pair of fish gave me three ovipositions during the summer of 1875, each consisting on the average of 150 ova.

The embryos of the Rainbow fish undergo a series of transformations analogous to those which I first indicated as occurring in *Macropodus*. Want of time and dread of affecting the existence of animals which are still rare prevented my following this investigation with all the attention that the subject deserves; but I propose to resume it hereafter.

All M. Carbonnier's observations on the fish were made in Paris, in small aquaria containing about 15 liters, the temperature of the water being kept at 23 to 25° C. (= 73.4° to 77.77° F.).

ON THE RELATIONS BETWEEN THE UNITED STATES OF AMERICA AND GERMANY, ESPECIALLY IN THE FIELD OF SCIENCE.[a]

By Herr WILHELM WALDEYER.

The rapid flight of time has again brought round the day that we gladly set apart for presenting to our illustrious protector, His Majesty the Emperor and King, our veneration and homage, and for offering him, with loyal gratitude, our hearty congratulations in the name of his Academy of Sciences, in which he retains a vivid interest, which he has especially signified this very day by presenting to the permanent secretary a golden chain of office.

May our knightly and warm-hearted prince continue to withstand, as heretofore, the assaults of advancing years, and may he be enabled to maintain enduringly and firmly that noble and lofty aim of his political efforts—the preservation of peace and its blessings. Indeed the past year, in which we have been forced to witness one of the most powerful dramas in the world's history, the first great struggle around the shores of the Pacific Ocean, brings this wish home to us. In the distant East there still resounds the din of the frightful war which began last year immediately after we had here assembled for a festival like the present. And now its convulsions approach our own borders! What the year just begun may bring to us from these almost inconceivable complications we know not, but one thing we do know—that we may trust our sovereign. God bless him and his house!

While a view of the East shows us a gloomy picture, toward the West we see a bright and joyous one. In the heart of the great American Union the peoples of this terrestrial ball assembled for a work of peace which we venture to hope may spread its blessings as far as our own boundaries. There indeed our own country, thanks

[a] Address delivered at the public session of the Royal Prussian Academy of Sciences, January 26, 1905, on the occasion of the celebration of the birthday of His Majesty the Emperor and King, and the anniversary of King Frederick II. Translated with revisions by the author from Sitzungsberichte des Königlichen Preusssichen Academie der Wissenschaften, IV, 26 Januar, 1905.

again to the initiative of our Emporer, took an honorable position, and in a competitive exhibit of industrial arts, particularly in the scientific field, obtained the unqualified and freely bestowed approbation not only of our American hosts, but also of all other rivals. We again recognized where our strength lies. May we never forget it!

To the youthful culture of America there was contributed during the past year, likewise through a noble impulse of our Emperor, a fresh memorial of our renewer and second founder, King Frederick the Great, whose memorial day we celebrate together with this anniversary of our Emperor's birth. The statue of the great king has been set up in the capital city of that Union toward which, at the time of its formation, he evinced deep interest and a friendly appreciation.

The fact that there are men who, as has been shown in this connection, think it necessary to find fault with everything, and, unfortunately, others to whose low and hardly human intelligence nothing seems worthy of esteem, should not trouble us. All this vanishes before the manly words with which the clear, wide-seeing, and nobly thinking President of the United States welcomed the gift of our Emperor. Seldom, indeed, has the great general, the provident statesman, the friend of science, and the true philosopher on the throne—Frederick the only—received so just a valuation as that from Theodore Roosevelt, the President of the great American Republic.

It seems appropriate on this occasion to recall the attitude of Frederick toward the young assemblage of States across the ocean whose waters afford an unimpeded passage to our own shores, and to associate with it the attitude of modern Germany toward the United States of to-day. This may be regarded as a legacy of the King, our renewer, reaching down as far as our own times, when thousands of hands have grasped each other with friendly pressure from across the sea.

George Bancroft,[a] the former ambassador of the United States at the court of Berlin, Friedrich Kapp,[b] and, recently, A. Pfister,[c] who have drawn so exhaustively from the archives of this country that there hardly remains anything for their successors to find, give us a clear picture of the sentiments of Frederick the Great toward the rising States of the Union, as of the attitude which he assumed toward them. A strongly woven historical bond unites the develop-

[a] Bancroft, George: History of the United States from the Discovery of the American Continent. Boston, 1874.

[b] Kapp, Fr.: Friedrich der Grosse und die Vereinigten Staaten von Amerika. Leipzig, 1871.

[c] Pfister, A.: Die Amerikanische Revolution, 1775–1781. Stuttgart und Berlin, 1904.

ment of the great North American confederation with that of the Prussian Kingdom, indeed with that of the new German Empire, if we recognize Prussia as the backbone of that Empire, and that King Frederick in the Seven Years' war, beginning with unsettled conditions, filled out and firmly united this backbone. In truth the Seven Years' war was by no means limited to the Germany of that period, Austria, and Europe. It affected as no previous war had done the Western Hemisphere and laid there the foundation for the wide-reaching power of the United States. England, at first in alliance with Frederick, attacked France, the enemy of Frederick, upon the sea and in North America, where at that time Canada and the entire interior beyond the English coast colonies as far as the great Mississippi River and the southern shores along the Gulf of Mexico were under French domination. After an unfortunate beginning in the conduct of the war on the part of the English, the day of Quebec, September 13, 1759, when two brave commanders, Wolfe and Montcalm, pitted themselves against each other and both lost their lives, decided the conflict in favor of Albion. As a victor's prize for this battle, which was small indeed as regards the number of combatants, but almost unexampled in its conduct and far-reaching results, the English obtained the whole of Canada, as well as unobstructed access to the Mississippi from the coast. "The Seven Years' war," says Bancroft[a] in this connection, "extended the English colonies to the Mississippi and gave Canada to England. 'We conquered America in Germany,' said the elder Pitt, ascribing to Frederick a share in the extension of the Germanic race in the other hemisphere; and in like manner Frederick in his histories treats the English movement in America and his own struggles in Europe all as one so long as Pitt was at the helm."

In this sudden extension of English rule over so wide an area of American soil it is easy to recognize one of the quietly working factors that led, a few years later, to the separation of the States of the Union from old England. George Washington, who as colonel in the Seven Years' war helped to win for England this vast country from its possessors, was the illustrious leader who afterwards freed it from her domination and the great statesman who secured permanent stability from the first fortunate successes. After the peace of Paris, in 1763, the thirteen English colonial states became aware of the future that lay before them—they also had proved their strength in the "Seven Years'" or rather "Nine Years'" war with France—and almost from that hour we may note their obstinate opposition to the measures of the mother country to which they had not agreed, until,

[a] History of the United States, Vol. X, p. 86. Boston, 1874.

in the last days of 1773, the "tea party" at Boston gave the opening signal for separation.

There is, therefore, a connection, both in time as well as in the persons concerned, between the origin of the Union and the establishment of Prussia as the leading German state.

Now, the reason for the still closer relations that ensued between young America and Prussia upon this historically prepared ground arose from the behavior of England toward Frederick in the last years of the Seven Years' war, in which she might be reckoned as an enemy rather than as a friend. King Frederick had not forgotten that, and treated as feasible the propositions of the Colonial States then struggling toward freedom in their conflict with England. Had he been able to provide a fleet he would have made a commercial treaty with the States while the conflict was still going on. Again and again he says that without a fleet he has no means of enforcing a treaty and making it operative. He was therefore obliged to content himself with stopping the passage through Prussian territory of the auxiliary troops England had obtained from various German states, particularly from Hesse, and with favorably influencing toward America other states, among them France and Russia. That the young Government might grow up to be the first great Republic was to the far-seeing monarch no obstacle. I need only refer in this connection to his noteworthy commentary, in which he compares the republican and monarchical forms of government.[a]

We should take care, however, not to place too much weight upon the expression by Frederick of favorable and friendly sentiments toward the United States. The great king was a practical politician; sentimental politics were entirely out of his line. With him the controlling principle was the welfare of his State, down to that of his humblest subject; hence the rule that directed his conduct was care for the intellectual elevation and education of his people. Bancroft[b] has an excellent, brief passage on this subject: "No prince could be further than Frederick from the romantic attempts to rescue from oppression foreign colonies that were beyond his reach. * * * His cares are for the country which he rather serves than rules; he sees and exactly measures its weakness as well as its strength; he cares for every one of its disconnected parts, and gathers them all under his wings; but he connects his policy with the movement of the world toward light and reason, the amelioration of domestic and international law."

Yet that might and did suffice for the equally practical sense and sober judgment of the Americans. In the United States Frederick the Great has always remained a national figure in the best sense of

[a] Oeuvres, I, 239. [b] History of the United States, Vol. X, p. 103.

the word. It is worthy of note that one of the last great political acts of Frederick was the conclusion of a commercial and friendly treaty with the North American Union. Although that treaty was not renewed at the expiration of the term for which it was fixed, this was merely because the commerce between Prussia and the Union was so slight that there were no strong inducements for renewal. Besides, matters in France absorbed all attention. Although Kapp says, with somewhat harsh judgment, that statesmen like George Washington and Hertzberg had exaggerated and confused ideas as to the significance of this treaty, I will not hesitate to quote a few words from letters written by Washington to Rochambeau and to Lafayette: "Some of the late treaties," says the man who was soon to be the first President of the North American Union, "and particularly that between the King of Prussia and the United States, seem to promise a new era in negotiation and to promise the happy consequences I have just now been mentioning. It is the most liberal treaty which has ever been entered into between independent powers. It is perfectly original in many of its articles, and should its principles be considered hereafter as the basis of connection between nations, it will operate more fully to produce a general pacification than any measure hitherto attempted amongst mankind."[a] What Washington here says is really contained in the articles of the treaty, and since these two great contemporaries—King Frederick and the first ruler of the Union—cooperated in this manner for a work of peace which they conceived as such, this treaty has actually since that time served as a pattern in all essential respects in our relations with America and will still continue to do so.

But how greatly have these relations developed in the last one hundred and twenty years! It is true that at an early period German immigrants were already an important constituent of the population of the United States. I recall the settlement of Germantown, in Pennsylvania, in 1683, to-day a suburb of Philadelphia, from whence the first protest against slavery was issued. But how greatly has the influx of Germans increased! Right in the center of America, upon the blessed agricultural fields of Missouri, Iowa, Illinois, Wisconsin, and Minnesota, around the head waters of the Mississippi, the Germans have settled, and there most faithfully shown their national peculiarities. Even to-day they constitute, next to the people of the United Kingdom, the strongest stream of immigration. And, if I may speak my thought openly, I will say that it is most desirable for the United States that this should continue. Those who first took possession of the land and have since cultivated it belonged to the Germanic race. The population derived from the Romance and Sla-

[a] Sparks, J: The Writings of George Washington, Vol. IX, pp. 182, 194.

vic races has been much less and will remain so. The intermixture of the native born with the immigrants will proceed most quickly and in the best manner if the latter come from states having a Germanic population. Considerably more than five millions of the inhabitants of the United States continue to speak their German mother tongue together with English, hold German schools, hear German church service, read German books and newspapers published in that country, maintain German customs, and know how to combine and preserve a love for their American fatherland with faithful memories of their maternal home.

The commercial and intellectual interchange between us and America amounts at the present time to millions of letters, telegrams, and articles of merchandise, and to-day we journey as rapidly from Berlin to New York as we did seventy years ago from Berlin to Königsberg. Next to the old mother country, Albion, Germany is the land whose ties and common interests with America come first in question and whose fostering care and requirements must above all be near to the hearts of both countries, since it has an historical as well as a natural foundation. The former we have endeavored to briefly set forth; the latter is shown by the unusual increase of trade which has developed in an entirely natural manner.

We may also go yet further and say that the relations of Germany to the North American Union are so determined by the geographical position and most intimate—I might almost say family—interests of the two countries that they entirely forbid to either any conflicts except those of a peaceful character. America and Germany are to each other like brothers. There may be contentions and misunderstandings even among brothers, yet this is soon followed in the reasonable course of things by the restoration of harmony. There are really no vital antagonistic interests between the German coasts of the North and Baltic seas and the ocean coast of America. This was expressed by Carl Schurz on the 7th of October of last year, the German day at St. Louis,[a] as follows:

> No international friendship could be more natural than that between this Republic and the German Empire. There are not only the bonds of blood and the common Germanic spirit that cement the relationship between the two nations; there is also the complete absence of any antagonism of great interests which might separate them. In fact, no one can show a single point in which the great interests of the two countries or even the directions of their just ambition run counter to each other.

These two political bodies, whose development has not as yet nearly reached the noonday height—indeed, Germany, since her unification was the later effected, may in this sense be called the younger—are

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[a] See the Westliche Post, edited by Doctor Pretorius, in St. Louis, of October 7, 1904.

brought together by what I might call natural gravitation. Each can lend to the other light and blessings of all kinds as international comity may demand and require, and it is therefore idle and irrelevant to dispute as to which may hereafter be the weightiest and most permanent organism. That rests in the bosom of time. It is enough that, judging by human foresight, they can not injure each other.

The task which, for both peoples and states, arises from this condition is that of effecting as close a union as possible and of avoiding everything that may tend in any way to injure existing harmony, for only so will both secure in the fullest extent the advantages which, as one may say, spontaneously arise.

The relations between peoples and States are manifold, hardly to be followed out and specified in detail. They can only be considered in large comprehensive groups: The international political relations and actions toward, with, and against each other; the relations with a third party, the military relations, and above all the commercial and industrial relations. These all deal with questions as to bare existence. But in the lives of cultivated peoples, as soon as a certain stage of development is reached, there are engendered many higher relations, such as those of morality and religion, art and science. In these matters, peculiar to man alone, lies that which makes life worth living. It is these that we are now to consider, especially the scientific relations between the United States and Germany, touching the others only in so far as they have a scientific basis or belong to history. I must, however, entirely omit the latter, as it would lead us much too far afield.

How should we conduct ourselves toward America in the great domain of science? In advance I will say one thing: If two peoples are to cooperate in the advancement of culture as also in the reciprocal demands of material interests, they must respect each other. Each must have something good and self-achieved to offer, each must preserve its own individuality without obtrusive ostentation, but with quiet certainty, such as that given by the natural feeling of one's own health and strength. He who does not have confidence in himself will soon lose the confidence in others. To our American brethren sprung from German stock I make this appeal in relation to the departments of art and science as well as those of morals and manners. Do not form an exclusive clan in a great State—but be a powerful root that brings healthy sap to the mighty, spreading, gigantic tree to which we may liken the Union. In this way you will obtain the regard as well as the full confidence of your fellow-citizens of Anglican stock, who, changed and transformed by the climatic exigencies of North America, make the nucleus of what we call the "American nation."

You may also be of use to us by counteracting tendencies that in an unauthorized way threaten to injure the mother country, by helping to remove prejudices that arise there and to clear up our own misunderstandings and unjust suspicions by pointing out the good which we often fail to see either through prejudice or from ignorance of the nature of the people and of the political and social institutions beyond the ocean. I am happy to say that this conception of the situation of the American citizen of German descent and speech prevailed as the keynote of the many demonstrations which were given at St. Louis on "German day," celebrated on October 6, 1904, and the same note agreeably sounded in my ears wherever I, in social circles, discussed this subject with intelligent persons.

In order to properly and usefully comport ourselves in scientific relations we must first of all know what the Americans in general think of culture and science, what is the present condition of science and scientific research in America, and how it is likely to be modified in the near future.

There is widely spread among us a false prejudice that Americans turn predominantly toward material interests and have but little inclination to purely scientific matters. Those who hold this forget that the most famous of the American universities, Harvard, in Cambridge, Mass., with an attendance of more than 5,000 students, celebrated not long ago the anniversary of its establishment in 1636; that Yale University, at New Haven, Conn., likewise highly regarded, has had a festival celebrating the two hundredth year from its foundation; that Princeton University, in New Jersey, Brown University, in Providence, R. I., and Pennsylvania University, in Philadelphia, are about as old as Göttingen. Besides these, Columbia University, in New York, which is striving in noble competition to reach the top, was established more than seventy years ago. They forget that in the course of from seventy to forty years five universities of the first rank have been established—the Johns Hopkins University, in Baltimore; the Cornell University, in Ithaca, N. Y., formerly under the direction of the worthy Ambassador Andrew D. White, who has recently sent us friendly regards from over sea in his "Autobiography;" the University of Chicago, Ill., the Leland Stanford University, Cal., and the Berkeley University, to which belongs the renowned Lick Observatory, on Mount Hamilton, in California. They especially forget the numerous great public libraries, with their model equipment, which make it possible for everyone to obtain intellectual food; only a few of us know how much these are used by all classes, including the working people.

The American knows very well that culture brings freedom with it, and that in the fierce struggle for life, in which he must either conquer or be overcome, methodical training is necessary if he would

keep his head above water. Hence the great care which we see in America for public schools, for advanced schools of all sorts, for museums, collections, laboratories, public lecture courses, all of which are of an abundance excelled by only a few similar establishments in the Old World, and in practical arrangement and facility of use are surpassed by none of our institutions, if, indeed, ours do not yield to them in this respect. Although their earlier progress was rapid, that of the last ten years exceeds all expectations. It needs no gift of prophecy to predict that in fifty years the institutions of the Union will far surpass ours in good arrangement, ease of use, and wealth of means offered.

Now, has anything been attained by this liberal provision for the equipment of scientific work? This leads us to some intermediate considerations.

The endowment of any special ability, whether bodily or mental, is an inborn gift of nature; it can not be increased in any organization beyond the limits permitted by that organization. A mathematician can not be made out of a man whose brain does not possess the necessary endowment any more than a singer can be made from anyone who is defective in the auditory centers of the brain, in the organs of hearing, or in the larnyx. These natural endowments are sometimes hereditary in families; quite often, indeed, perhaps oftener, the reverse is the case. Neither material prosperity nor high social position have anything to do with the production of these endowments; on the contrary we often see capable intellects of the first rank emerge from the great mass of the people, from those in poor circumstances as frequently as from families that have long enjoyed favorable conditions—a benificent, equalizing justice of nature. It can not be denied that certain races are preferred—the history of science teaches it. They are those which, with a generally healthy and harmonious development of the body, possess brains of the largest size relative to the body mass. Another factor has doubtless an influence here; I refer to all that is generally inferred when we use the word "climate." Neither the excessive darkness of the polar regions nor the flood of sunlight at the equator appears favorable; it is in the temperate zones, in countries much diversified by land and water, with fertile soil and a complete alternation of seasons that we find the most favorable climatic factors. In such countries one can not rely upon fruit dropping into the mouth; one must work, but the work rewards and at the same time tempers the worker. I think it is clear that the factor of climate does not work directly. I am much more inclined to believe that it works by producing well-built, healthy men with good brains.

Now, on the other hand, it is not the less true that a certain already attained development of culture and institutions likely to

have a favorable influence—such as good means of instruction of all kinds, libraries, methods of intellectual interchange and others—frequently aid in the bringing forward of men of intellectual force. That is, however, easily explained. Given two muscles equally well organized, the one will become more efficient that is given opportunity to exercise and test itself, so if we take two equally endowed brains the one will prove the most effective to which the best intellectual nourishment and the most opportunity for exercise is afforded. How many highly endowed heads have never attained their full working power because they were surrounded by barriers through which they could not break? Men of true genius, like Napoleon I, Shakespeare, Gauss, may perhaps overcome every obstacle and by reason of their original creative force do without many things and yet succeed, yet easily accessible aids will arouse and inspire many capable men whose powers would otherwise remain obscure.

If we now compare "old" Europe, as we sometimes hear it called over there, with the United States, we find that in both regions the climatic factor is of the highest quality, although there are in western North America wide areas unfavorably situated, yet there are very large portions of the country that lie as favorably and are as well formed as any part of Europe. The human type is the same, for, indeed, all Europe has contributed of her best to form a large part of the population of the Union. The cultural appliances are similar and in many respects better; America excels, as has been said, in ease of their use and in their manifold character. With these appliances America will doubtless develop in the course of time a high average of capable men and women in all spheres of activity. The advantage of such an intellectual support, equal to all the growing demands of the great whole, is to be prized much higher than that of an equal number of men of great corporeal strength, although I certainly do not wish to undervalue such men; there is no truer saying than "Mens sana in corpore sano." The truth of this saying has, however, been recognized in the education of American youth.

It is by no means in the natural and technical sciences alone that the Americans have distinguished themselves. From the excellent work of H. Münsterberg, professor of philosophy in Harvard University,[a] who is highly regarded on both sides of the ocean, we find, together with the names of naturalists such as Audubon, Cope, Osborne, Marsh, Dana, Alexander Agassiz, Wolcott Gibbs, Rowland, Newcomb, and Gould—the six last being all corresponding members of our academy—the names of the political economists and jurists, Charles Francis Adams and Sumner; of the historian of literature,

[a] Münsterberg, H., Die Amerikaner. Berlin, 1904. See especially Vol. II, chap. 20.

J. Child; the orientalist, Hilprecht; the Sanscrit scholar, Whitney; the philologist, Hadley; the philosophers, Emerson and Royce, as well as the historians, Bancroft, Parkman, and Charles Kendall Adams—all of the best renown. From the imposing list of names cited by Münsterberg I have here selected only a few best known to me by their works, and upon these I do not attempt to pass judgment.

To rightly understand the Americans we must remember that even their oldest cities never had walls; that there have never been there any of those endless petty feuds of single cities with each other and with their overlords which, in their day, did so much to retard the development of Germany; that they have never had imposed upon them any compulsory feudal service or similar burdens other than those they themselves voluntarily assumed; that the state does not concern itself with religious creeds—there being no question of "the church" as a political force—nor do the creeds trouble themselves about the state. All this produces a breadth of view and a feeling of personal independence, which feeling the Americans likewise inherit from the founders of the Republic and traditionally maintain in their education. This is again reflected in their great scientific establishments, as an example of which we may take the Smithsonian Institution at Washington to show the magnificent manner in which such views are realized.

This Institution is a scientific central station for the entire Union and effects an exchange of writings and scientific objects with the museums and scientific establishments of the entire world. It also administers a museum remarkably rich in specimens relating to natural history and ethnology, especially that of America; an astrophysical observatory of the first rank, and a zoological garden, which, among other objects, seeks to perpetuate those species that are threatened with extinction. A considerable library of some 200,000 volumes is attached to it. The executive body of the Institution, administering it under the ægis of the Government, has among its members some of the most notable men of the country. At its head is the President of the United States for the time being. Besides about half a million of dollars appropriated annually by Congress, the Institution controls considerable means derived from its own resources. These are used for the furtherance of researches of the most various kinds, as is done by our own academies and learned societies.

Other establishments similar to this are by no means wanting in the United States. They have not, however, yet reached the importance enjoyed by the great academies of the Old World. The most important and noteworthy American academy is the National Academy of Sciences. It was established in 1863, has a membership practically limited to 100 members, and has always held a very high rank.

Membership in it is considered one of the highest honors that can be attained by a scientific man. It is made by law the accredited scientific adviser of the Government. Another of the more important American academies is the Washington Academy of Sciences, which acts as the federal head of a series of affiliated societies devoted to anthropology, archæology, general biology, botany, chemistry, entomology, forestry, geography, geology, history, medicine, philosophy, and physical sciences. There should also be mentioned the American Association for the Advancement of Science and the National Educational Association. Besides these I will here mention the Stanford University, at Palo Alto, Cal., as an institution of the first rank. It was established in 1891, has an endowment valued at $40,000,000, and has on its staff of teachers some of the first scientific men in the United States. Its president is the eminent ichthyologist, Dr. David Starr Jordan. Finally, I must not omit one of the youngest of the great establishments of this kind, the Carnegie Institution, established in 1902 by Mr. Andrew Carnegie, with an endowment of $10,000,000. It has for its special object the furtherance of original scientific research.

I was repeatedly able to personally satisfy myself upon the spot as to the progress which is being made, especially in the biological sciences and their application. I also had an opportunity, at the St. Louis Exposition, of examining the educational sections in all their ramifications. I find that over there they are equal to us in all essential respects—in the kind and method of scientific work, in the value of the same, in the fitting up and equipment of laboratories, in the materials for instruction, in the style and method of imparting knowledge. Visit the great workshop of Alexander Agassiz at Cambridge; the anatomical laboratories of Huntington, in New York, at Columbia University; and of Mall at Baltimore; the Peabody Museum at Yale University in New Haven, so richly filled by Marsh; the Anthropological Museum at New York, and others, and you will say that I am right. J. Orth recently published a similar opinion.[a] In a few years the new buildings of the medical school of Harvard University will be ready, and what I saw of the plans at the St. Louis Exposition leads me to think that in them we shall have the best yet produced.

I have sought to give a concise sketch of what the great American Union has done for science up to the present time and what it is in a condition to offer us to-day. What should we do to maintain and increase the natural ties that now knit together the scientific interests of that great country and our own?

[a] Orth, J.: Über ärztliche Schulen und Anstalten in Nordamerika, Berliner klin. Wochenschrift, 1905, No. 2.

If we proceed to compare the scientific capital that we possess with that of America we find that as regards the factor of climate and the creative and thinking human material we are about the same. The advantage which we perhaps possess as regards the age of our materials for culture and historical background will disappear in the course of time. Our scientific institutions are good, but we should be careful not to restrict the free development that they have always had hitherto, for if we do so we will quickly fall behind America. Science and art thrive only in the open air! One thing should be mentioned in which America is excelled by the Old World of western Europe—I do not refer alone to Germany—that is in scientific discoveries and theories which open entirely new scientific domains, such as the discovery of a surprisingly large number of new chemical elements; spectral analysis, together with astrophysics; the great discoveries in the chemistry of dyes and sugars, the physical chemistry of the phenomena of solutions, the liquefaction and condensation of gases, especially liquid air, the Röntgen and Becquerel rays, radium and its rays, color photography, the electric dynamo, electric lighting—indeed, most of the investigations and applications of electricity as a source of power—the electric furnace and its application, so fruitful in the arts; then in the field of biology, almost our entire knowledge of the protista and of bacteriology, with the light which they throw upon epidemiology, toxines and antitoxines, the development of the doctrine of immunity, the discovery of the recondite phenomena of fertilization and karyokinesis, the doctrine of descent and Darwinism, and, crowning all, the conception and establishment of the great idea of the conservation of energy.

These are the discoveries and theories of European investigation of the last fifty years; many of them belong to quite recent time. In the realm of the historical and philosophical sciences also there could be named a great number of men and works which would easily show that here too the preponderance of attainment still rests with Europe. Theodor Mommsen, Moriz Haupt, Leopold von Ranke, Macaulay, Gaston Paris, Karl Ritter, and many others of which Europe may be proud, have indeed passed away; yet their influence is felt throughout many schools that are continuing their work with honor. Europe with Germany in the heart of it has retained up to the present day its fresh and youthful vigor in intellectual work. So long as the climatic conditions remain as favorable as at present there will be no lack of intellectual achievement.

Certainly the education of our youth has hitherto been good, and I do not lightly value the independence of our universities. It is by no means desirable that they all should be made to correspond to a common pattern; we should rather maintain their well-tested organi-

zations. We ought to especially oppose too great a uniformity. The strength of an investigator, of a scholar, or of a teacher lies in the development of individuality. Among the Germans the individuality of investigators and teachers is usually well marked; this should remain so, especially as in the United States there is a tendency to a certain uniformity.

Although to-day the cultured states of western Europe occupy the first place in the field of science, we should not lull ourselves to sleep with the pleasant security that this will always continue to be so. America's scientific capital, as I have above endeavored to show, is equal to ours; she is well in the way of preceding us in the culture of the sciences. She has already produced in considerable numbers men of the first rank whose performances were also of the first rank; others may arise at any time. Let us then seek to keep company with America in our pursuit of science. Let us unhesitatingly allow to the Americans whatever they may have that is as good or better than ours; let us gladly receive it from them. If then, by our own effective ability, we preserve their regard and esteem, we shall help more and more to strengthen in the scientific field the bond that naturally exists between America and Germany. And now I will touch upon an important point which at the present time is of marked interest. Hitherto young Americans have come to us in order to learn from us, but the time has now arrived in which the German and European students should travel in America for the purpose of broadening their culture. This scientific exchange from person to person, from university to university, and from academy to academy should be favored as far as possible. Let us be as liberal as they are to us in the reception of all those eager for knowledge and in granting them everything that they need. Let us place the published results of their work in our libraries, at least in the great Royal Library of the chief city of the Empire. Let us in all things show them that in Germany they come to a people intellectually allied, under whose political and social institutions even they with their free views may feel at home. Everyone who has been their guest can say in their praise that they treat us in this manner. Americans welcome men of science with a feeling of appreciation and friendliness. So may we also, while fully guarding our interests and our individuality, contribute much toward keeping up the relations between the two peoples, or indeed toward knitting them more closely together.

We should act toward America as the Americans do toward Germany. We should also try to form a correct judgment of the scientific work of the Americans by personal examination. We should, more than hitherto, inform ourselves upon the spot. It would do no harm if annually a number of German students should seek to widen

their horizon by a course at American universities. I also unhesitatingly favor the scheme already in operation for several years, and first thoroughly agitated by our fellow-member, Mr. Harnack, of allowing American investigators to give full courses at German universities, and vice versa German teachers at American ones. The further realization of this arrangement should be hailed with joy.

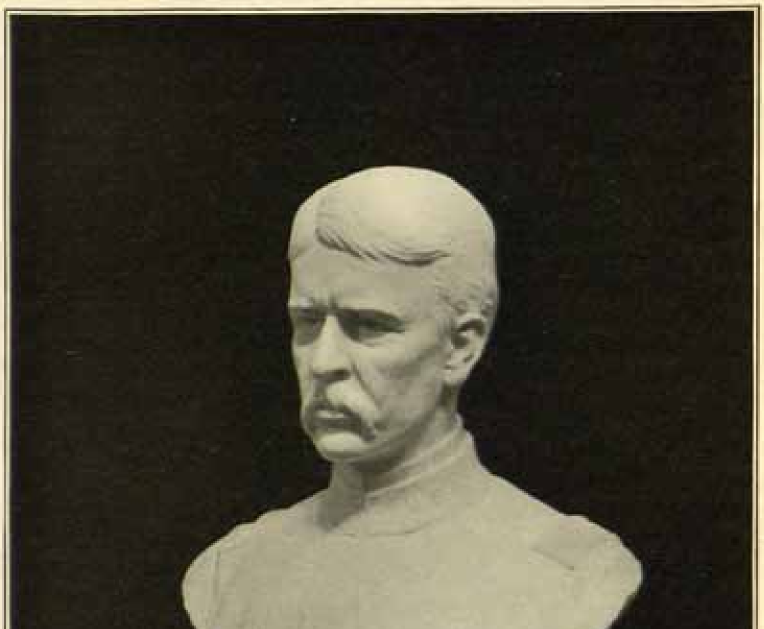
In the association of academies a wider bond of union is afforded. Our academy has always willingly met the wishes of the learned institutions of America, of which not less than forty-four have established with us a regular exchange of publications.

May all this be looked out for, futher developed, and followed up, in order to adapt itself to the natural tendency that, in the scientific field, inclines us toward the United States. I do not feel called upon to advise the Americans as to their future behavior toward us, for if we remain at the level we now occupy they will need no advice, but will willingly maintain and extend their old relations in the pathway of science.

And then, aside from all other considerations, looking merely upon science and its service, will not such an intercourse fulfill the noblest and highest mission that comes within the province of science—the advancement and elevation of culture from people to people?

However, in these thoughts we only reflect the sentiments and resolves of our great protector, the Emperor and King, whose birthday we here celebrate. As the history of his reign unequivocally shows, he cherishes for the trans-Atlantic Republic the same open and friendly feelings as did his great ancestor. We can to-day offer no more suitable wish than this: That the noblest aspirations of both peoples, carrying blessings in their train, may be fulfilled.

There is yet another wish that is near our hearts to-day, which, with due respect, we may be allowed to express. His Imperial Highness the Crown Prince of the German Empire and of Prussia has contracted an engagement with a noble princess, who will be called to stand by his side during life while he accomplishes the lofty task which will in the future be assigned to him. May hope and peace, health and blessings attend the imperial and royal pair.



WALTER REED.

WALTER REED.[a]

A MEMOIR.

By WALTER D. McCAW.

It is given to but few scientific men to lay bare a secret of nature materially affecting the prosperity of nations and the lives, fortunes, and happiness of thousands. Fewer still succeed in so quickly convincing brother scientists and men in authority of the truth of their discoveries, that their own eyes behold the glorious result of their labor.

Of the fifty-one years of Walter Reed's industrious, blameless life, twelve only were spent in the study of the special branch of science in which he became famous, but his name now stands with those of Jenner, Lister, and Morton as among the benefactors of humanity.

Walter Reed was born in Gloucester County, Va., September 13, 1851, the son of the Rev. Lemuel Sutton Reed and Pharaba White, his wife.

The circumstances of his family were modest, and some of the years of his boyhood were spent in a much-troubled section of the South during the great civil war. He acquired, however, a good preliminary education, and at an age when most boys are still in the schoolroom, he began the study of medicine at the University of Virginia, graduating as M. D. in 1868, when only 17 years old.

A second medical degree was received later from Bellevue Medical College, New York, and then came terms of service in the Brooklyn City Hospital and the City Hospital, Blackwells Island.

Before the age of 21, Reed was a district physician in New York City, and at 22 one of the five inspectors of the board of health of Brooklyn.

He entered the Army of the United States as assistant surgeon with the rank of first lieutenant in 1875, and for the next eighteen years, with the usual varying fortunes of a young medical officer of

[a] Published by Walter Reed Memorial Association, 1904, and reprinted by permission.

the Army, he served in Arizona, Nebraska, Dakota, and in the Southern and Eastern States.

According to the exigencies of the service he was moved frequently from station to station, everywhere recognized by men of his own age as a charming and sympathetic companion, and by older officers as an earnest and intelligent physician whose industry, fidelity to duty, and singularly good judgment gave brilliant promise for the future. In the poor cabins and dugouts of the pioneers in the sparsely settled districts where he served his flag Reed was ever a messenger of healing and comfort. At that time army posts on the frontier were usually remote and with small garrisons. The young medical officer, generally the only one at the station, was called upon by the settlers for miles around. Without help, and with only such instruments and medicines as could be hastily stuffed in his saddlebag, he was summoned to attend a fractured thigh, a child choking with diphtheria, or, most trying of all, a complicated childbirth.

Such experience schools well in self-reliance, and in the formation of quick and accurate observation.

For a man like Reed, already an earnest student, no better preparation could perhaps have been had. His earlier army service must have singularly tended to develop in him the very qualities most necessary to his final success. To the end of his life it was noticeable that even when he had long given up the practice of medicine for the work of the laboratory, he was nevertheless unexcelled at the bedside for rapid, unerring diagnosis and sound judgment in treatment. So also were the series of experiments which robbed yellow fever of its terrors especially remarkable for simplicity, accuracy, and completeness, or they never would have so quickly convinced the world of their truth. Too much reverence for accepted teachings and too little experience in grappling with difficulties unassisted and they might never have been conceived or carried out.

In 1890 he was assigned to duty in Baltimore and remained there over a year. Here he had the great advantage of working in the laboratories of Johns Hopkins University and the happiness of winning the close friendship of his distinguished teacher, Prof. William H. Welch.

In 1893 Reed was promoted surgeon with the rank of major, and in the same year was detailed in Washington as curator of the Army Medical Museum and professor of bacteriology at the newly organized Army Medical School. Here he worked industriously at his specialty and wrote many valuable monographs, all characterized by accuracy and originality. His excellent judgment made him especially valuable in investigating the causes of epidemic diseases at military posts and in making sanitary inspections. He was therefore frequently selected for such work, which, with his duties as teacher

and member of examining boards, occupied much of the time that he would otherwise have spent in his laboratory. Here again it seems that duties which must often have been irksome were specially fitting him for his culminating work.

During the Spanish-American war the camps of the volunteer troops in the United States were devastated by typhoid fever, and Major Reed was selected as the head of a board to study the causation and spread of the disease. This immense task occupied more than a year's time. With the utmost patience and accuracy the details of hundreds of individual cases were grouped and studied. The report of the commission, now in course of publication by the Government, is a monumental work which must always serve as a basis for future study of the epidemiology of typhoid fever.

The most original and valuable work of the board is the proof that the infection of typhoid fever is spread in camps by the common fly and by contact with patients and infected articles—clothing, tentage, and utensils—as well as by contaminated drinking water.

In June, 1900, Major Reed was sent to Cuba as president of a board to study the infectious diseases of the country, but more especially yellow fever. Associated with him were Acting Asst. Surgs. James Carroll, Jesse W. Lazear, and A. Agramonte.

At this time the American authorities in Cuba had for a year and a half endeavored to diminish the disease and mortality of the Cuban towns by general sanitary work, but while the health of the population showed distinct improvement and the mortality had greatly diminished, yellow fever apparently had been entirely unaffected by these measures. In fact, owing to the large number of nonimmune foreigners, the disease was more frequent than usual in Habana and in Quemados, near the camp of American troops, and many valuable lives of American officers and soldiers had been lost.

Reed was convinced from the first that general sanitary measures alone would not check the disease, but that its transmission was probably due to an insect.

The fact that malarial fever, caused by an animal parasite in the blood, is transmitted from man to man through the agency of certain mosquitoes had been recently accepted by the scientific world; also, several years before, Dr. Carlos Finlay, of Habana, had advanced the theory that a mosquito conveyed the unknown cause of yellow fever, but did not succeed in demonstrating the truth of his theory.

Dr. H. R. Carter, of the Marine-Hospital Service, had written a paper showing that although the period of incubation of yellow fever was only five days, yet a house to which a patient was carried did not become infected for from fifteen to twenty days.

To Reed's mind this indicated that the unknown infective agent has

to undergo a period of incubation of from ten to fifteen days, and probably in the body of a biting insect.

Up to this time the most generally accepted theory as to the causation of yellow fever was that of Sanarelli, who claimed that the bacillus icteroides, discovered by him, was the specific agent of the disease. Major Reed, in association with Doctor Carroll, had, however, already demonstrated that this bacillus was one widely disseminated in the United States and bore no special relation to yellow fever.

In June, July, and August, 1900, the commission gave their entire attention to the bacteriological study of the blood of yellow-fever patients and the post-mortem examination of the organs of those dying with the disease. In 24 cases where the blood was repeatedly examined, as well as in 11 carefully studied autopsies, bacillus icteroides was not discovered nor was there any indication of the presence in the blood of a specific cause of the disease.

Application was made to Gen. Leonard Wood, the military governor of Cuba, for permission to conduct experiments on nonimmune persons and a liberal sum of money requested for the purpose of rewarding volunteers who would submit themselves to experiment.

It was indeed fortunate that the military governor of Cuba was a man who by his breadth of mind and special scientific training could readily appreciate the arguments of Major Reed as to the value of the proposed work.

Money and full authority to proceed were promptly granted, and to the everlasting glory of the American soldier, volunteers from the Army offered themselves for experiment in plenty, and with the utmost fearlessness.

Before the arrangements were entirely completed, Doctor Carroll, a member of the commission, allowed himself to be bitten by a mosquito that twelve days previously had filled itself with the blood of a yellow-fever patient. He suffered from a very severe attack, and his was the first experimental case. Doctor Lazear also experimented on himself at the same time, but was not infected. Some days later, while in the yellow-fever ward, he was bitten by a mosquito and noted the fact carefully. He acquired the disease in its most terrible form and died a martyr to science and a true hero.

No other fatality occurred among the brave men who, in the course of the experiments, willingly exposed themselves to the infection of the dreaded disease.

A camp was especially constructed for the experiments about 4 miles from Habana, christened Camp Lazear in honor of the dead comrade. The inmates of the camp were put into most rigid quarantine and ample time was allowed to eliminate any possibility of the disease being brought in from Habana.

The personnel consisted of three nurses and nine nonimmunes, all in the military service, and included two physicians.

From time to time Spanish immigrants, newly arrived, were brought in directly from the immigrant station; a person not known to be immune was not allowed to leave camp, or if he did was forbidden to return.

The most complete record was kept of the health of every man to be experimented upon, thus eliminating the possibility of any other disease than yellow fever complicating the case.

The mosquitoes used were specially bred from the eggs and kept in a building screened by wire netting. When an insect was wanted for an experiment it was taken into a yellow-fever hospital and allowed to fill itself with the blood of a patient; afterwards at varying intervals from the time of this meal of blood it was purposely applied to nonimmunes in camp.

In December five cases of the disease were developed as the result of such applications; in January, three, and in February, two, making in all ten, exclusive of the cases of Doctors Carroll and Lazear. Immediately upon the appearance of the first recognized symptoms of the disease, in any one of these experimental cases, the patient was taken from Camp Lazear to a yellow-fever hospital, 1 mile distant. Every person in camp was rigidly protected from accidental mosquito bites, and not in a single instance did yellow fever develop in the camp, except at the will of the experimenters.

The experiments were conducted at a season when there was the least chance of naturally acquiring the disease, and the mosquitoes used were kept active by maintaining them at a summer temperature.

A completely mosquito-proof building was divided into two compartments by a wire screen partition; infected insects were liberated on one side only. A brave nonimmune entered and remained long enough to allow himself to be bitten several times. He was attacked by yellow fever, while two susceptible men in the other compartment did not acquire the disease, although sleeping there thirteen nights. This demonstrates in the simplest and most certain manner that the infectiousness of the building was due only to the presence of the insects.

Every attempt was made to infect individuals by means of bedding, clothes, and other articles that had been used and soiled by patients suffering with virulent yellow fever.

Volunteers slept in the room with and handled the most filthy articles for twenty nights, but not a symptom of yellow fever was noted among them, nor was their health in the slightest degree affected. Nevertheless they were not immune to the disease, for some of them were afterwards purposely infected by mosquito bites.

This experiment indicates at once the uselessness of destroying valuable property for fear of infection. Had the people of the United States known this one fact a hundred years ago an enormous amount of money would have been saved to householders.

Besides the experimental cases caused by mosquito bite, four nonimmunes were infected by injecting blood drawn directly from the veins of yellow-fever patients in the first two days of the disease, thus demonstrating the presence of an infectious agent in the blood at this early period of the attack.

Even the blood serum of a patient, passed through a bacteria-proof filter, was found to be capable of causing yellow fever in another person.

The details of the experiments are most interesting, but it must here suffice to briefly sum up the principal conclusions of this admirable board of investigators, of which Reed was the master mind:

1. The specific agent in the causation of yellow fever exists in the blood of a patient for the first three days of his attack, after which time he ceases to be a menace to the health of others.

2. A mosquito of a single species, *Stegomyia fasciata*, ingesting the blood of a patient during this infective period is powerless to convey the disease to another person by its bite until about twelve days have elapsed, but can do so thereafter for an indefinite period, probably during the remainder of its life.

3. The disease can not in nature be spread in any other way than by the bite of the previously infected Stegomyia. Articles used and soiled by patients do not carry infection.

These conclusions pointed so clearly to the practical method of exterminating the disease that they were at once accepted by the sanitary authorities in Cuba and put to the test in Habana, where for nearly a century and a half by actual record the disease had never failed to appear annually.

In February, 1901, the chief sanitary officer in Habana, Maj. W. C. Gorgas, Medical Department, U. S. Army, instituted measures to eradicate the disease, based entirely on the conclusions of the commission. Cases of yellow fever were required to be reported as promptly as possible, the patient was at first rigidly isolated, and immediately upon the report a force of men from the sanitary department visited the house. All the rooms of the building and of the neighboring houses were sealed and fumigated to destroy the mosquitoes present. Window and door screens were put up, and after the death or recovery of the patient his room was fumigated and every mosquito destroyed. A war of extermination was also waged against mosquitoes in general, and an energetic effort was made to diminish the number bred by draining standing water, screening tanks and vessels, using petroleum on water that could not be drained, and in the most systematic manner destroying the breeding places of the insects.

When the warm season returned a few cases occurred, but by September, 1901, the last case of yellow fever originated in Habana, since which time the city has been entirely exempt from the terrible disease that had there kept stronghold for a hundred and fifty years. Cases are now admitted into Habana from Mexican ports, but are treated under screens with perfect impunity in the ordinary city hospitals. The crusade against the insects also caused a very large decrease in malarial fevers.

The destruction of the most fatal epidemic disease of the Western Hemisphere in its favorite home city is but the beginning of the benefit to mankind that may be expected to follow the work of Reed and his associates. There can be no manner of doubt should Mexico, Brazil, and the Central American Republics, where the disease still exists, follow strictly the example set by Habana that yellow fever will become extinct and the United States forever freed from the scourge that has in the past slain thousands of our citizens and caused the loss of untold treasure.

More recent investigations into the cause and spread of yellow fever have only succeeded in verifying the work of Reed and his commission in every particular and in adding very little to our knowledge of the disease.

Later researches by Guiteras in Habana, by the Public Health and Marine-Hospital Service in Veracruz, and lastly by a delegation from the Pasteur Institute of Paris in Rio de Janeiro all confirm in the most convincing manner both the accuracy and comprehensiveness of the conclusions of the American commission. It has been well said that Reed's experiments "will always remain as models in the annals of scientific research, both for the exactness with which they were adapted to the points to be proved and the precautions taken that no experiment should be vitiated by failure to exclude all possible sources of error."

Appreciation of Reed's work was instant in the scientific world. Honorary degrees from Harvard University and the University of Michigan were conferred upon him, learned societies and distinguished men delighted to honor him, and after his death Congress voted a special pension to his widow.

To the United States the value of his services can not be estimated. Ninety times has yellow fever invaded the country, carrying death and destruction, leaving poverty and grief.

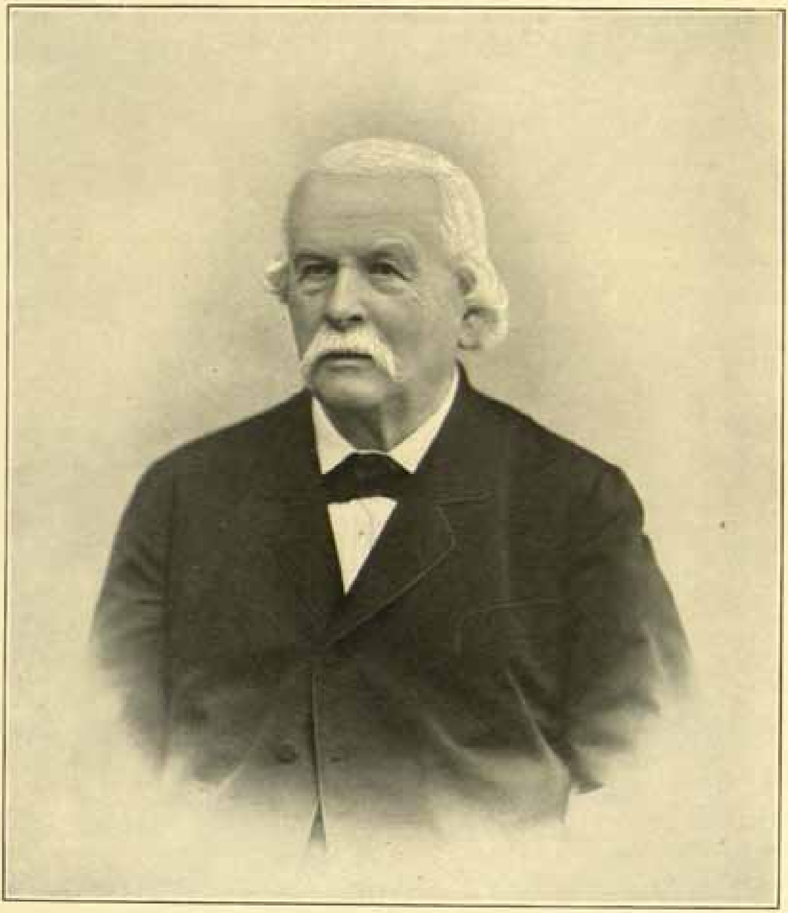
New Orleans, Memphis, Charleston, Galveston, Portsmouth, Baltimore, Philadelphia, New York, and many smaller towns have been swept by the disease.

The epidemic of 1853 cost New Orleans 8,000 lives; that of 1793 wiped out 10 per cent of Philadelphia's population.

The financial loss to the United States in the one epidemic of 1878 was estimated as amounting to $15,333,000; but suffering, panic, fear, and the tears of widows and orphans can never be estimated. Now, however, if yellow fever should again cross our southern border there need be no disturbance of commerce or loss of property in the slightest degree comparable with that which epidemics in the past have caused.

The death of Major Reed took place November 23, 1902, in Washington, from appendicitis. It is gratifying to think that, although his country and the scientific world were deprived of one from whose future services more benefit to humanity might reasonably be expected, nevertheless he was privileged before his life's close to know that his discovery had been tested and that a great city was freed from her ancient foe, to know that his conscientious work had contributed immeasureably toward the future prospects of an infant Republic, and even more to the welfare of his own beloved country, whose flag he had served so faithfully.

In the national capital and in the great cities of the United States there are stately monuments to the country's great ones. Statues of warriors, statesmen, and patriots stand as silent witnesses of a people's gratitude. Is there not room for the effigy of Walter Reed, who so clearly pointed out to his fellowman the way to conquer America's worst plague?



RUDOLPH ALBERT VON KOLLIKER.

RUDOLPH ALBERT VON KÖLLIKER, M. D.,[a]

Professor of anatomy in the University of Würzburg.

By William Stirling,

Professor of physiology and histology, and dean of medical school, University of Manchester, England.

The death of Professor Kölliker was announced in the British Medical Journal of November 11. The venerable scientist died on November 3, of pneumonia, after an illness of thirty-six hours.

The name of Kölliker has been familiar to all histologists and anatomists for nearly half a century, for there is scarcely any department of histology to which he did not contribute largely by his original work. The whole animal kingdom was laid under contribution, and his contributions dealt both with the structures as they appear in adults and with tissues and organs in their development.

Born at Zurich in 1817, just four years after the birth of Claude Bernard, Kölliker began his studies in the university of his native town in 1836. In 1839 he proceeded to Bonn, and later in the same year to Berlin, where he became a pupil of Johannes Müller, who exercised a profound influence on the young and ardent student. Müller's wide survey of physiology led Kölliker to take the same broad view of histology. He took the degree of doctor of philosophy at Zurich in 1841, and because that university insisted on a viva voce examination when he presented a dissertation for a medical degree, he elected to take his degree in Heidelberg in 1842, presenting on the occasion a thesis on the development of *Chironomus* and *Donacia*.

Schleiden, of Jena, published his work on vegetable cells in 1838, and Schwann his cell theory in 1839. In the memoir entitled "Microscopical researches into the accordance in the structure and growth of animals and plants," the cell theory was formulated. Kölliker was thus fortunate in finding a field of research which he cultivated with such marvelous success that up to 1899, when he published Erinnerungen aus meinen Leben, when he was over 80 years of age, the total number of his papers is given as 245, most of them on histological

[a] Reprinted by permission, from the British Medical Journal, London, No. 2342, November 18, 1905.

and allied subjects. At Zurich he listened to the stimulating lectures of Oken on zoology; in 1839, in Bonn, he attended the clinic of Nasse, who gave his lectures in Latin. The future anatomist tells how at the clinic at Bonn he was unable to find the vein in the arm of a very fat lady patient who was ordered to be bled. The turning point in his career came in Berlin in 1839, where he fell under the spell of Johannes Müller and Jakob Henle, whose influence on him was powerful. Under Müller he studied comparative anatomy and pathological anatomy, and under Henle normal histology. Henle instilled into him the epoch-marking doctrines of Schwann and directed his attention to the microscopical structure of the body. There also he got much encouragement from Ehrnberg, Meyen, and Robert Remak. He took a private course under Remak, who gave lectures and demonstrations at his own house on "Development of the chick." This led in future years to a study of development in mammals and many other animals and to the publication in 1861 of his Entwicklungsgeschichte des Menschen und der höheren Thiere.

Kölliker tells how, at his Staats-examen, he knew all about the finest branches of the cranial nerves, the structure of the ear, brain, and eye, yet he could not answer a simple question on the portal vein. In the session of 1841–42 he became assistant to Henle, who at that time was professor of anatomy at Zurich. In 1842 began the first of a series of journeys to other lands, which were always utilized for scientific purposes. The first was undertaken with Nägeli to Naples, where he devoted his time to comparative anatomy of aquatic forms, a subject which began to be studied in the thirties and forties by Stannius, W. Peters, J. Müller, Milne-Edwards, and Quatrefages. While there he made eight researches in all, on amphioxus, cephalopoda, on the hectocotylus of Argonauta, and kindred subjects. After Henle left Zurich in 1844 to go to Heidelberg the chair in Zurich was divided, and Kölliker, at the age of 27, became professor of physiology and comparative anatomy, with an income of 1,200 francs. In 1847, when 30 years of age, he was called to Würzburg, largely through the influence of Henle and the then rector, Professor Rinecker. Originally at Heidelberg he taught physiology, but Kölliker made it a condition that as soon as the chair of anatomy became vacant he was to have it, for he desired to devote himself to microscopical anatomy. During the Zurich period he published papers on the Pacinian corpuscles, the tissues of the tadpole, independence of the sympathetic nervous system, development of *Cephalopoda*, on blood, spermatozoa, and the structure of smooth muscle. By the use of nitric acid he showed that smooth muscle is made up of fusiform cells. He also found that cellulose existed in the skin of tunicates.

At Würzburg he taught physiology, and added to this microscopic anatomy and development, so that in 1849, when the chair of anatomy became vacant, he taught all these subjects and was the head of two institutes. Kölliker, in his first decennium in Würzburg, was particularly fortunate in his associates and assistants, for he had as friends the gifted Heinrich Müller, Carl Gegenbaur, and Franz Leydig. Professor Rinecker had a microscopical institute, with Franz Leydig as an assistant, but Kölliker gave the first microscopical course in 1848. On the death of Heinrich Müller, in 1864, physiology was separated from anatomy, and Prof. A. von Bezold was called to fill the chair of physiology.

In 1849 Kölliker had as prosecutor Gottfried von Siebold, and in the same year these two founded and edited the Zeitschrift für wissenschaftliche Zoologie. Many papers on zoological subjects were contributed by him to this journal. Among his later assistants were Eberth, Forel, C. Hasse, M. Flesch, R. Fick, Grenacher, Eimer, M. v. Lenhossék, M. Heidenhain, and Ph. Stohr, who succeeded him on his retirement from active duty as an anatomist in 1897, when he had completed his eightieth year and his fiftieth as an active professor of anatomy. He still retained what he called his second institute, namely, that for comparative anatomy, microscopy, and embryology.

Kölliker, on arriving in Würzburg, found the want of a scientific society, and to him was largely due the foundation, in 1849, of the well-known Die physikalisch-medicinische Gesellschaft in Würzburg.

As showing the width of his training Kölliker lectured on human anatomy, physiology, comparative anatomy, gave a microscopical course on normal histology, and lectures on topographical histology and comparative histology, and also courses on embryology—human and comparative. He also gave short courses on comparative anatomy and physiology and on topographical anatomy.

Kölliker, of course, was the recipient of many honors. In 1897 there was conferred on him the title " Excellenz " by Prince Luitpold of Bavaria. Only once, however, was he rector of his university, and he did not take any very active part in the inner academic life.

In early youth Kölliker was a great gymnast and indulged largely in manly sports. He was a keen sportsman, especially as a hunter. He also was a great climber, and he records that in 1837 there was not an inn in Zermatt. *Sic tempora mutantur.*

He also traveled much and was a splendid linguist. English he spoke with great fluency, and he was a great admirer of English life and English ways. French and Italian he knew well, and he published papers in all three languages. In 1840 he visited Heligoland and worked up the fauna of the surrounding sea, for most of his

visits had a scientific object. Naples and Sicily were visited in 1842. In 1845 he first visited London, and on his way stopped at Louvain to make the acquaintance of Schwann and Van Beneden. In London he made the acquaintance of Sharpey, who was then professor in University College. A close friendship sprang up between them, and Kölliker had the highest regard for Sharpey, who was greatly interested in the young histologist, who demonstrated to Sharpey the termination of nerves in Pacinian corpuscles. He also became the friend of Owen, Bowman, Todd, Kiernan, Wharton Jones, and Ed. Forbes. Spain was visited in 1849, Holland, England, and Scotland in 1850. To London he was accompanied by Czermak. In Edinburgh he was the guest of Goodsir and Simpson.

In his letters he gives a charming account of the Edinburgh professors of those days. He says he knows only three anatomists and physiologists in all England who do not practice medicine for a profession, namely, Owen, Sharpey, and Grant. He placed Sharpey and Bowman at the head of English microscopists. When he and Czermak were the guests of Goodsir in Edinburgh, Goodsir gave him Tom Jones to read in bed. When he was tired he got up and blew out the gas, but fortunately he did not fall asleep just at once. The smell of the gas aroused him, else the career of the young histologist might probably have been short. He was present at the meeting of the British Association in Glasgow in 1855 as the guest of Allen Thomson, and on that occasion read several papers. He made another visit to Scotland in 1857 and again in 1861. He delivered the Croonian lecture in 1862. He visited Manchester to see the histological work of the late Professor Williamson on fossil plants. In 1887 he visited Pavia to study under Golgi his method of preparing sections of the nervous system, though he was then already 70 years of age. He published about twenty papers on the results he obtained on the nervous system by the Golgi and Cajal methods.

To give a detailed account of Kölliker's work would be to write a treatise on comparative histology. His Gewebelehre was published from 1850 to 1854. His Handbuch der Gewebelehre was first published in 1852 and reached its sixth edition in 1893–1899. The Manual of Human Histology was translated by Busk and Huxley for the Sydenham Society in 1853–54. Even as late as 1851 Virchow held to Schwann's doctrine of "free cell formation." Before this Kölliker had rejected this theory. His studies on the eggs of cephalopods had shown him the untenable nature of Schwann's views. He attached great importance to the study of protozoa and the simplest animals.

Kölliker published but little on ordinary naked-eye anatomy. His work lay chiefly in microscopical studies. He was an excellent lecturer, good draftsman, and a most methodical teacher. For eighteen

years he taught physiology, and admits that the physical and chemical side of this subject were left somewhat in the background. His microscopical course was largely attended and was given in the evening; each meeting lasted two hours. He regarded the incisures of Lantermann, the funnels and spirals of Golgi, and the Ewald-Kühne networks in nerve fibers as artificial and produced by the action of reagents. He supported Ranvier's view of the outgrowths of nerve fibers from a nerve cell.

That he did not do more work in naked-eye anatomy, and, in fact, produced only one large work on this subject, On the Position of the Internal Female Sexual Organs (1882), he explains by the fact that his scientific activity fell at a time when microscopical anatomy and embryology were in their infancy. Comparative anatomy he was fond of, partly because it stood in such intimate relation to the Darwinian theory, a theory which he subjected to keen criticism.

Kölliker made many important observations in physiology. He studied the action of poisons such as curare, strychnine, veratrin, upas antiar, and conium. He was specially interested in curare, for in 1856 he showed that there were poisons that, although they paralyzed intramuscular nerves, left the excitability of the muscle tissue itself intact. He published his researches on curare before those of Bernard were published. He also extended the study of poisons to other muscular tissues, such as the heart. The emission of light by *Lampyris* and *Noctiluca* was carefully studied. He also made some experiments on the electrical condition of the heart and on the secondary contraction resulting when a nerve of a nerve-muscle preparation is laid on a beating heart.

On embryology he published his great work in 1861, of which a second edition appeared in 1879. His Grundriss, on the same subject, reached a second edition in 1884.

Many papers were published on bone; the most elaborate and the best illustrated is "Die normale Resorption des Knochengewebes und ihre Bedeutung für die Entstehung der typischen Knochenformen," 1873. In 1872 he coined the word "osteoclast" in lieu of Robin's word "myéloplaque," and linked up their function with the production of Howship's lacunæ.

To the subject of Darwinism he contributed several papers, and he gives in his Erinnerungen a broad and excellent account of the doctrine of descent as it affects the cellular and other elements of the body.

Classifying his published papers, we find that on histology he published 108, including in this number his various text-books and their editions; on anatomy, 2; physiology, 16; embryology, 52; Darwinism, 5; comparative anatomy and zoology, 19, including his

Icones Histologicæ and 5 papers on unclassified subjects. This gives a measure of the variety of his work, but not of its importance. He continued to produce good scientific work until a very short time before his death.

When the writer first made the acquaintance of Kölliker his hair was already white—not so much with age, for it appears that his hair changed its color rapidly. This gave to his suave and noble face a pleasant and reverend appearance, which, coupled with a charming manner, made Kölliker an attractive personality, while his great knowledge, keen interest in all that was new, and his vast experience made him a veritable Gamaliel at whose feet it was a pleasure to sit and easy to gain inspiration and profit.

Dr. J. Dulberg (Manchester) writes:

When I was at Würzburg some sixteen years ago or so, Kölliker was still, in spite of his advanced age, one of the most indefatigable workers in the medical school, and it was a real pleasure to listen to him when either lecturing or demonstrating. It was touching to see the solicitude with which he used to arrange his microscopical specimens with his own hand and the pride he took in them. On one occasion, particularly, I remember he kept me for over a quarter of an hour discussing the merits of a section of the spinal cord which he told me was the finest he had ever seen. He examined me in anatomy for the "doctor examen," but instead of asking me questions he spent nearly the whole of the time allotted to me in giving me a miniature lecture on some anatomical detail. Even in his ordinary conversation he would not forget that he was an anatomist. When I went to say good-by to him before leaving Würzburg he presented me with his photograph, which stands before me as I write, and in doing so pointed out to me that the photographer had exaggerated the activity of his corrugator supercilii. As a teacher Kölliker was kind, patient, and helpful, far more than the generality of German professors, and to foreigners he was particularly attentive. What an army of doctors all over the world there must be to mourn the loss of one who has been a teacher for well-nigh three generations!

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